



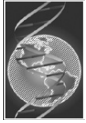
THE EVOLUTION OF THE HUMAN BRAIN

CENTER FOR HUMAN EVOLUTION
PROCEEDINGS OF WORKSHOP 5

MARCH 19-20, 2005

Foundation For the Future

123 105th Ave SE • Bellevue, Washington USA



Foundation
For the
Future

*The Evolution of the Human Brain
Center for Human Evolution
Proceedings of Workshop 5*

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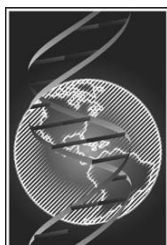
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The comments and deliberations of all participants are deemed very important by the Foundation For the Future. While every attempt has been made to preserve the accuracy of dialogue in the workshop sessions, it is impossible to guarantee that no errors or omissions were made in the course of transcribing and editing the live-session tape recordings. All participants were afforded the opportunity prior to publication to review and amend their comments recorded in this document.

The Foundation advocates no causes or positions. Its goal in publishing the proceedings of the workshop is to encourage human minds to ponder issues that may shape humanity's future.

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April 2006

Dear Readers:

Making a science of human beings is a touchy matter in our society today and, as a result, we do not adequately understand what drives the human mind. The brain has basically two parts: the cortex, which is largely a reservoir of knowledge, and the limbic system, which controls emotions, drives, and motivations. The more we can study and come to understand both parts of the brain, the better equipped we will be going forward into the future of the species.

The Foundation For the Future was established with the mission to increase and diffuse knowledge concerning the long-term future of humanity, and the Center for Human Evolution focuses that mission on evolution, an arena of vast application.

In March 2005, the Center for Human Evolution brought together eight noted scholars to offer their research and perspectives on the evolution of the human brain. I am pleased to present to you the proceedings from that workshop. This book is a record of the papers presented, the questions and answers engaged as a result of the papers, and the scholars' views on emerging knowledge of the brain and its implications for the long-term future.

I hope you will enjoy reading the comments of prominent scholars on these challenging and important issues.

Sincerely,

Walter Kistler
President and Benefactor



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The eight participants of the workshop “The Evolution of the Human Brain,” whose broad expertise and indefatigable seeking after knowledge formed the basis of the workshop and whose contributions will be valuable well into the future. These participants include William H. Calvin, Ph.D.; Terrence Deacon, Ph.D.; Ralph L. Holloway, Ph.D.; Richard G. Klein, Ph.D.; Steven Pinker, Ph.D.; John Tooby, Ph.D.; Endel Tulving, Ph.D.; and Ajit Varki, M.D.

The staff of the Foundation For the Future, for their dedication and commitment to ensure that event planning and facilitation resulted in a smooth and memorable experience for all involved. This staff includes Kathy Carr, Special Programs Manager; Jean Gilbertson, Public Relations and Publications Manager; Jeff Holdsworth, Creative Director and IT Manager; Tom Price, Executive Assistant; and Mary Stroh, Executive Assistant.

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Bill Wright, for extensive photographic coverage.

The Trustees and Executive Director of the Foundation, for reposing their trust and confidence in all of us.

Sesh Velamoor
Deputy Director, Programs

Donna Hines
Deputy Director, Administration

Acknowledgements



Introduction

The fundamental objective of the Foundation For the Future's Center for Human Evolution workshops is to bring together prominent thinkers from a variety of scholarly disciplines for the purpose of sharing their knowledge and perspectives of the evolutionary factors affecting the long-term future of humanity.

Center for Human Evolution workshops are convened on a periodic basis as the need arises for an in-depth look at a specific aspect of evolution. Five workshops have been conducted to date. The proceedings of all five colloquies, with transcripts of presentations and discussions, may be downloaded from the Foundation's website at www.futurefoundation.org/programs_pub.htm.

All Center for Human Evolution workshops are held at the Foundation building in Bellevue, Washington USA.

The Foundation For the Future maintains a neutral stance in regard to research and perspectives in the scientific and social sciences fields. In keeping with its mission to increase and diffuse knowledge concerning the long-term future of humanity, the Foundation does not advocate positions, but rather believes that it is the dissemination of research findings and scholarly dialogue that benefits the full community of scholars and ultimately all of humanity.



The Proceedings Sections

Summarized below are the contents of each Section and Appendix of the *Proceedings of the Center for Human Evolution Workshop 5*.

SECTION 1 cites the critical questions that formed the basis of the Center for Human Evolution workshop on “The Evolution of the Human Brain.”

SECTION 2 summarizes the purpose, organization and management, activities, and workshop programs of the Center for Human Evolution.

SECTION 3 provides specific details describing Workshop 5.

SECTION 4 provides transcripts of the presentations and dialogic sessions from the two-day workshop.

APPENDIX 1 is the workshop agenda, noting key activities from the President’s welcome to closing remarks.

APPENDIX 2 provides biographical information on the participants in Workshop 5.

The Proceedings Sections



List of Participants



William H. Calvin, Ph.D.
University of Washington
School of Medicine
Seattle, WA



Steven Pinker, Ph.D.
Harvard University
Department of Psychology
Cambridge, MA



Terrence Deacon, Ph.D.
University of California, Berkeley
Department of Anthropology
Berkeley, CA



John Tooby, Ph.D.
University of California
Department of Anthropology
Center for Evolutionary Psychology
Santa Barbara, CA



Ralph L. Holloway, Ph.D.
Columbia University
Department of Anthropology
New York, NY



Endel Tulving, Ph.D.
University of Toronto
Baycrest Centre for Geriatric Care
Rotman Research Institute
Ontario, Canada



Richard G. Klein, Ph.D.
Stanford University
Program in Human Biology
Stanford, CA



Ajit Varki, M.D.
University of California, San Diego
Glycobiology Research and
Training Center
Department of Medicine
La Jolla, CA

List of Participants



Section 1

The Critical Questions

The Evolution of the Human Brain

1. How might the evolution of the human brain be assessed in terms of past, present, and future, where “past” refers to the evolutionary context; “present” means the current state of knowledge on the human brain; and “future” takes into account potential applications of genetic and germline engineering, technological augmentation, cultural indoctrination, and space colonization?
2. What are the implications of “brain plasticity” in the “nature versus nurture” debate?
3. Will human brains be significantly different in the future, given the potential of technological intervention?
4. Will/should a global “brain protocol” emerge aimed at regulating intervention and manipulation of the human brain?



Section 2

Center for Human Evolution Overview

Purpose

The Center for Human Evolution was established by the Foundation For the Future to sponsor research and conduct workshops related to the understanding of the evolutionary factors affecting the long-term future of humanity.

Organization and Management

Established in 1998, the Center for Human Evolution became fully operational in early 1999. It is directed by the Foundation For the Future and managed by the Deputy Director, Programs, overseen by Walter Kistler, founder and President of the Foundation.

Activities

Activities of the Center for Human Evolution include providing funds for: studies in the field of human evolution, publishing the results of research in human evolution, and hosting seminars and workshops concerning human evolution. Additional activities may be determined by the Foundation's Board of Trustees.

Workshops

The subject of workshops 1 and 2, held in November 1998 and February 1999, respectively, was "The Evolution of Human Intelligence." Workshop 3 was held in November 1999 and convened scholars to discuss "How Evolution Works." Workshop 4, on "Cultural

Evolution," was held in May 2000, and Workshop 5, which is the subject of this proceedings, was held in March 2005 on the topic "The Evolution of the Human Brain."

Center for Human Evolution workshops focus on a wide range of evolution questions including, but not limited to:

- How did human intelligence evolve and how is it currently evolving?
- What role does culture play in the evolution of human societies?
- How do genetic factors influence human behavior, intelligence, innovation, motivation, and achievement?
- What role will medical and genetic technologies play in the future evolution of human intelligence and in the long-term evolution of human societies?
- What role does dysgenics play in the development of human societies?

Participants

Each workshop brings together six to ten scholars, experts in fields related to the evolution topic designated for the workshop. Participation is by invitation only. Researchers interested in participating in workshops on specific aspects of human evolution may contact Sesh Velamoor, Deputy Director, Programs.



Section 3

Description of Workshop 5

“The Evolution of the Human Brain” was the theme of Center for Human Evolution Workshop 5. Eight scholars were invited to participate, specifically selected to allow for a solid, scientific look at the human brain and its evolution, both past and future. The invitees were selected by Walter Kistler, President of the Foundation, and Sesh Velamoor, Deputy Director, Programs.

Each participant was asked to prepare a paper for presentation and discussion at the workshop. Abstracts of these papers were received sufficiently in advance to allow time for distribution to all attendees prior to the event. During the workshop, each participant was given approximately one hour to deliver his presentation and respond to questions and comments from the other attendees.

In addition to the eight scholars, three officers of the Foundation For the Future and four outside observers took part in the discussions.

Venue and Themes

The Center for Human Evolution Workshop 5 was held in the main conference room at the Foundation For the Future building in Bellevue, Washington. In addition to the views of human brain evolution that were presented in the eight papers, the workshop discussions led spontaneously into a wide-ranging dialogue on emerging knowledge of the brain and the long-term implications for humanity.

Publication of Results

Transcripts of all presentations and discussions in the workshop “The Evolution of the Human Brain” are published in this document, which is available in hard copy upon request to the Foundation as well as downloadable from the Foundation’s website at http://www.futurefoundation.org/programs_pub.htm.



Section 4

Workshop Transcripts

Center for Human Evolution Workshop 5 addressed a variety of issues related to “The Evolution of the Human Brain.” Eight participants, whose expertise ranged from neurobiology and anthropology to psychology and cellular and molecular medicine, were charged with assessing the past, present, and future of the human brain.

These scholars hold professorial and research positions at university and research institutions. They presented lectures sharing the perspectives of their disciplines and study.

Center for Human Evolution workshops are structured as colloquies. Each participant is given approximately one hour to present a paper and answer questions generated by the presentation. Following each paper, a round-table discussion provides a means of synthesizing the wide-ranging material. Finally, each group of scholars discusses critical themes related to the subject. Following are transcripts of these presentations and discussion sessions in Workshop 5, “The Evolution of the Human Brain.”

Introductory Session

Eight participants – all experts in one aspect or another of the human brain – gathered at the Foundation building for the workshop “The Evolution of the Human Brain.” In the opening session, they were welcomed by Foundation officers, then introduced themselves with comments about their professional affiliations and research interests.

BOB CITRON: Good morning. We are glad to see you all here for this workshop. I would like to introduce Walter Kistler, the President and benefactor of the Foundation.

WALTER KISTLER: Good morning, everybody, and welcome to this meeting. This promises to be a most interesting meeting. I hope you will enjoy these conversations on the human brain over this time we have together.



*Where have we come from?
Where are we today? And where
are we going as a species thousands
of years into the future?*

CITRON: Thanks, Walter. Just a few words now about the Foundation For the Future: All of you have seen our new brochure, which gives you a good sense of what the Foundation is and what its purpose is. An important point to emphasize is that the Foundation is here in perpetuity – it has an endowment; it never seeks outside funding. A thousand years from now, 40 generations into the future, there will be another group such as yourselves sitting around a table discussing similar issues to the ones you’re going to discuss today, and the Foundation will host those people.

Four or five years ago we produced a 15-minute film that places the Foundation in context: Where have we come from? Where are we today? And where are we going as a species thousands of years into the future? Not the near-term future but the long-term future.

As you deliberate in the next day and a half, keep in mind that when we talk about where the human brain is going, we’re talking about multimillennia, not just the near future.

With that, we’re ready to roll the video, *Cosmic Origins*, which was created for us by a filmmaker from WGBH in Boston who also makes films for the *Nova* series and *Frontline*. After the film, Sesh will open the workshop.

[Showing of film *Cosmic Origins*]



*In the next day and a half, I am
hopeful that we can cover much
ground with respect to three specific
aspects of the brain: the past,
the present, and the future.*

SESH VELAMOOR: Thank you, Bob. We are ready to start the deliberations for the morning, and first I want to put into context why we’re here and what the focus of the workshop is. Essentially, the workshop is all about the human brain. In the next day and a half, I am hopeful that we can cover much ground with respect to three specific aspects of the brain: the past, the present, and the future. We expect that the papers that will be presented today will set the stage for assessing the human brain in the evolutionary context, bringing us all the way from the past to the present, in terms of what we know about the brain.

The conversations tomorrow will focus on what the future is of the human brain over the next thousand years – the very long-term aspect is a matter of specific interest to the Foundation. Our conversations tomorrow morning will formulate the questions for those discussions, specifically taking into account all of the interventions and augmentations, and perhaps even possibilities for evolution if we were to colonize some other planetary body in space. So, those are the objectives that we’re trying to accomplish.

Let's start with introductions of the participants, beginning with Dr. Pinker.



... my empirical research has been concentrated on one very small phenomenon of language, the difference between storage in memory and real-time computation ...

PINKER: I'm Steve Pinker, Professor of psychology at Harvard. I am interested in all aspects of the mind. My empirical research has been on visual cognition, earlier in my career, but mostly on language: language development in children, language in the brain, the structure of language, the use of language in real-time.

In the last ten or fifteen years, my empirical research has been concentrated on one very small phenomenon of language, the difference between storage in memory and real-time computation, which I study by contrasting regular and irregular inflectional morphology: the difference between "walk-walked," on the one hand, and "bring-brought," on the other. The idea is that though both of them are matched in terms of what they do in language – they are just two different ways of talking about something that happened in the past – one of them is a productive, combinatorial process, so that when a new verb enters the language, like *spam*, everyone instantly knows that the past tense has to be *spammed*. Even though they never memorized that word, they don't have to go to the dictionary to look it up.

On the other hand, for the irregular forms like *sing-sang*, *bring-brought*, and so on, you have no choice but to memorize them. So, it's a way of contrasting the role of memory in computation in language. I've looked at how regular and irregular forms develop in childhood, how they change over historical time periods, how they differ in closely related languages, and where they are processed in the brain.

About ten years ago, I started to write books for a wider audience. My first two books were highly technical books on language acquisition. I wrote a book called *Language Instinct: Everything You Always Wanted to Know about Language*, followed by a book with the modest title *How the Mind Works*, which tried to do the same thing for the other cognitive and emotional faculties such as visual perception, reasoning, the emotions, humor, music. In 1999, I wrote a

book called *Words and Rules*, which tried to present my research on language in a framework that would make the microscopic study of one phenomenon of language widely accessible. My most recent book was the one I spoke about last night, *The Blank Slate: The Modern Denial of Human Nature*.



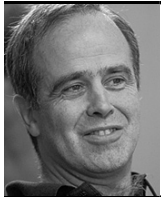
Specific things that we've worked on ... have demonstrated, for example, that reasoning fractionates into a series of content-specialized systems.

TOOBY: I'm John Tooby, and I'm presently a Professor of anthropology at the University of California, Santa Barbara. My wife and lifelong collaborator, Leda Cosmides, and I are co-directors of the Center for Evolutionary Psychology.

My background is in psychology, evolutionary biology, and anthropology. Since I was an undergraduate, I have been interested in exploiting the really great and under-used inferential power present in bringing together what we know about natural selection, the cognitive revolution, and other phenomena to see, if you put it all together, what inferences you can make about the computational organization of the human brain and mind. We've been trying to do a number of existence proofs or demonstrations of the empirical power of these kinds of applications, working backwards from adaptive information-processing problems we believe our ancestors were subject to, to see if that would lead us to discover phenomenon structures or adaptive, functional, regulatory architecture in the human brain that people hadn't thought was there before, in contrast to the idea that the thing that is doing most of the inferential work in the human brain is some sort of general set of content-independent learning and inferential systems.

Specific things that we've worked on – to our own satisfaction, not to anybody else's – have demonstrated, for example, that reasoning fractionates into a series of content-specialized systems. There's an inferential system that is specialized for reasoning about hazards, danger, and precautions, and there's a system for reasoning about exchange. So, the foundation economic activity is, in fact, a specialized ability for doing conditional reasoning in the context of contingencies of interpersonal interaction.

We have moved out into other areas of emotion. Reasoning was one of the hardest cases because that's what people had assumed was completely a content-independent kind of system. But we have been moving systematically into other aspects of cooperation and conflict. We think there is a distinct coalitional set of inferential and motivational and emotional specializations existing in groups for dealing with other groups, for navigating within your social group, for collective action, for competition in groups, even including aggressive competition in groups. So, maybe our history of endemic, small-scale, inter-group conflict might have led to some specializations, and we have evidence about how these collective-action systems operate.



There are lots of differences in human brains and nonhuman brains, and I have been very interested ... in trying to understand what the crucial difference is.

DEACON: I'm Terry Deacon. I am currently at the University of California, Berkeley, in anthropology and neuroscience. My background is mostly centered around the question of what's unusual about human brains, or, rather, to use Gregory Bateson's phrase: *What's the difference that makes a difference?* There are lots of differences in human brains and nonhuman brains, and I have been very interested all of my career in trying to understand what the *crucial* difference is.

I began my benchwork actually studying different species' connections with respect to memory in the hippocampus. I did my Ph.D. work on the connections of what one might call homologues to language areas in primate brains, tracing connections from the homologue to Broca's area, Wernicke's area, anterior singulate supplementary motor and a number of brain stem nuclei that control, for example, tongue and larynx. I found that they were strikingly similar to what people had predicted about human brains, and now that more and more imaging has come out, I think that most of those correlations have shown it to be the case that the connectivity, at least, of monkey brains is very much like our own.

I have gone on from there to study developments and, over the last decade, I spent a great deal of time

doing fetal neural transplantation – actually across species. My purpose was to find out how axons find their targets and to find out if it is different in different species. What we found out, surprisingly, was that it's not very different. In fact, this work went on to be used in transplantation work in people for Parkinson's disease, Huntington's disease, and others – even across species, to some extent against my will. But what I can say is that, as far as we could find, there was very little difference.

Subsequently, I have shifted my attention a bit from the development to ask another question that's related to that: How is it that our behavior has changed our evolution? This is a question I asked many years ago in my book *The Symbolic Species*. I've essentially repudiated some of my thoughts, then, and I'll talk a little bit about that today.



I'm a biological anthropologist ... I'm really interested in human variability, particularly brain variability.

HOLLOWAY: My name is Ralph Holloway. I'm in the Department of Anthropology at Columbia University. I'm a biological anthropologist, a dying breed. I got my degree in geology from the University of New Mexico and found myself working as a metallurgical engineer the next year in Burbank, California. That experience was so shattering that I went to Berkeley and got a Ph.D. degree in anthropology.

My main interest is to find out how this species became so insane. That is really my target. My main interest when I got out of graduate school was to do quantitative neural histology on primates, having done it on rats in the visual cortex. I came to Columbia University with that hope, but since I wasn't studying *Aplysia*, the sea slug, there was no possibility of learning anything about primate brains. I ended up looking at something that I had said in my dissertation was absolutely useless, which was brain endocasts, that is, the cast of an inside of a skull. That's what I've been doing for the last 35 years: looking at the inside of skulls and working with latex rubber, and so forth, which is a very delightful process. I brought for your consideration a hobbit brain, in case at some point during the proceedings you would like to talk about it.

My interests, though, are very broad. I'm really interested in human variability, particularly brain variability. I've worked on sexual dimorphism of the brain, particularly corpus callosum in males and females. I'm interested in sex differences, naturally. I'm interested in racial differences. And I'm about to retire in another two years.



I've always been interested in trying to integrate the evidence for human biological evolution with the evidence for the evolution of behavior ...

KLEIN: I'm Richard Klein. I lecture on human evolution at Stanford University. I guess I'm an archaeologist – I'm not sure. I like to think there's a field called paleoanthropology that combines the study of human fossils and the study of the artifacts that occur with or without the fossils but in the same time period. I've always been interested in trying to integrate the evidence for human biological evolution with the evidence for the evolution of behavior, the archaeological evidence.

I have been particularly interested in the question of when and where people like us evolved, and I suppose you could also add to that *why* – I'll talk about that later. It seems to have happened about 50,000 years ago in Africa that modern humans in the fullest sense emerged, modern humans both in their anatomy and their behavior, and they spread from there to the rest of the world. I would like to talk a little bit about that in my presentation.

In terms of what I actually do, every summer I go off to South Africa and I dig up some old bones and stones, and analyze them. I hope that I do it in an open-minded way and don't just attempt to fortify a position, which you'll see I have, about the relatively sudden origin of modern humans about 50,000 years ago.



... by far, the most interesting, most mysterious object left for scientists to study is human consciousness.

TULVING: I am Endel Tulving. I am essentially interested in consciousness. I've always been interested

in it, since my high school days. It took me a long, long journey to actually get close to it as an object of scientific interest, but what I'm trying to do now is to convince as many people as I can that, by far, the most interesting, most mysterious object left for scientists to study is human consciousness. I will be talking about the future later on today, which turns out to be a part of human consciousness. It's something that only the human brain can produce in its particular manifestation.

My training has been in cognitive psychology. Psychologists are people who, when they're hard up for new ideas or new discoveries, change at least the names of the ideas they already have. So, I started as an experimental psychologist, then became a cognitive psychologist, then became Professor and now Chair of something called cognitive neuroscience.

I do not know anything at all about the brain. I finally figured out what the front end of the brain is and what the back end is. I know a few technical terms, but what goes on in there is totally and utterly beyond me, but it turns out, too, to my own satisfaction, that one really doesn't have to know very much about things that one is interested in, in order to make some sense of them.



... what I now focus on is how you avoid speaking incoherent nonsense ... how your brain creates ever more coherent arrangements of ideas ...

CALVIN: I'm William Calvin. I'm a neurobiologist. I started in physics, wound up doing a Ph.D. in physiology and biophysics, working on nerve cells – basically their electrical computing properties. I moved on to emergent properties of circuits of cells, and what I now focus on is how you avoid speaking incoherent nonsense, that is to say, how your brain creates ever more coherent arrangements of ideas in the several seconds before the words come out of your mouth.

But I'm also fascinated with why such quality bootstrapping has evolved, presumably sometime in the last few million years of human evolution. So, I write books like *A Brief History of the Mind: From Apes to Intellect and Beyond*. I scratched the surface, at least, of linguistics. I, too, write about consciousness.

When evolution is rapid, climate changes are usu-

ally part of the push, and so for the last 20 years I've also been paying a lot of attention to the paleoclimate studies. It turns out that the glacially slow ice ages were punctuated by hundreds of very fast flips – big changes like drought, but everywhere – and they flip back even faster into a warm and wet climate like today's.

In 1998, I was asked to write a cover story for *The Atlantic Monthly*, which came out as “The Great Climate Flip-flop.” 1998 was a time when no one had yet heard much about what's currently in the news and in the disaster movies. The effect of flips on human evolution is what my previous book was about, called *A Brain for All Seasons: Human Evolution and Abrupt Climate Change*.



If you want to understand the human brain, you need to understand the human condition ...

VARKI: I'm Ajit Varki, a Professor of medicine and cellular and molecular medicine at the University of California, San Diego. I earned a medical degree and proceeded to complete training in hematology, oncology, and internal medicine, and even practiced for a while, but then I became what is called “a physician-scientist.” I got interested in science, using my background in medicine, so that's really my job at UC San Diego.

In 1984, my daughter was born, and no amount of education in medicine and pediatrics prepared me for watching the human mind emerge. The second thing that happened in 1984 was I saw a patient in whom there was an immune reaction against animal products – and it turned out that we then found the first known molecular and genetic difference between humans and our closest cousins, the chimpanzees. So, in the middle of the 1980s, I got very interested in this question of what makes us human. Since then, I have been pursuing it mostly at a molecular and cellular level but also collaborating with other people at different levels. I'm involved in the Chimpanzee Genome Project and other issues related to great apes.

I guess I've come a long way from starting out in medicine. But I think I have the advantage that medical education forces you to learn lots and lots of things about everything, and you're not scared of finding out about anything new. I like to go into new fields and learn. I realize I'm naïve about some of these things.

As far as this particular meeting goes, I'm not sure I have so much to say about the brain, but my point is going to be: If you want to understand the human brain, you need to understand the human condition, just as much as if you want to understand a disease in a human, you don't study just the specific organ or system where you think there is a disease; you have to study the whole human. That's the way I think we should approach the problem of the human condition.

VELAMOOR: Thank you, all. We have a most interesting and qualified group to discuss the human brain.

Section 4.1 | Transcripts

Introductory Session

Scholar Presentations

Throughout the first day of the workshop, the eight participants presented papers on aspects of the human brain. Here, Program Director Sesh Velamoor provides guidelines for the presentations.



Our objective is to assess the past, present, and future of the human brain, and each of you has prepared a presentation on an aspect of the brain ...

VELAMOOR: We are ready to begin the presentations of the papers. Our objective is to assess the past, present,

and future of the human brain, and each of you has prepared a presentation on an aspect of the brain in which you are particularly interested. We have allotted approximately an hour to each paper, with breaks between the papers. Following each presentation will be an opportunity for the speaker to entertain questions from the other participants or from the observers in the room. Let's begin.

Section 4.2 | Transcripts

Scholar Presentations

The Once and Future Brain

Presentation by William H. Calvin, Ph.D.



Intellect is not about set pieces but mostly about things we haven't done before, a way of repackaging things.

CALVIN: Intellect is not about set pieces but mostly about things we haven't done before, a way of repackaging things. It tends to be about novel assemblages of things, particularly long and complex like the sentences we're capable of speaking. There's a great deal of need to do quality control just to improve the assemblage and to ignore nonsense.

Because brain size is often all we have to go on, together with some of the endocast findings, we tend to assume that bigger brains are better. There are certainly comparative studies over many species that do suggest some role of that, and it may, indeed, be true for some of the period of brain evolution, but I'm going to raise the issue of whether it's really important in human evolution, *per se*.

There's certainly a reorganization in the brain, size aside, that is surely very important. Language sharing, novel plans that are right the first time, and creativity – all those things require some brain reorganization and that may, in fact, be what the brain size increases are about.

Just to remind those of you who aren't anthropologists, the ancestral environment for the great apes is typically forest with clearings [slide: river forest, woodland, savanna]. Some of the chimpanzees can live out in woodland, but that's the specialty of the bipedal woodland apes, which are the australopithecines and such. By the time you get to *Homo erectus* and probably earlier, they are clearly able to make a living out in the grassy areas where there is not a convenient tree to climb. Woodlands are very nice for a transition population: You can nest in trees. You can climb them. The woodlands also have a lot more rea-

sons to climb trees than the forests do, namely lions.

There is, on the other hand, this enormous resource of meat on the hoof [slide: herds of zebra and wildebeest], and there are probably some behavioral changes that one can speculate about early on, by 1.8 million years ago. For example, there's probably some way of dealing with the lions and the hyenas, and so forth, which are going to show up pretty quickly when a kill is made. Certainly what many species do to deal with larger animals is the so-called "mobbing behavior" that you see often in birds. I assume that our ancestors learned that there was safety in numbers – that if they all rushed toward the lions, throwing clods of dirt or whatever, they could buy some time for one of them to amputate a leg and run off with it. It would be fairly sure that the lions wouldn't follow because they would have the rest of the carcass there, which would be terribly tempting.

There was likely an improvement in sharing behaviors back then. It's one of the advantages of big prey as opposed to small. You might be able to eat the whole thing yourself if it's small prey but not the big prey. The best strategy then is to give in to all the others that come around and want a piece, and to expect reciprocity.

The other thing I suspect they're going to need, certainly by the time they get out into the savanna, where there just are no good places to nest at night, is a social organization that would lead to an ability for most of the people to sleep while only some stay awake. Those are what you might expect to be early behavioral changes.

There is a big brain puzzle [slide: Brain size is perhaps *not* driven by a steady improvement in tool-making during the first 2 million years.] This is just an old picture of brain size I've rearranged a bit that shows you this modern range in the human brain size. This shows the ice ages and major stages in hominid toolmaking. A steeper slope of brain size comes in somewhere in the last half to three-quarter million

years. There is a substantial conservatism in toolmaking styles from the initial invention at 2.5 million years ago to the first really major improvement at 1.7 million years ago. That isn't to say that the old style didn't continue. The improvement clearly did not replace it.



If bigger brains are cleverer, it doesn't really show up very well in the first 2 million years of toolmaking ...

It's interesting to note that bigger brains did not necessarily make them cleverer at toolmaking. In other words: If bigger brains are cleverer, it doesn't really show up very well in the first 2 million years of toolmaking, so maybe it is growing for some reason other than toolmaking.

However, reorganization in a brain may have something to do with it. Let me tell you what I mean by *reorganization*. The temporal lobe houses categories in regions that are about objects for tool use, animate/inanimate, and so on. But the visual area, the V5 area, that is right in the middle of the temporal lobe beneath the auditory specializations in monkeys, has moved all the way back to the occipital parietal junction in humans. If you have to reorganize something, as anybody who has had to reorganize an office knows, it's sure nice to have some surge space. That is to say, it's nice if you can increase something without having to downsize something else simultaneously. So, in any generation, the individuals who by chance happened to have larger brain size were also the ones where the reorganization would go more easily. So, brain size in some sense could be an epiphenomenon of reorganization. I like to put it this way: We might be able to take our present brain size and downsize it back to one-third, and as long we kept the same organization, it might function pretty similarly. I don't know what size, *per se*, adds to anything yet.

Protolanguage is certainly one of the things that brain reorganization might be better for. Protolanguage is the words and short sentences like a two-year-old has. For short sentences, you don't need syntax. You can get along pretty well without all the clues of who the actor is, who the recipient is, and so forth. It's not that hard a problem. But surely the growth in sentence complexity would require some

brain reorganization.

Sharing is one of these things that, the more items you share, the more people you share them with, over longer periods of time – all have a growth curve that keeps on giving. Throwing accuracy is like this too. No matter how good you are, getting twice as good has additional payoffs in terms of days per month that your family can eat a nutritious and relatively sterile source of food. So, all of these have great growth curves, which is unlike a lot of things in evolution. Once you've invented a carrying basket, it's played a very important role probably in human evolution, but it doesn't have this kind of growth automatically.

Staged toolmaking is the idea that you make one thing and then from it you make something else. For example, if you create a ledge, you can come along and strike it, shaving off single-edged razor blades. That's an example of what is meant by staged toolmaking. Blades come in by about 280,000 years ago in Africa and are well established by 120,000 years ago.

The time frame for the designation “anatomically modern” was moved back a few weeks ago to 196,000 years ago instead of 165,000 or so. But there wasn't a big step up in behavioral complexity then. Everybody, I think, would agree that images – the sort of thing you see in cave paintings – are behaviorally modern. Certainly if the holes in the snail shells [referring to slide] were well polished, you would be fairly convinced that these were used for necklaces. There's also a lot of red ocher found in various places that people have argued represents a body decoration such as war paint. Chimpanzees love to decorate themselves. I don't think that's the issue. The issue is that it's hard to imagine apes sticking to a task like this long enough, and that same argument is probably true for our ancestors up to some point. If these were beads for necklaces, it does bespeak a notion that humans by that time had a capacity to maintain agendas, revisit them, and update them, and so forth, in a way that was perhaps lacking earlier.

The big brains, while they might be necessary, are not sufficient to get modern behaviors. There's likely something else we have to deal with here.

[Slide: though “anatomically modern” came in 200,000 years ago, the “Mind’s Big Bang” took another 150,000 years, taking off only about 50,000 years ago in Africa.] This is the last 400,000 years. There were some big brains already back in *Homo heidelbergensis* times. The halfway-modern stuff is all in the period of 90,000 down to 40,000 years ago; we call it 50,000 for convenience. There is a gap of 150,000 years – when this gap was first postulated 50 years ago, it was more like 15,000 and you could easily imagine things just changing place. Now it has expanded about ten-fold. It tells you something: The big brains, while they might be necessary, are not sufficient to get modern behaviors. There’s likely something else we have to deal with here.

I want to now go through some candidates that have been proposed for what makes this behaviorally modern – what traits had to be there for it to happen. One is mimicry.

Now, mimicry can be done with a bird-sized brain [slide: much mimicry is seen in birds]. This is not an argument about size. The problem is that even if mimicry is easy, you don’t see much of it in chimpanzees (though orangutans often mimic). For example, Tomasello did this nice experiment at Yerkes, taking a couple of young chimps out of a playgroup of young chimps and teaching them, just with standard conditioning practices, to make a gesture in order to get a food reward. I don’t know what he did, whether it was patting his head or pulling his ear, or something like that, but he trained up a couple of the animals this way and put them back in the playgroup. Then the experimenters came around with a pouch of goodies and every chimp there knew what the goodies were for. But only the two animals that had been trained ever got any of the goodies and all the rest were standing around trying to figure this out. Not a single one of them ever picked up on either of the two gestures they had been trained for. It shows that arguments about how useful it would be for them to do this really break down here. There’s something about the chimpanzee

mindset that doesn’t make “monkey see, monkey do” the standard practice that you might have thought.

Yet there’s a lot of mimicry in us humans. There’s so much of it that we do a lot of it unconsciously: mirroring or echoing or matching – the sort of thing where two people are talking and one crosses his legs, and in the next minute the other person is likely to cross his legs. That’s what is referred to here. People will synchronize breathing; they’ll do all sorts of things, even with strangers. It appears to be part of establishing rapport. There was an experiment with graduate students working as waitresses, who on alternate nights of the week would match, fully sympathetic, whatever the tone of voice the person ordering was using and mimic some of their body gestures. They got a lot more tips those nights than on the alternate nights when they avoided doing those things. So, mimicry is one of the candidates.

Creativity is often mentioned as another candidate for the transition to *Homo sapiens sapiens*. Language, of course, is another, as are logic, more working memory, planning. And consciousness could be, to some extent, thought of as an umbrella term covering the rest. I like all of these. I would just add the word *structured* to them, so you end up with mimicking sequences, with the kind of creativity that includes getting set offline, and not just protolanguage but long sentences that you need syntax for, and not just a logical inference but chains of logic where there’s a lot more possibility to go wrong. Maybe it’s not “more working memory” but a better-structured working memory. Maybe it’s not simply planning, but planning that has contingencies built in, so if one thing doesn’t work – for example, if you can’t go to the country this weekend, you could go to the movies on Sunday instead.

Coherence-finding, when we discover hidden patterns amongst seeming chaos, is the sort of thing ... we have to do to reconstruct the past or to make a projection into the future.

The best-known example of structuring amongst the higher intellectual functions is, of course, syntax. With syntax, you can even nest sentences like: “I think I saw him leave to go home.” The other higher intellectual functions include things like games with arbitrary

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rules, which, of course, is a lot like logic where you have to check against an arbitrary set of rules. Music that goes beyond rhythm and melody to use multiple voices in parts-singing or in symphonies. Coherence-finding, when we discover hidden patterns amongst seeming chaos, is the sort of thing, as I was mentioning earlier, that we have to do to reconstruct the past or to make a projection into the future. We're engaged in trying to find things that hang together well.

Complex thought, as in figurative speech, narrative frameworks, parables that map one story onto another but leave out certain attributes, are examples of structured thought and they all pretty much separate humans from the great apes. Now imagine us without them – in other words, looking fully human but not having the structured aspect of these things. It's very hard to find examples of that. Oliver Sacks has a nice description in his book *Seeing Voices* [University of California Press, 1989] about the deaf. This is a boy who is being tested at age eleven but for the first ten years of his life he was mistakenly diagnosed as being mentally retarded and no one taught him sign language. The average age for diagnosis of deafness is age three, which means that a lot of deaf children are undiagnosed for three years. And if the average is three, there are an awful lot that aren't diagnosed until ages five and six. It's something that could be so easily fixed before the infant ever leaves the hospital. It's quite sad that these kinds of tragedies occur. Here is a paragraph from *Seeing Voices*:

Joseph saw, distinguished, categorized, used; he had no problems with perceptual categorization or generalization, but he could not, it seemed, go much beyond this, hold abstract ideas in mind, reflect, play, plan. He seemed completely literal – unable to juggle images or hypotheses or possibilities, unable to enter an imaginative or figurative realm.... He seemed, like an animal or an infant, to be stuck in the present, to be confined to literal and immediate perception....



... any intrinsic aptitude for language has to be developed by exposure during early childhood ...

There are similar cases like this that indicate that any intrinsic aptitude for language has to be devel-

oped by exposure during early childhood, and Joseph really didn't have the opportunity to observe syntax in operation. Whatever instincts there might be for it are clearly something that kids pick up. They pick up the syntax of their own culture and surroundings by having a lot of examples.

This premodern mind probably had some things like Freud's sense of "trial action." But without structuring plus the offline quality improvement that you need to make it work, you can't create novel sentences of any length or complexity and you likely cannot think such thoughts either. You might dread, for example, another repetition of something unpleasant, but you couldn't worry about novel threats without structure and imagination and some quality control. Joseph is a candidate for what our ancestors – even the ones that look like us – might have been like until 70,000 to 50,000 years ago when real creativity finally appeared on the scene.

Certainly there are parts of the brain that have a lot of movement planning and there are areas of the brain that we think of as language areas – there's a fair amount of overlap.

So, how could this happen? What stepped up? Well, a lot of things that happened in evolution are on the basis of what you might call "borrow first and buy later." That is to say: Behavior invents some new moves. If the move is particularly useful, the biological variations that make it more efficient will reproduce better. Natural selection thus reinforces what was basically a behavioral invention. Certainly there are parts of the brain that have a lot of movement planning and there are areas of the brain that we think of as language areas – there's a fair amount of overlap. One can imagine protolanguage going to language via some sort of borrowing like this. Nested movements like throwing are things that have to be planned in great detail.

Doing something novel for the first time is handled by a lot of animals very simply by just going slowly and fumbling their way into it. There are very few situations that really demand advance planning, and they're the ballistic movements because the feedback really can't guide you. A dart takes an eighth of a second. It also takes an eighth of a second to send a message into the

spinal cord and go back out again. The whole motion from the time you start is truly ballistic: There's no calling it back and changing it. So, the ballistic movements are good candidates for what you might need a lot of this for. And throwing is hard; you have at least four joints to coordinate, hundreds of muscles, a need to guess the movement combinations that hang together to get it on target ... and the trouble is that while there may be hundreds of combinations that would work, they're hidden in a sea of wrong answers, millions of them, any one of which would cause dinner to run away. There's a real premium here upon being right the first time as you get set to throw.

The other good setup for syntax is in the area of sharing. It's pretty standard in us, compared to apes. It has a long growth curve: As I say, sharing more things over longer periods of time, etc. Sharing also has this cheater problem at every step, having to combat the freeloaders. It's been suggested, by Derek Bickerton [co-author with William Calvin of *Lingua ex Machina*, MIT Press, 2000] in particular, that you have a need to keep rough track of who owes what to whom, amongst all the hundred people that you deal with, by, in effect, tagging some of your memories with whether this person is an actor or a recipient and the value of things exchanged. That's one of the ways to make the cooperation curve go a lot further than it would otherwise.

Once that mental capacity is there for doing the sharing problem, then it's likely that you can make use of the same neural machinery in order to gossip about who did what to whom. That is to say: It's not entirely a free lunch. It was paid for by the natural selection for the sharing problem, but once you've got the circuitry for monitoring sharing, then you can use it for other things.

In this creative-explosion period, sometimes called "the Mind's Big Bang," for some skills, clearly earlier is better. For languages, as in Joseph's situation, later is much more difficult. So, you can imagine a scenario for a sensitive period early in life where being exposed works much better than it does otherwise. For example, some individuals manage to solve the syntax problem with something like case marking, where there are different forms of the word for if the person is an actor versus a recipient (*he* and *him*; *she* and *her*), and now there are kids overhearing this structured language at an age where they're more

impressionable – literally, kids can softwire for these things, apparently, becoming much more capable.

[Slide: sensitive period of early childhood] The standard neurobiological thinking on this is that these are plots of the number of connections or inputs per cortical neuron, and there's quite a growth in them in the first eight months of life in humans – the first two months in monkeys – and then they tend to drift down. They drift down different amounts in different areas of cortex, but some, like the visual cortex, go down by about half. While this all could be perfectly random, of course, the general thinking is that there is a "use it or lose it" going on here and that what you're doing is creating a pattern this way. It's just like doing woodcarving: removing material in order to leave a pattern there. This is the kind of speculation that one makes about what's going on.

[Slide: natural selection for long sentences] This is a hypothetical construct showing proficiency as an adult as a function of being exposed to things at various ages – so it shows "how acquisitive" and "when." Suppose a person is basically acquisitive for structured stuff at the age when he has enough fine motor control to do throwing, as an example. I suspect that a lot of food preparation would qualify in here, too. If this curve is out beyond this inflection, it really doesn't make much difference at what age you do it because this curve is flat. Now, suppose that that curve shifts into the area where now there is a lot of increased proficiency as an adult if your basic acquisitiveness for the knowledge shifts back. So, if the acquisition age is heritable, the better adults create even earlier variants, and this repeats. That is to say: You would expect the curve to march back because of the steepness of that.

[Slide: dominant task shaping the softwiring of childhood] This is a model for how you might take a dominant task, something like throwing or food preparation that would be in later childhood, and move it back into a region where it's now operating upon observational stuff instead, such as language. Now language tunes up the circuitry in an area when softwiring is really much easier and produces these permanent effects into adulthood. Now we have this situation where kids handle structured sentences at an age when they still can't tie their shoelaces – they have the speed of operation for the vocal system but still not for the limbs.

The other thing about intellect that I want to say is that there are levels of intellect just because of our ability to handle abstraction. I want to remind you that levels of organization are a very common notion and a level is semi-independent of its foundations, a study unto itself. For example, if you start with fleece and you spin it into yarn, you produce something that doesn't backslide into fleece very easily. There's a stabilization. Yarn can be woven into cloth; cloth sticks together into clothing. Each of these things is a study unto itself. You can understand how to do clothing without understanding anything about weaving or spinning. That's one of the other characteristics of levels.



... one of the things that the arbitrariness of symbol buys you is this ability to play the same games with abstractions that you're playing with concrete objects.

We see levels in the natural sciences all the time. Mendeleyev figured out the table of organization of the elements without really understanding any of the quantum mechanics of electron orbits. You can study the electron orbits without really understanding what's going on in the nucleus, and so forth. This is a familiar kind of thing to us, and one of the things that the arbitrariness of symbol buys you is this ability to play the same games with abstractions that you're playing with concrete objects.

You also see a pyramiding of levels. As babies encounter the patterns in the world around them, you get at least four levels. Babies first pick up the short sound units called *phonemes*, and once they've found the common ones in their experience, they form categories around them. Then they start acquiring the patterns of phonemes called *words* at a very substantial rate just by hearing them. Then they tune up to the patterns within strings of words – these things that span many seconds – and the regularities in it with things that we call *syntax*. Then they go on to this fourth stage where they are pattern-finding over many minutes – these things that we call *a good story* or a proper narrative. So, there are four levels in four years, the pyramiding of taking, in effect, the categories made at an earlier level and looking for patterns and how they assemble.

Doing all these things, you have this enormous

problem of quality control, because most of the combinations you make of things are nonsense. All the elements have to hang together despite the combination being novel so that there's no exact memory of it to go by. Most are nonsense. But we create quality every time we speak a sentence we've never spoken before. This is a routine, everyday occurrence that even kids of low IQ can do.

Looking at intellect rather than language *per se* shows us, first of all, that general cleverness and creativity may be rather late – 50,000 years ago, the last one percent of post-ape, pre-*sapiens* evolution. I like to think of it as something like a new operating system for old hardware. That is to say: an ability to handle various things at the same time in a way that you weren't doing very efficiently before.

Structuring and quality bootstrapping, when you add them atop the ape-like cognitive abilities, create this qualitatively different kind of mental life for us.

Structuring and quality bootstrapping, when you add them atop the ape-like cognitive abilities, create this qualitatively different kind of mental life for us. I would also point out that there's not much time here to get the bugs out. If this is the sort of thing that that creative explosion at 50,000 years ago is about, 50,000 years is just not very much time to debug anything of this complexity. So, *all* the parts of higher intellectual function – particularly all the planning and inference and game-playing with rules and all the logical aspects – are, as any psychology textbook will show you, just riddled with paradoxes and certainly inefficiencies.

Finally, I'll say a few words about what's next in human evolution. Once we understand the mechanistic aspects of mind, which we're on the way to doing, will we see a second Mind's Big Bang? There are various things you can postulate. I'm going to stick to something very simple: the number of concepts you can juggle at the same time: the 7 ± 2 business and, of course, the speed with which you can make good decisions and move on. These are heavily involved in the subtests for IQ. About 60 percent of the variance in the general intelligence score comes from tests that emphasize these two things, so you can immedi-

ately see that if you had a mechanistic understanding of mind that allowed you to train for either of these things, you could very likely improve kids coming out of that training to be higher in, at least, IQ. I tend to think IQ and intelligence are somewhat different things, but you could certainly change IQ scores if you were able to train early for such skills.

... for a second Mind's Big Bang, you probably don't need gene changes ... what will affect the most people in the most places will be a better-informed educational practice ...

I would point out that for a second Mind's Big Bang, you probably don't need gene changes. I'm sure they will be tried, but I think what will affect the most people in the most places will be a better-informed educational practice: knowing what to do when in the softwiring period of early childhood, in particular. The analogy I like to use is that in the 20th century medicine went from being probably 10 percent scientific and 90 percent empirical to, in the course of the century, becoming closer to 50–50. We began to understand what worked and why it worked, and we began to understand all the things that didn't work, even though they seemed perfectly logical and worked in some settings.

It is very much like leaving bleeding and purging behind. Bleeding is a very good treatment for iron-retention disorders, as it turns out, but over-generalizing it and using it for everything was ineffective. Finding such errors and improving the bottom-up approaches made great strides in 20th century medicine.

I tend to think that 21st century education, once it has developmental psychology and a lot of cognitive neuroscience to go on, will be able to make a transition something like 20th century medicine did. That is to say: If you figure that, of the current educational practices, only about 10 percent are informed by science, imagine it getting closer to 50–50. That would be the major development. While the babies that pop out of the womb might not be different from today, by the time they pop out of the school system, they could be substantially different than they are today.

Thank you. Are there questions?



What I don't see, when you go through the fossil record, is trying to take into account the relationship of body size to brain size ...

HOLLOWAY: The size of the brain is an old chestnut in anthropological figuring, and the old chestnut has been that there's just no relationship between brain size and behavior or cognitive tasking, and so forth. The recent studies that have now been replicated over 20 times involve using MRI and algorithms to calculate brain size. These are correlated with cognitive tests at the level of between 0.4 and 0.6.

In a recent metastudy, a meta-analysis was done on all of those studies and it came out to be about 0.3 in terms of a correlation coefficient – the correlation coefficient being extremely significant. So, there is some aspect of the size thing. What I don't see, when you go through the fossil record, is trying to take into account the relationship of body size to brain size, because you've got both allometric and nonallometric kinds of changes in brain size with time.

CALVIN: Yes. One of the things I'm fond of pointing out about brain size is that as you get a bigger body, you get longer conduction distances for the nerves. Unless you do something to increase the conduction of velocity, your reflexes are going to slow down substantially. The basic cure for this is to insulate the nerves better with more myelin so that you can get the messages there in the same amount of time. That takes a lot of space. When the corpus callosum myelinates, the number of axons it can get through the corpus callosum drops by about 70 percent or 80 percent. Myelin size within the brain has to be a substantial part of the so-called brain size increase and it's not about intellect at all. It's about compensating for body size.

What you point out in terms of cortical thickness having some correlations, I'm not surprised at all. What we don't understand is that you can do things like putting rats from the standard impoverished environment of a cage by themselves into enriched environments and cause, temporarily at least, even an 88 percent increase in the number of synapses per neuron. This isn't to say that that's permanent. You certainly can't keep doing that or the head would explode.

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The problem is: How do you create new patterns in the brain to do these things? Clearly, part of that is epigenetic and there's an awful lot about what culture you grow up in that determines what brain wiring is available in adulthood. I think that that's a big part of the puzzle. Culture is going to be very important here but the genetics will still be there because they'll help make it more efficient and they'll fill in behind. They won't necessarily get rid of the bugs because bugs, at least in the side effects of medicines, are things where it's very hard to get rid of one and save the other. And evolution is just full of genes that do more than one thing and it can be difficult to change one without making another part of the system so inefficient that you get developmental failures.



How strong are the inferences that you can make from material culture to brain structure?

TOOBY: Things that strike people as interesting expressions of uniquely human abilities are, of course, rooted in the brain very importantly, but also because – as you describe, and other people do – this cultural effect of improving the quality by it being processed and reprocessed is something that involves the size of the social network. I, myself, am open-minded – *skeptical* would be too strong a way of putting it – that people put timing in the biology by looking at the paleoarchaeological record, but one thing that's happening is that population sizes are very low then, so to identify the creative explosion as a time when biological changes happened seems to me to be not a strong inference. If you look at the Tasmanians, if you took three of us and dropped us on some island off the shore here, in two generations we would look like Tasmanians: We wouldn't have computers; we wouldn't have anything.

My question is (and maybe Richard would be able to speak to this as well): How strong are the inferences that you can make from material culture to brain structure?

CALVIN: Clearly there are a lot of things that are just carried along by cultural practice and it's very easy to lose them if you get a disease that comes through

that happens to wipe out the experts before they've trained another generation. This is, presumably, what happened to the Tasmanians.

TOOBY: I'm saying the other way around. What if you had really smart people 200,000 years ago but they're in very small groups, and then you only start to get the significant large population sizes often enough that they start to show up in the record 50,000...?

CALVIN: I agree that there could be a substantial gap in there. One of the things that genetic changes do, even as simple as the one I'm hypothesizing here – taking the acquisitiveness curve and moving it back – is make a cultural practice more efficient and more likely to be reinvented. That is to say: It's sufficiently strong now that a deaf kid will invent his own sign language to use with another deaf kid. There are some instincts now that are serving as backups but they're very general in how detailed they are.



Maybe there were many attempts to "take off," so to speak, and so when we finally see a take-off, we assume that that was the first take-off.

VARKI: Following up on the matter of population, I think that really is an issue. When we talk about "human universals" – let's say that music is a human universal. Well, it's not, in the sense that many people in the population couldn't carry a tune if they had to, to save their lives; then there are others who are Mozarts. It's possible that what happened is that you had these abilities maybe 150,000 years ago, but as the population grew and they started bootstrapping this culture, then maybe that one population got wiped out. Maybe there were many attempts to "take off," so to speak, and so when we finally see a take-off, we assume that that was the first take-off.

We were talking at the break about the 400,000-year-old spears from Germany that are still unexplained. Somewhere, someone was able to make these incredible balanced javelins out of whole trees. Whoever those people were, they didn't make it, obviously, because we would have seen signs of that technology around after that. I'm not discounting the possibility of some specific genetic event or events. I'm saying that it's also equally plausible that you

could have had a problem of bootstrapping that kept recurrently failing until it finally...

But then, if that was the case, we would have expected a larger effective population size in the end, because if there were many peoples that were capable of this and, finally, one group had to take off, that culture would have dispersed. Instead, what we see in the genetic record is a relatively constrained, small-group origin.

CALVIN: Indeed. As I suspect Richard will tell us, the population density in some of the areas where we

think this was going on, like Southern Africa, this was a low point. It's not as if you can argue big populations.

Furthermore, the climate was constantly flipping back and forth, so there were always big drought downsizings in this period. About 16,000–15,000–14,000 years ago, the climate was flipping every couple of centuries. This was a very unstable situation. They could build up a good population size in the warm and wet, but then it is crashing back down.

VELAMMOOR: Thank you, Dr. Calvin.

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Presentation by William H. Calvin, Ph.D.

Erasing the Slate: Devolving toward Increased Complexity of Brain Function

Presentation by Terrence Deacon, Ph.D.



I actually think of our own species as a kind of degenerate chimpanzee ... in a very serious genetic sense and neurological sense.

DEACON: What I want to say today is something that I think you'll find very counter-intuitive. Evolution is one of the hardest things to study because it fools us every time. We always think that anybody who has gone through high school knows how evolution works; they know how it's supposed to be. But, in fact, I think they're confused most of the time. I think *we* are confused most of the time. As much as we've gone through 150 years of studying this process, we still have a lot to learn.

What I'm going to suggest today is not a story about all of evolution. There's no chance that I could fit that in. I'm going to talk about one very counter-intuitive feature that I've been looking at recently. I'm not going to talk a lot about brains but this all has to do with brains. The question that I want to talk about has to do with the nonprogress side of the story. I am going to say that the nonprogress side of the story may be one of the most interesting parts of it – you sometimes have to fall back to leap ahead. There is a significant feature of human evolution, and I think this may be generalized to many aspects of evolution, and that is where what we might want to call *devolution* turns out to be tremendously powerful. I actually think of our own species as a kind of degenerate chimpanzee. I don't mean this just humorously; I mean this in a very serious genetic sense and neurological sense. I'm going to try to make that idea clear.

[Referring to slide] These are the chimpanzees; we see the bonobos over here in blue. This is the mitochondrial DNA tree. Here we are, this little red bush over here. The Neanderthals are pretty close; in fact, they're closer to us than most of the chimpanzee groups are

to each other. What you might think is: *If I saw this in any other natural history study, I would say that this is a species on the way out. This is a species that has lost its genetic variance. This must be a tiny corner someplace in the world where they are about to go extinct.* We haven't. One of the reasons, I think, is because there has been a kind of degeneration process going on. That's what I want to suggest to you here. I don't want to suggest that this is everything there is to know about evolution, but I think that we tend to overlook it and maybe it is more important than we think.

What is the flexibility of our evolved cognitive and emotional adaptations to cope with the highly divergent social, technological, and living environments that we're involved in now and are about to produce?

What matters most for the next thousand years, since that's where we're looking here? Brain evolution, certainly by spontaneous natural means, is probably not going to be in the cards unless we get really isolated on Mars or somewhere else for a very, very long period of time. In that case, perhaps some interesting things will happen. But I think a number of things *do* matter. One is: What is the flexibility of our evolved cognitive and emotional adaptations to cope with the highly divergent social, technological, and living environments that we're involved in now and are about to produce? We're going to move into very alien environments. I think that's a pretty remarkable and troubling issue. What's the sensitivity of our brain development to these significant departures from the species' typical environments? Brains have evolved for environments. They have evolved to take advantage of things in the world around them. One of the things I'm going to talk about today is exactly how that process happens.

Finally, what's our capacity to co-opt old, adaptive complexes to serve phylogenetically unprecedented, novel,

adaptive functions? Clearly, something like reading and writing is a case in point where phylogenetically old and unrelated faculties have been drawn into this very novel process.

I titled my book *The Symbolic Species* [subtitle: *The Co-Evolution of Language and the Brain*, W.W. Norton, 1997] because I have all along been of the impression that we've been significantly altered biologically by evolving within a symbolic niche. I think that the use of symbols is quite old – perhaps there will be debate about that. In any case, if we have been living in a symbolic niche for any significant period of time, that could have had a remarkably powerful effect on our biology and I want to talk about how that might have happened. I want to talk about how things get distributed, not just inside of our heads but across all those influences that might affect cognition.

There's little doubt that we have unique biological capacities and unprecedented features that make us capable of acquiring language. I actually think, as Steve [Pinker] does, that these were honed by extensive natural selection, that we went through a very long and intensive period in which the features that now drive language have changed our brains to make it easier for us in a variety of ways. It's an important background piece of the story.

I want to ask a few questions: What's the nature of the contribution if it's made by the evolved changes that have affected our brain structure? What is the contribution of what we are doing now or what we possibly can do that can be attributed to brain structure itself? Are there other significant influences affecting language, competence, and structure that are not in the brain, so to speak? (I'll use language as my example throughout this talk.) What might there be that has an effect on language and the structure and even our competence to do language that is not in the brain? Finally, how could such capacities have evolved – either one of these kinds of capacities? One of the things I'm going to suggest is that, in part, they evolved because of things falling apart.



... to the extent that epigenesis can take advantage of these kinds of things ... the genome will cede control of these and shift to a more regulative role ...

I'm going to title this "the lazy gene hypothesis." Obviously, it has inverse connotations with other gene terms. The point I want to make is that we now are very familiar with lots of what often are called "self-organizing" processes in biology. Lots of systems assemble themselves, organize themselves into cyclic processes. They are not regulated and they are not instructed in a strong way. So, to the extent that epigenesis can take advantage of these kinds of things – self-organizing, self-assembly, or environmental invariance in the world – the genome will cede control of these and shift to a more regulative role, handling contextual variables instead of trying to instruct the specifics. We've seen this again and again as we've begun to trace genes and their effects in cells and developing embryos.

My favorite example is the Fibonacci spiral, which occurs all over in the plant world. We now know that with a simple physical model of simply dripping liquid metal onto a watchglass, we can produce Fibonacci spirals by just adjusting the rate at which the drips occur. The Fibonacci spirals are there in nature because of spatial phenomena, not because they're encoded in the genome. But what they *do* provide is a wonderful distribution so that the sun hits all the leaves reasonably well in a plant that's growing up a stalk. It has adaptive advantages but that adaptive advantage can be utilized without having to encode it directly. You still have to encode things that affect growth, and so on.

I'm going to make a genetic parsimony argument that will be behind all of this. It basically can be laid out in three parts: Extragenomic support for structure formation or functional operation that can be obtained extragenomically will tend to degrade corresponding information embodied in the genome, and will do so by masking the forces of stabilizing selection that maintain its structural integrity. It will lead to a random-walk mutational diversity in degradation of those systems. The key word here that I'll come back to again and again is *masking*. That is,

selection can be masked by a variety of phenomena, some of them produced simply by behavior.

I want to contrast two extreme views. One claims that everything that's relevant to language is somehow in a box in the brain, and that there was a wonderful, hopeful-monster mutation someplace in the past. Various of us might want to place this wonderful human-making mutation at some place, nearby or far back. According to this view, that's what makes language possible – that there's a unitary, modular, domain-specific, mental algorithm that does it all. In fact, it's the strong computer model.

I'm going to make a very different model – a model that talks about the distribution of control, because in all other biological systems we often find that control gets distributed, gets shoved off of the genome. My argument is that it's a system of neural, behavioral, and social regularities all working together. There's no single feature that controls this. They are self-organizing processes within the brain, within embryogenesis, within the genome, and within social interactions. They're all playing a role in this.

Mostly today I'll be talking about the effects of higher-order organizing phenomena on the lower-order systems. I will give you some neurological and genetic examples and then show you some simulations we've run.

While we used to think that maybe one or two structures might be doing language, it's now becoming clear that a vast number of structures are playing crucial roles.

One of the stories that we've come to realize over the last decade and a half is that the more we look for structures in the brain that are doing something relevant to language, they multiply daily. While we used to think that maybe one or two structures might be doing language, it's now becoming clear that a vast number of structures are playing crucial roles. Whether it has to do with automatization in the basal ganglia or whether it has to do with intentional phenomena that are controlled both in mid-line cortex and all the way down in cerebellum, we're finding all kinds of multiple contributions. It's the kind of thing that when you have a very complex process that could involve many supports, you can recruit a lot of helpers to do it, and the

more you recruit and the more you can integrate that help, the better your processing can be.

Alfred Russel Wallace asked: How can you explain the complexity of human cognition? It goes so far beyond what you might imagine to be survival value. The answer to this at the end of the 19th century was posed by a number of researchers who made a kind of end-run around Lamarckian-inherited stories to talk about what is now called "the Baldwin effect," although it was actually discovered by three people independently – James Mark Baldwin, Lloyd Morgan, and Henry Osborne – in fact, all in the same year. The argument was that you could acquire innate capacities by virtue of your plasticity: If early-on you had relatively little innate support but a lot of trial-and-error support for a behavioral adaptation or a phenotypic adaptation that was simply a physiological adaptation that had some plasticity to it, it would, in effect, shield selection. So, individuals who could make it by their plasticity and flexibility for transmitting information generation to generation could, in effect, do so long enough so that spontaneously variants could show up in the population – we would say *mutants* today. This could eventually replace this clumsy way of doing it with a more innate, more streamlined way of doing it. Baldwin called it "organic selection." It has come to take on his name after a number of critics called it "the Baldwin effect" in the 1950s.

A parallel idea – I'm going to show you that it is, in fact, a very different idea – was proposed in the 1950s and 1960s by the geneticist Conrad Waddington. He called it "genetic assimilation." But Conrad Waddington didn't do it theoretically – he *showed* it. We now know what the genetics of his experiment was. It turns out that although I have based a good part of my argument on these views – at least in my book *The Symbolic Species* – as I went back to review it, I realized that they both don't work the way these men thought they did. What I'm going to tell you is some of the evidence we've gathered to show how they *don't* work and to show you that something else much more interesting shows up.



You can unmask selection by putting animals in difficult spots and then lots of things that normally wouldn't have been selected suddenly become available ...

Baldwin and Waddington are, in fact, quite different. Baldwin suggested sea level as a kind of metaphor for this: Above sea level is what selection can get to, and what selection can't get to ... think of it as erosion in the body, and this is the expression of the genotype. You can unmask selection by putting animals in difficult spots and then lots of things that normally wouldn't have been selected suddenly become available for natural selection to pick at and work at. Baldwin suggested that, in a sense, sea level rises and a whole lot of stuff can now freely vary, so you can sample a wider space because of your learning ability, or because of your plasticity.

Waddington, on the other hand, put animals in a very much more stressful environment, an environment full of ether, for example, or an environment that was very hot, and showed that you can also unmask a lot of variants and subject those to selection.

They're very different effects. They both have effects on the genome and what I want to talk about is what those effects are.

The problem with the Baldwin effect was pointed out right about the time Baldwin was writing, but it's mostly been forgotten. It was picked up again by George Gaylord Simpson in 1953 and subsequently forgotten and variously brought up and down again. The basic argument is this: The phenotypic plasticity that allows the Baldwin effect will mask the very forces of selection that would be necessary to shape up those innate surrogates that would be appropriate to eventually supplant that adaptation. In other words, the very mechanism that should allow it blocks the natural selection that would allow it to be replaced. That's a challenge: This will inhibit their evolution and, more than that, it will actually degrade any existing partial innate analogues because you've reduced stabilizing selection.

Now, there are special cases in which it can happen and those simulations in which it has succeeded, and we've run some of these as well. You have to have a very high cost/benefit ratio between the acquired

and innate trait; you have to have a very tight genotype/phenotype correlation, one-to-one; and you have to have something like a hopeful-monster saltational mutation. In other words, in one step you already get an adaptive function. You don't work your way up to it, because, in fact, selection has inhibited that process.

PINKER: There was a computer simulation of evolution of neuronetworks by Geoffrey Hinton and Steven Nowlan.

DEACON: I'll talk about the Hinton-Nowlan project a little bit later because actually we re-ran it under slightly different, more realistic conditions and it failed. I'll tell you why.

PINKER: It seemed there was an extra condition there that wasn't in your list, namely that acquisition of the trait is not "all or none" – that what could drive selection is how early in ontogeny you master it. So, even if something is acquired, it could be acquired after 100 trials or after 50 trials or after 10 trials, and the replacement of learned with innate structure moves the age of acquisition earlier, with the assumption that the sooner you get it, the sooner you enjoy the adaptive benefits.

DEACON: It's part of the cost/benefit problem. In effect, as you can move things earlier, you lose some of the costs.

PINKER: Right.

DEACON: You can weight it in a variety of ways. The cost/benefit is absolutely crucial to drive this. What we also show, and what Geoff [Hinton] doesn't show, is that the cost/benefits will come to a middle. It won't drive learning all the way out and it won't drive innateness all the way out. It will come to a balance point.

PINKER: My understanding was that that *was* their conclusion – they never got 100 percent.

DEACON: They never got 100 percent. They got better than we've ever gotten.

PINKER: In terms of how many of the connections are innate?

DEACON: That's right.

PINKER: But, as I remember, it was some proportion that was innate but, because the learning never went

away, the selection pressure was never high enough to drive every last connection to the innate state.

Lesions in the auditory areas damage your ability to take advantage of early learning. They also, if they're significantly damaged, make the sound different.

DEACON: That's right. The bottom line is that the advantages decline as you approach it.

All right, let me give you an interesting example that I've been studying recently. This comes from the work of a man named Kazuo Okanoya in Chiba University. He was looking at birdsong and the control of birdsong in the brains of these birds. [Referring to slide] Here we see a domesticated species called the Bengalese Finch and a feral species. He recently found the ancestor to this domesticated species. The species has been domesticated for over 250 years, domesticated for its coloration. It does not have a very pretty song: chirps and clicks and that sort of thing. But he wanted to study its song because it was a very easily bred bird and it did have a song of some interest.

A very interesting phenomenon came up that caused us to argue for a while and have to go out and chase down the feral cousin, and then to figure out what's happening, because here's what we found: The domesticated species was fun to study because it had a complicated song. The song had lots of different elements; it had a lot of variability over time; there was a lot of learning in it. However, the feral cousin had a very stereotypic song. The species that it came from had a song that was very limited and, in fact, the feral species does not learn its song. There's a slight amount of learning, but it's pretty minor; whereas the domesticated species had a tremendous amount of learning going on. Kazuo Okanoya was initially convinced that, to some extent, there must be some unconscious breeding for song going on in this process, or that there might be some wonderful linkage between coloration and song. It's not impossible and that's still a hypothesis we haven't falsified.

Let me show you a little bit more about it. [Referring to slide] Here's the transition. If we break up this song into song units, one of the things we find is that the wild species has a lot of repeats and you can show this by having the various song units and the tran-

sition probabilities between them diagrammed. The domesticated species has a much more complicated song. It can move around. Its song has a family history, that is, it acquires its song from its parent and has the variants of its parent and plays with those variants but not other variants. They don't have syntax but they have, in a sense, the movability of parts, and he calls it "syntax" parenthetically, to talk about this as a process of shuffling parts.

In the wild species, there is a fairly simply syntax, or structure, and there's very little individual difference and very little regional difference, whereas in the domesticated species you can find a generation-to-generation difference if you simply cross-rear them. You can find remarkable differences in song structure.

Okanoya was originally studying the structure of the brain and what controls song, something that's been studied for a number of years now. There is a lot of wonderful work. I find it very influential in helping us understand how language in the brain is processed. His discoveries about the song were that if you damaged one structure, for example, you would get increased linearity of the song. If you damaged another one, you would reduce the structure of notes – there would be fewer transition differences. And if you damage yet another structure, the final common output from the brain, you basically get a significant reduction in the number of elements in the song altogether.

The interesting thing is that this paralleled this species difference – though I remind you that it's not a species difference; it's a breed difference. Lesions in the auditory areas damage your ability to take advantage of early learning. They also, if they're significantly damaged, make the sound different. The animal doesn't actually pick out its sound well.

What about the wild cousin? If the wild cousin is damaged in all of these areas, it does almost nothing to the song. What's happened is that the wild cousin uses very little of its brain. The White-Back Munia really has the thing specialized. It's using just the RA structure, its primary motor structure, and it produces this song. It could care less about who's singing what. By the time it reaches adulthood, it knows what it is going to sing because it's well built-in.

The hypothesis I want to suggest here is that domestication masked selection that was maintaining song structure. What was it maintaining? Well, it was

maintaining the complex asymmetries of transition probabilities between these various song components. That was well represented and could be easily automatized in just a few areas of the brain. But with domestication, I think the innate transition biases between these song elements is regressed toward the mean, and, indeed, that's what you see if you try to look at these values. They've approached very, very similar values all the way across all the possible combinations. The result is that you get a quite complex song.

You could talk about this as complexity or more noise – I leave that up to you – but let me tell you about a simulation we've run on it just recently. This is done with agents that are acting like birds. These "birds" have begun their lives in an environment where there's a lot of selection. They're not real birds; they're computer birds. They have to acquire their song. There's selection on whether you pick the song right because if you mate with someone that's singing the wrong song, you don't produce babies.

In the first phase, there's quite a bit of selection on this and we see a bunch of interesting things. In fact, the average fitness goes up as you get better and better at doing this. Your song gets more stabilized, and all the variants of song begin to disappear. By the second phase, we get a very stabilized system in which there are a few song variants. The birds – I keep saying *birds*; you might call them *agents* or you might even call them *algorithms* – don't have to do a lot of work to learn it. It's fairly straightforward and they're pretty successful with it. These birds now have an auditory template for picking out who is singing the right song and they have a motor template for producing the right song. What we did is simply make it so there's no cost to making a mistake.

What would happen if the birds were, for example, being bred by hand by somebody else, and it didn't matter who they mated with? Well, in the first phase, after Stage 2, the songs look a lot like those of the feral cousin. What happens when we mask selection is that everything starts to fall apart. Song linearity decreases; the complexity of the song increases; the number of transitions increases; the filter that the bird needs to pick out somebody else degrades. This is a filter degrading. It doesn't actually recognize anybody. This is what you would predict is going on.

One of the surprising features is that the load on the learning mechanism actually increases in this pro-

cess, even though there's not a cost, because there's so much variability. What we see in these songs is something very similar to what we see in this domestic species. We see that the song transition probabilities have become much more complex.



How could the masking of selection have also resulted in the evolution of complex distributed functional integration ... if there was no selection?

So, what does this tell us about neurocomplexity? This is a story not just about song but also about complexity of the brain, and let me tell you why. How could the masking of selection have also resulted in the evolution of complex distributed functional integration and recruitment of the multiple brain structures in the domestic species if there was no selection?

Here's what we hypothesize and this is what seems to be characterized by the learning mechanisms that we've shown in the simulations: In the stabilizing selection, the song template is well built into this structure. There's genetic control of it. We have a sort of gene analogue that's controlling the template and that can be degraded if selection falls off, which is exactly what happens. When we block selection, it gets degraded. The capacity for this to do it on its own begins to flag or, rather, the biases become closer to each other. The result is other systems that contribute some bias now have the possibility of contributing their biases. When the biases in the driver were so powerful that they could determine the outcome without any significant variation, there was no possibility for this. But as this degrades, other systems can now contribute a bias. You get increased song variability under this, and if this continues, one thing that happens is that the learning mechanisms get more distributed.

The system had to be partially degraded for the function to be distributed across the brain.

In the case of the transition for White-Back Munia and Bengalese Finch, what we actually see is something very interesting: As the transition probabilities drop

down close to equal, a whole variety of other biases that are acquired in the lifetime of the bird suddenly become able to make a difference, but those biases get into the system by virtue of other mechanisms: by virtue of auditory processes, by virtue of motor capacities, by virtue of mimicry capacities, and so on. All of these systems can now play a role where they couldn't before. The system had to be partially degraded for the function to be distributed across the brain.

Are there finch analogues in language? I think there are plenty of them. I don't think it's *everything* about language – I want to be clear about this. But I think we should pay attention to this.

There's a significant loss in simplification in the cooptation of innate call systems. We don't have the kind of innate call variety that other species of apes have, certainly of chimpanzees. There has been what I would call a degeneration of vocal transition biases. We can produce almost any vocal sound after any other one, with a few mechanical constraints on it, and a few breathing constraints, but we don't have very strong transition biases between our speech elements. We have increased influence of auditory experience, like the birds. We have an increased capacity for auditory vocal learning, again like the birds. I think this is only going to play a role if you've decreased the template structure here. And also there's been a decoupling of social/vocal behavior from the arousal systems in us. You don't have to be really aroused to produce speech. We can produce it in very low arousal states. I think that's given us an increased potential to link sounds with diverse sensory motor experiences. In other words, I think we had to take a step backwards in this process, as well as steps forward.

... the release-like phenomenon of babbling in early children suggests that both the arousal decoupling and the allowance of multiple kinds of transitions are characteristic features of this kind of release phenomenon.

Another part of the finch analogues is that the release-like phenomenon of babbling in early children suggests that both the arousal decoupling and the allowance of multiple kinds of transitions are characteristic features of this kind of release phenomenon. There are a variety of others as well.

I told you I would say something about Wadding-

ton. Waddington's experiments were in breeding fruit flies. He showed that if you breed them in ether, a small number of them develop bithorax – something we now know can be generated by homeotic mutations. He showed that this was a facultative feature but if you breed them in regular environments, they don't produce this feature. If you breed, however, bithorax-producing animals who produce it only under ether, and do it for about 30 generations, they will produce bithorax without ether. In other words, this is the apparent acquisition into the genome of an acquired characteristic, and he called it *genetic assimilation*. I think it's a misnomer. We now know a couple of his examples. One was with a cross-wing vein pattern that's been recently studied. It turns out to have to do with heat shock protein variants. These animals were raised in heat and a small number of them raised in heat produced an unusual cross-wing vein pattern. In the normal environment, none of them produces this, but if raised in heat, a small fraction of them do. What Waddington did was he simply regularly bred those flies to show this pattern. It's a facultative adaptation – you might think of it as something having to do with distribution of heat in the wings or fluid in the wings, but by about 30 generations he was able to get animals that produced this without heat. So, something that was acquired or, in a sense, conditional on the environment became nonconditional – innate, in some sense.

What we now know about this is that there are multiple variants of heat-shock proteins on different loci. What was happening is that Waddington was co-assorting these loci. Each of them had some potential under heat to produce this effect, but when you put many of them together independently, they will produce this effect independent of that. These genes were there in the population already, but they were distributed and could not have this effect.

One of the reasons that heat-shock proteins also have the kind of variability they do is that they're not under selection in every generation. Many generations never express many heat-shock protein effects, so they have high variability, but you can get them to express their effects and if you then breed on the basis of those expressed effects, you're effectively inbreeding these biases toward cross-wing vein pattern. Waddington exposed this phenotype and then bred for it.

What I want to argue is something I'll call *parallel distributed selection* in which both of these are playing a role, in which the masking effect, which generates degradation and, indeed, differentiation of systems, also will produce distribution of selection onto other systems that are not degraded. It will increase the conditionality and plasticity that I've just shown, but that means that anything that has a role to play in the bringing of that plasticity into the system will now also suddenly be exposable to selection. This will unmask selection on variants that were not selected before but were relatively neutral and varying. The result is that you'll get this kind of co-assortment. It's a way that evolution can, in effect, sample for incipient synergies that are not there, but they're distributed across the population. Why? Because there are multiple loadings on a single phenotype and if that phenotype is being selected, you'll also be selecting on all the possible contributors to that phenotype. That's why I call it parallel distributed selection.



... language, culture, tools ... have radically altered the niche that we human beings have been in for a very long time and that has changed our biology.

I want to end by bringing us back to the question at hand and an idea that I posed in my book *The Symbolic Species*, which has since gotten a better name, *Niche Construction*, although I think it's not quite the same. Beaver dams are the classic example. Beavers are aquatic rodents because beavers build dams. Beavers have changed their environment, changed their niche, and their bodies, their biology, have responded to this changed niche. That niche has special requirements. What I want to argue is that language, culture, tools, the whole range of things that are relevant to us, have radically altered the niche that we human beings have been in for a very long time and that has changed our biology. Depending on how long you carry this back, it could have a very significant effect on our biology. What will it do?

This is masking of a different sort. I think this is what is most interesting for our future, but it's also interesting for our present. If the masking of this effect is not by something that I do but by something that's going on outside of me that I can interact with – for

example, a social process – where I contribute to it but I am not making it happen by myself, then the masking effect can have a very troublesome consequence. A bunch of genes producing a protein produce some function many steps away, and selection increases the probability of that gene being present in the next generation. But what if this function is masked by something outside, something in the environment? What will happen is selection will be masked on this system and this gene will take a random walk – *only*, of course, if this persists for a long period of time and is fairly stable.

***We've become addicted to vitamin C.
We have to get it from the outside.
We can't make it ourselves.
This is a masking from the outside.***

I think this has happened in a number of cases. I want to highlight one of them: vitamin C dependency. Somewhere around 35 million years ago, primates became diurnal and began to parasitize trees for their fruit. Now, birds have been doing this for a long time. Trees have apparently been advertising ripeness – when it's the right time for the birds to steal – by changing color. Fruits keep oxidated metabolism from causing damage to this wonderful source, to which they are going to attract these distributors, by virtue of the vitamin C that's packed into many of these plants. The result is that if you eat this regularly, you won't need to produce your own vitamin C. Most mammals do. Primates, anthropoid primates particularly, don't. We've become addicted to vitamin C. We have to get it from the outside. We can't make it ourselves. This is a masking from the outside.

Primates themselves, by their behavioral plasticity, created this masking but it has an unusual effect. It changed the physiology – in fact, it's recently been studied. The gene has been cloned for endogenous production of vitamin C – LGO, it's called. We know that in humans it's on Chromosome 8. Why do I say that? Because it's a pseudogene in us. In fact, it's a pseudogene in all the anthropoid primates that have been looked at. We can actually even now do the family tree of this pseudogene and see how it has changed across these various primates.

What has happened is that this gene has taken a ran-

dom walk. It has accumulated a couple of stop codons and some major deletions. In fact, for all intents and purposes, those mutations are noise. They're randomly distributed. This gene has taken a random walk under masking, under the fact that behavioral flexibility could allow this system to degrade. But now we're addicted to vitamin C.

But when you get addicted to something from the outside, it's quite a bit different, because now anything that helps you get it, just like anything that could bias your song, is now subject to selection. It becomes unmasked so that something that was controlled by one locus, LGO, can now be controlled by any number of loci that have any effect on increasing and maintaining the probability of getting vitamin C.

Selection becomes distributed across the genome onto genes that may play very irregular and unlikely roles in this process. My suggestion is that one of those is color vision. We find that when we look at the anthropoid primates, there are some interesting effects in terms of when three-color vision shows up. It's not all been fully worked out but now we're looking at some of the variants that exist, and it looks at though they all date back to pretty much the same time. This is the result of a gene duplication event: again, a duplication, redundant function, masking, and variation – a similar sort of process at the genome.

I want to suggest to you as a hypothesis that color vision in primates is an adaptation for vitamin C. I think we've shifted selection for making vitamin C onto the opsins on the X chromosome.

I want to suggest to you as a hypothesis that color vision in primates is an adaptation for vitamin C. I think we've shifted selection for making vitamin C onto the opsins on the X chromosome. They've become duplicated to produce color vision. I think this is a very powerful phenomenon. It's a phenomenon that will shift selection across the genome and pick out synergistic functions. We don't have color vision just for our fruit eating. We have lots of other capacities. [Referring to slide] This is a variant of the Hinton and Nowlan experiment but we did it with a vitamin C model. What you see here is the onset of vitamin C being available in the world. It's lower in the world here. We have endogenous vitamin C-mak-

ing happening here in this picture. But a little bit later in time we drop off the vitamin C so there's not quite as much available in the environment. We have three other systems that at various times came online that could get it. So long as you had some vitamin C in the environment, it could aid because you couldn't make it all yourself. When those came online, they were maintained. These were learning adaptations, in effect, that needed something in the environment. But when vitamin C got produced in huge amounts, the endogenous production system dropped to zero. There was no longer selection on it; it accumulated noise and failed to work.

In this case, you can completely eliminate one component, whereas in the other direction we can push it to equilibrium, so to speak. With this kind of masking effect, you can completely eliminate function, but under these circumstances, these three adaptations became necessary. When vitamin C availability dropped down in this model, you had to keep these up and they increased in their probability in the population over time. All three of them supported each other.

I want to make the claim that language and culture and tools – you put them all together and you get the ultimate of an artificial niche. I want to claim that the creation of a symbolic niche recruited this highly robust, metastable, many-segmented, component system. Not one mutation, not one place, but many systems simultaneously drew them together by virtue of, first of all, the masking effects of culture that allowed the system to, in effect, accomplish these things in a variety of social ways. This masked a lot of other functions, including, I think, a lot of vocalization functions that we were now being able to carry on by other means, allowing the release of some of these functions to be taken up elsewhere. The reason that we have such a widely distributed and multi-component system that has been adapted for language function is, in part, because it was degenerated then re-recruited by this process.

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What you get is a very complicated system, in which we have to look at all of these levels and understand their interaction, and that's not a trivial problem.

The multi-stable system that will result from this kind of recruitment can make learning appear innate and totally pre-specified, not because there's one place that does it, but because there are so many cooperating biases in the system that the system will, in a sense, fall into what we call attractors so easily under these circumstances. The real challenge is that this makes the problem really complicated. Where are you going to find all these? You can't now look for the single magic bullet in the story. What you get is a very complicated system, in which we have to look at all of these levels and understand their interaction, and that's not a trivial problem. But who thought evolution was trivial? And who thought language and brains were trivial? Thank you. I'm open for questions. Steve?

PINKER: I don't know finch phylogeny very well, but I imagine that these Munias must have relatives and ancestors that had fairly elaborate song and that it may have been lost in the lineage leading to Munias?

DEACON: Many finches have had a different song variety.

PINKER: Is it possible that the unmasking consists of basically unmasking genes that, perhaps for adaptive reasons, were suppressed in the Munia lineage, presumably because in many environments birdsong would have costs but no benefits – say, low parasite load, high predator attraction – and that really a lot of the complexity didn't come because there was some underlying plasticity that was allowed to emerge but there was a fair amount of specificity from a finch ancestor that just in that lineage was suppressed, that the selective breeding may have selected out inhibitory genes that suppressed this preexisting system?

DEACON: The question is: What would keep those genes in the population when they're being masked from selection?

PINKER: Yes.

Every time you mask selection, so long as you allow the random walk noise effect, it's very hard to go backwards.

DEACON: We've actually been trying to simulate this exact question. If you have one template that you can mask and knock out, why can't you throw a bunch of partial templates into the system and see what happens? As far as we can tell so far, you get the same effect. Every time you mask selection, so long as you allow the random walk noise effect, it's very hard to go backwards. It's hard to go backwards because when you make something noisy, it's hard to make it, in a sense, organized again.

What has to happen under those circumstances is exactly what you described. There has to be a reason to keep them around but to inhibit them. Now that's certainly possible and there's no way to know at this stage if that's what we're dealing with.

PINKER: If you can reconstruct the phylogeny of the finches, it could be that they have a close relative, the Munias, that perhaps indicate that a fairly recent common ancestor did have elaborate song, which was being unmasked....

DEACON: I know a little bit about those in Northern India where this was picked up, and most of the ones around this do not, but that doesn't mean that finches in general don't. So, I don't know for sure whether that's true. One of the things we're trying to do now is a finch genome study in which we can begin to look at this question.

One thing that we think has happened in this process is that, in effect, the genome of the finch in captivity has become progressively degraded like it does in many domesticated species in which you get a lot of variants showing up – you get a lot of random-walk effects. A question we want to ask is: Exactly what genes were hit by this; can we trace it out? A lot is known about genes that are active in song production, so I think this will be a very fruitful way to go.

PINKER: You said that the human vocal call repertoire is smaller than that of other great apes such as chimpanzees.

DEACON: Not smaller than all great apes, of course, because orangutans have an almost zero....

PINKER: Is that well established, especially if you were to include among human vocalizations things that may have been given linguistic output but which, nonetheless, might be triggered – like swearing, like exclamations of various kinds, epithets, expletives? Even though they have as output sequences of vowels and consonants in your native language, we also have reason to believe – you covered some of this literature in *The Symbolic Species* – that they have subcortical loci that can be unmasked in case of aphasia, and so on.

DEACON: It's interesting that with all the subcortical loci, now that we know something about these, they are not the subcortical loci involved in call production. That's the natural assumption; it turns out they're mostly basal ganglia. The point could be made even stronger, and that is I think prosody has so many features that are characteristic of primate calls. We have totally recruited it for language. To do so, I think, we had to degrade its control system. It still plays a role in signaling some of the same emotional states, and so on, but it doesn't have the stereotypic function that it did have. What I'm talking about is not elimination, in this case, but reducing some of these constraints and flattening out some of the probability distribution so that it can become utilized under these circumstances.

PINKER: So, the calls that we may have inherited from the common ancestor with the chimpanzee might still be present in humans?

DEACON: I think that most people who have pursued this would argue that most of them are gone, and those that we have that are highly stereotypic are very different from chimpanzee calls. For example, most all other primate calls do a significant amount of vocalization on inhalation breath. It hurts us to do that. It's not something we do well, so even when we laugh and sob we try not to do it. It's only when we sob that we have any kind of inhalation vocalization, but it's very, very common in most other primates. So, a number of things seem to have shifted even in the innate calls that we do have, suggesting that there's really been a reorganization in that system. I don't mean to suggest that it's gone.

PINKER: Is it a reduction or just a reorganization?

DEACON: It's a little of both. Obviously we don't have the range of stereotypic calls, but we have a handful of stereotypic calls. Most people put it somewhere around ten, maybe a little below, depending on whether you are a lumper or a splitter. We could probably go around the room and figure them out here – it's pretty easy. But even those are not nearly as stereotypic as many of the chimpanzee calls.



... it may be that one component of this complex system ... might have to be some core engine that does some kind of mapping from propositional structure onto signals.

PINKER: The third question: I know that you meant to draw the dichotomy stronger than you would ultimately push it, but in the last slide that you showed, with the various self-organizing, co-dependent systems, it could still be compatible with some kind of partial specialization for grammatical language, if it wasn't enough just to tune up attention, just to tune up memory, and so on. It won't necessarily give you grammatical language with a complex mapping of propositions onto syntactically strong signals.

I'm very sympathetic to the overall story, but it may be that one component of this complex system distributed among capacities in the auditory system, the motor system, attention, and memory, still one of those boxes might have to be some core engine that does some kind of mapping from propositional structure onto signals.

DEACON: Could be. Obviously this is something that we don't know the answer to. In one of the studies that we're doing now – again, a simulation study; Simon Kirby has been working with me on this stuff – there are a number of self-organizing kinds of models that he's been showing, generating various components of syntactic structure – not anything complicated, but confidentiality and that sort of thing. Right now we're running a model in which the population is, in effect, given an innate grammar to do those things that we know can self-organize in the environment. It looks as though we get the same effect. In other words, if it can be generated by self-organizing processes outside of the template, even having the template to begin with

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is not enough to keep it there. It's a very interesting finding, but clearly there may be many components that you just can't do that way. And if you can't, those are the things that will *have* to be put in.

PINKER: The components could be fairly abstract and generic and need the support of all of these other cooperating systems.

DEACON: That's right.

OBSERVER: Do you expect that these distributive, synergistic systems that happen by masking and unmasking are fragile or robust?



It's one of the most remarkable things in the world that the vast majority of living human beings acquire language almost effortlessly.

DEACON: I think they're quite robust. What's happened is that we've shifted from a single locus or a few loci onto a highly distributive set of loci. What that means is that any one or two or three or four of those might be knockable and not actually affect the whole final system.

This is also an argument about how you evolve toward metastability. It's unfortunately also an argument about how you evolve toward epistasis. These genes will now become more and more dependent on each other in complicated ways.

A theory that we've not really had good data for yet is how you get the kind of epistasis we're now seeing in the genome. This is an argument that would say that it's a spontaneous consequence. Things may fall into epistasis under these circumstances. But epistasis – in the way I've described it here, and it's certainly not true for all epistasis – would tend to produce what I would call metastability; that is, if you've got multiple, partially redundant supports, you're not so fragile, and that is, of course, what we find with language. We could do a lot to a human brain and still have language function. It's one of the most remarkable things in the world that the vast majority of living human beings acquire language almost effortlessly. I think part of the story has to be that there is a kind of metastability to it. It's hard to fail.

TOOBY: I'm wondering about the distinction you're trying to draw, in the sense that wouldn't everything

always already be this way? You have this notion that there is this initial state in which there is a single, isolated, sort of modular thing in which genetic effects map onto unique structures that are causally isolated from the rest of the system, and then the thing gets more complicated and degenerates. You drew this opposition between prespecified and things that end up looking like innate and prespecified. What you call things that would have ended up looking like innate and prespecified was always my model of what innate and prespecified was anyway.

DEACON: If that's true, then there's no difficulty here. The other side of this argument is: How do you start this process? This is a hierarchic process, if you think about it. This is a process in which higher-order relationships are being superimposed, not one in which you're sticking new genes in. However, I think gene duplication contributes to this significantly. Gene duplication is an internal way to produce masking effects. This is how you'll generate new starting points, and then wander away from those starting points and build new higher-order relationships. I actually think that this is an effect that we have to follow through all of evolution, because when we talk about what we might call *synergistic effects*, this has to come into play. That would be at the cellular level, at the multi-cellular level, at the brain level.



This system will almost never have a uniquely causally isolated, single solution that develops independently. That's not the way any biological system would look.

TOOBY: It follows from the distinction between human engineering and natural selection, which is: Everything that has an effect on an output that's under selection will come under selection. Throughout the system, in any complex engineering system, that will be a lot of things. This system will almost never have a uniquely causally isolated, single solution that develops independently. That's not the way any biological system would look.

DEACON: Absolutely. And that's certainly what this shows.

Another piece is that this is a challenge to aspects of the modularity argument, in which you can get

modular function with a distributed system. There are some very interesting questions to be asked because what this basically says is that you might get multi-component contributions, but they're all drawn by a central function. They're all drawn by a central phenotypic effect that's become unmasked, so you could

get what I would call facultative modularity quite easily out of this story. I think there are some very interesting questions to be sorted out in terms of how the two sides of this coin fit together.

VELAMOOR: Thank you, Dr. Deacon.

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It's the endocasts that give you the direct evidence of what may have happened to the brain.

HOLLOWAY: I'm going to deal with endocasts. It makes sense to me that if you're really interested in the evolution of the brain, it would be wise to study the direct evidence for it. It's the endocasts that give you the direct evidence of what may have happened to the brain. I'm going to take you through what I've been trying to do over the last 35 or 40 years to understand what things you can see on fossil brain endocasts.

First of all, we have to ask this question: Is paleoneurology paleophrenology? The answer is: You better believe it. If you don't have localization of function, somewhere to look to, the game is lost at the very beginning. [Referring to slide] Here is our father figure, Frantz Gall. He's not a hero figure in anthropology, as you can well understand, but at least in his very early days he came up with the ideas of localization and demonstrated that the brain was not some homogenous blob or mass without distinctions.

[Referring to slide] These are endocasts, or are they really? You really can't be sure that I haven't put a couple of different kinds of baking potatoes in there. But these are really true brain endocasts; they are the dorsal view. What you're seeing at the top is the anterior frontal portion and what you're seeing in the bottom, of course, is the inferior portion. *Pan paniscus*, the bonobo or pygmy chimpanzee; *Pan troglodytes*; and *Gorilla gorilla* – this gives you some idea of the size of these. The collections that I have put together over the last 30 years include about 44 *Pan paniscus*, roughly 34 *Pan troglodytes*, and roughly 44 *Gorilla*.

There's very little you can say about them. You can say something about size because you can dunk them in water and find out how much water is displaced.

You can say something about the relative shape of the frontal lobe – how long it is, how broad it is, and so forth. But you'll be hard-pressed to find the central sulcus, to find the lunate sulcus, and so forth. On the very top is a picture of a brain. The blue is the central sulcus. The red is the sylvian fissure, the anterior portion being to the left, and on the bottom is an endocast. It looks like a Mayan pot, almost.

What do you see on the endocast? Precious little, and that is the problem with endocasts. When I wrote my dissertation in 1964, I said, "Endocasts are useless; you can't do anything with them; why bother?" There's a long story there, about the Department of Biology and how if you couldn't study *Aplysia*, the sea slug, and find out what was happening in the brain, how could you find out what was happening in a primate brain? So, there went my career in quantitative primate neurohistology. I had an opportunity to go to South Africa and study under Philip Tobias for a half-year and I became entranced with endocasts once again, even though I had thought I had demolished them in my dissertation.

This is a dorsal view of the same. If you look at the right-hand side of the brain, you will see that the left occipital cortex extends posteriorly and is wider. And if you look at the top part of the frontal lobe, you can detect that the right frontal lobe is a little bit wider. Those are asymmetries that have been well described, particularly by Marjorie LeMay in the past, and they have a very, very strong correlation with handedness. So, when you find a left occipital/right frontal, in 90 percent of the cases, you're dealing with a right-handed person. You can see this on the endocast as well. If you look at the endocast on the left-hand side, look at the left occipital portion at the bottom; I think you can see that it extends posteriorly and is also a little bit wider than it is on the right. If you can detect the midline on the endocast, you can see that the right frontal is probably wider as well.

These are some of the things that we tend to use

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when we examine endocasts to get some idea of what the cerebral structures might have been, at least in terms of possible laterality.



... there might have been some cerebral specialization taking place, at least with regard to handedness, 1.8 million years ago.

[Referring to slide] This is KNM-ER-1470, which is now called *Homo rudolphensis*. There was a time in which it might have been an enlarged *Homo habilis*. In any event, it's really about the first *Homo* that we have in Africa going back to about 1.8 million years. There's a little bit of distortion in this skull but there's no question that you get a left occipital petalia pattern and you get a right occipital/frontal with pattern as well. So, this sort of suggests that there might have been some cerebral specialization taking place, at least with regard to handedness, 1.8 million years ago. In fact, from about 1.8 million years ago, when we go through *Homo ergaster*, when we go through *Homo erectus*, and so forth, even Neanderthals, we do find these asymmetries.

I want to back up just a little bit, because there have been claims that you find these asymmetries on gorillas, chimpanzees, orangutans, and so forth, and all I can tell you is that what you do not find is this torque pattern of left occipital/right frontal. What you do find, on gorillas in particular, who are highly asymmetrical, is perhaps a left occipital or perhaps a right occipital. But they never tend to be associated also with the opposite side in terms of the frontal, so you don't get the torque pattern of asymmetry. It's a very different thing and I don't think there is very good evidence that the great apes show a great deal of handedness, at least not at this point.

These are two specimens, a left lateral view of them: *A. garhi* on the top, a possible stem ancestor for *A. africanus*, and some part of it might have gone into *Homo habilis*, though possibly not. *A. boisei*, of course, is the robust *Australopithecine*, or *Zinjanthropus boisei*, if you like. These are both from Ethiopia. The green that you see on *A. garhi* is a reconstructed portion but almost all of it was available on the underlying plaster that Tim White sent me, so I feel fairly good about the reconstructed portions. On the

A. boisei, the orange that you see at the bottom is the reconstruction, but I had OH5 to go on; I had SK1585 from Swartkrans to go on; I had a whole series of other *afarensis* and *Australopithecines* that I could use to help model these missing parts.

The lateral portions of *A. garhi* and *A. boisei* look very much the same, outside of the fact that one was reconstructed in blue clay and one was reconstructed in yellow clay. But when you look at this view, you see that the shape change is extremely different in terms of the occipital view. What you get is this very, very broad width in *A. boisei* and a much narrower one in *A. garhi*, indicating, very likely, that there are some probable differences in the brain organization as well, although from the endocast you're certainly not going to be able to say what that brain organization was that shows the difference.

So, this is a third aspect of brain endocasts that is useful. The first is that you get size; the second is that you get asymmetries; the third is that you get some indication of possible shape differences and then possibly, using multivariate analysis on large samples, you might be able to glean something functional from that. So, endocasts are not totally useless.

... the concept of reorganization ... what I meant by it was that there were quantitative shifts in neural components and once you had a quantitative shift in a neural component, that really meant reorganization in the brain.

What I became interested in, back in 1964 when I did my dissertation, was the concept of reorganization. I certainly did not invent this concept. The concept of reorganization has been around a long time, certainly Grafton Elliot Smith used it; Raymond Dart certainly used it. But what I meant by it was that there were quantitative shifts in neural components and once you had a quantitative shift in a neural component, that really meant reorganization in the brain.

You can get a change through time, from Time 1 to Time 2, in which size only is changing. You could take the anterior dotted line on the top sort of as a central sulcus. You could look at the bottom one as perhaps a lunate sulcus, which separates primary visual striate cortex. You simply enlarge it and nothing really is happening. They are scaling exactly isometrically. In the case of reorganization, however, you can change the

growth patterns as to what is developing through the ontogenetic time. Here we see that the size is the same thing, but look what has happened to what I would call the lunate sulcus here: It is moving posteriorly and you're getting a reduction in primary visual striate cortex (area 17) and what might be an increase in the parietal lobe or extra-striatal parts (areas 18 and 19).

That's just one example of reorganization. You could get reorganization if you change the hierarchy or maturation rates so that you would get different fiber distributions in here, which might not change the size at all. But you are never going to be able to discover those from endocasts. Those are lost in the prehistory.

You get degrees of different asymmetries. I think there are, possibly, also changes that you find in neuroreceptor distribution, as you see between Time 1 and Time 2. I haven't studied voles. When I look at a vole brain, the prairie and mountain voles look exactly the same to me. If I weighed their brains I don't think I would find any differences in their weight particularly. If I examine the morphology, as lissencephalic as it is, what do I find? Nothing that I can tie on, and yet look at those behavioral differences between them in terms of, particularly, motherly care. What's the difference? The differences are in oxytocin distributions throughout the cerebral cortex and the rest of the brain. One group lights up like a Christmas tree; the other is very blank. You can imagine that there can be these possible kinds of reorganizational change in the hominid record and you're not going to find these in endocasts either.

The things I'm concerned with are the reduction in area 17 – primary visual striate cortex – and possible asymmetries in Broca's cap region.

Just to remind you, this is the famous Brodmann's area 17. The things I'm concerned with are the reduction in area 17 – primary visual striate cortex – and possible asymmetries in Broca's cap region. Now, Broca's cap region includes 44, 45, and 47 down here. These do show up in fossil brain endocasts. Of course, you have very, very important things that are happening in area 39 and 40 in the angular gyrus, and it gets very complicated in area 37.

One of the things you can do if you go to the comparative record is take a look at the marvelous dataset that came out of Stephan *et al.* in 1981 and is still being used. They had these brains; they got their overall sizes; they had their body weights for something like 46 different species, including ourselves, of primates; then they did the histological sectioning, and then calculated the volumes of different parts of the brain, and so forth. What I've put up here is Logbase 10 of striate cortex versus Logbase 10 of brain weight. We have to use logs because scientists' minds go only in straight lines. This is the human point here. If you don't use the human point and you get the regression line for this – this being chimpanzee and gorilla up here – you end up with a correlation coefficient of about .97 or .98. It's extremely high, as one would expect from these kinds of allometry studies. If you then ask: What would I expect, then, for a primate of this brain size, if it were human; what would its striate cortex be, based on this nonhuman regression line? What you would come up with is that the regression line is up here and this distance actually is 121 percent less than would be expected, so the predicted volume is 121 percent more, if I could put it that way.

I would suggest that when your predictions are off by more than 100 percent, it's time to think about it and look at it carefully. I think that's a very important argument for the reduction, speaking relatively and allometrically, of primary visual striate cortex in humans. I would translate that, then, into a relative increase of posterior parietal association cortex – that is, through time.

We didn't evolve from chimpanzees, so please keep that in mind ... we always play the game of using the chimpanzee as our stem ancestor. Be careful in that kind of reasoning.

We didn't evolve from chimpanzees, so please keep that in mind, because we go back and forth from the comparative record to the phylogenetic evidence from fossils, and so forth, and we always play the game of using the chimpanzee as our stem ancestor. Be careful in that kind of reasoning.

[Referring to slide] These are predictions for *Homo* for various structures you can get out of these figures. Terry [Deacon] did the same thing years ago

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and published it in the international journal *Primateology*. As I said, what you get is 121 percent, if you use all of the 45 primate species. If you just use Old World and apes, it comes down to 66.6 percent but that's still a respectable amount. If you're doing the lateral geniculate body, which, of course, relates to primary visual striate cortex (area 17), it's 146 percent less than would be expected. If you're doing cerebellar weights, 6.2 percent. Now, remember that this is log data; confidence intervals are going in this direction, narrowing toward the central part of the regression line, and getting increasingly divergent at the ends of the distribution. Consequently, 6 percent is possibly meaningless in any significant statistical sense.

However, consider the diencephalon, which is 54 percent greater than expected, or the septum, which is 20 percent greater than expected, or the amygdala, which in humans is, for whatever reason, 53 percent less than expected. I don't know what to say about that. I'm not sure that 53 percent is truly statistically significant. My intuitive feeling is that differences above 15–20 percent should be examined more carefully as possible candidates of examples of reorganization. I would want to really look at the difference between the amygdalas in great apes and humans, and explore whether, for example, fear responses, or amygdaloid/cerebrum interconnections play some functional role in differentiating their respective fear responses.

[Referring to slide] This is not a fried potato or dumpling. This is *Australopithecus afarensis*, AL162-28, an endocast that's possibly around 3.2 million years of age. You're looking directly on the occipital surface of this endocast – these being the occipital poles right here, the cerebellum line here. The anterior portion is broken off. The main thing to look at is this groove that you see here. In all great apes, the lunate sulcus – the anterior boundary of area 17 is always bounded by the lunate sulcus. Coming down from the pre-central sulcus to the lunate sulcus is the interparietal sulcus. That always abuts posteriorly on the lunate sulcus in great apes. Hopefully, this slide helps. John Gurche made this rendition for me because the actual photographs are very difficult to interpret.

What you have here, then, is this groove we were talking about being identified as an interparietal. If it is interparietal and it is ending here and this is a great ape pattern, then the lunate sulcus has to be here. Dean Falk's argument was, in fact, that this is

the lunate sulcus; therefore, it is a great ape. But the problem is that the lambdoid suture is also there, and the anterior part of the lambdoid suture always has a little groove in it that appears on the endocast. This was shown way back in 1936 by LeGros Clark. So, you have the cerebellar lobe here. Notice the occipital pole. The distance between here and here is 15mm. Any chimpanzee is at least 25 to 30mm. The chimpanzee of the same size as this – this is about 385cc in terms of volume – has a lunate sulcus that's at least twice the distance to the occipital pole.

What this tells me, as a hypothesis, is that I've got major reduction in primary visual striate cortex starting roughly 3.5 million years ago.

[Referring to slide] This is a beautiful chimpanzee braincast. There was a time in which I was so disposed that I was taking measurements every 5 degrees on the surface of the endocast, going to a central homologous point, and then doing a multivariate analysis of this. The upshot of it was that I got most of my variation on a large comparative sample in this region back here where you find the lunate sulcus. Thank god I threw that dataset away. I would never want to go back to it.

[Referring to slide] But now you can see a nice chimpanzee brain. I got this from Wally Walker many years ago. There's the lunate sulcus. There's just a sample of five more chimpanzee braincasts that I have, and I've put arrows at the lunate sulcus in each case. The point here is that they show variability, of course, but that variability is still in a very anterior position and now we have measured something on the order of 80 chimpanzee hemispheres and the average distance from occipital pole to lunate sulcus is roughly on the order of 30 to 35mm.

[Referring to slide] Remember old Taung, the child here? This is part of the summary of the arguments. When Dart studied it in 1924 and 1925 and published on it, he thought that the lunate sulcus was in this region. Remember that Dart studied under Grafton Elliot Smith in London, and Grafton Elliot Smith was the one who put the lunate sulcus on the cognitive map (if I could put it that way) of neural anatomy. Falk disputes that. This is Falk's dimple, which she insists was the lunate sulcus. The lunate sulcus, according to Falk, would have come pretty much down like this.

When we took the chimpanzees from the previous slide and got the coordinates for it, then put it back

onto Taung, the chimpanzee average lunate sulcus would fall along here. I think if you look fairly carefully at this, you'll see that if you have a lunate sulcus going here, it's going to violate the morphology that's already there. It's going to cut across gyri and you see no cuts across those gyri at all. So, I think it's a reasonable way of testing the hypothesis that Falk's dimple is too far anterior. If you put the chimpanzee there, it is also too far anterior, given what you have in the endocast. So, I think Dart was probably right.

Here you can see it again from the occipital view: lunate sulcus on a chimpanzee here; Falk's dimple; average chimp lunate sulcus here; and possibly Dart's lunate sulcus in this region. The problem, of course, is that this is where the lambdoid suture is. The lambdoid suture, unfortunately, is probably masking whatever true lunate sulcus morphology is in there. There's nothing we can do about it. That's the way it is.

Now, there is another endocast – it's Stw 505 from Sterkfontein, South Africa – that has been recently described and I'm so pleased to tell you that it really does have a lunate sulcus, and here it is, right here. You're looking at the posterior part of the frontal lobe over here. The midline is somewhere in here and you have about 20mm of difference between the midline and where you would expect the lunate sulcus to be, and that is in a relatively posterior position, because this thing is about 56cc. You would expect it to be roughly about 40mm out to the side.

Now we're looking at *Pan troglodytes*. You're looking at the base of it. I just want you to look at these regions here and I think you'll see that they're unremarkably symmetrical, or at least nothing is popping out at you to say: "Wow, I'm asymmetrical." At least not from the endocast.

PINKER: Is this the ventral surface?



We know that cerebral asymmetries have something to do with cognitive differences and specialization in the two hemispheres.

HOLLOWAY: Yes, that was the ventral surface. What I was pointing out to you was what we would call Broca's cap in those regions right in here. Now you're looking at modern *Homo sapiens*. I think you can pos-

sibly detect that there might be some asymmetries in that region. If we look at the frontal view of this *Homo sapiens*, the same one, I think you can detect asymmetries, very visible in what we call Broca's regions.

Do these asymmetries have any functional aspects? Different researchers get different views. I'm not really sure that these are very useful, but on the other hand, there are asymmetries in Broca's region, and sometimes they seem to favor the left; sometimes they seem to favor the right. It might be prudent at least to look at these and see how they come out. These are casts of the frontal lobes. You're now looking at the ventral surface of it, this being the orbital surface of the frontal lobe here. I've got roughly about 40 or 50 of these so far. Yes, you can see asymmetries, but it's not enough to say, "There's an asymmetry here." You really want to give some quantitative estimate or demonstration of what that is. That's the next research project we're involved in.

This is Jebel Irhoud; it's a Neanderthal. You're looking at the basal view of it, so this is left Broca's cap here and here's right Broca's cap. I think you might agree that you see some asymmetry there – rather striking asymmetry – the same kind, roughly, of asymmetry you find in modern *Homo sapiens*. This is Sambungmacan (SM3), the *Homo erectus* recently discovered. (There is now an SM4.) This is the cranium of SM3. This is the brain endocast that we prepared, and I had one of my friends draw red around those areas that we could identify as basically Broca's cap region, and so what you see is this larger left Broca's cap appearing then on the right side.

Well, it's fascinating. It certainly doesn't prove language in *Homo erectus* times, but it's very suggestive. So, if it looks like a duck, acts like a duck, walks like a duck, sounds like a duck, is there some outside possibility that it might be a duck?

We're looking at brains that show cerebral asymmetries. We know that they relate to handedness. We know that cerebral asymmetries have something to do with cognitive differences and specialization in the two hemispheres. We also see asymmetries in Broca's caps. Are we entitled to be uniformitarianists and argue that if you see these things in modern *Homo sapiens* then you can make these connections? Are you entitled to make them into the past? I would say yes.

These would be the major areas of cortical regions

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that were important early in hominid evolution, running from area 17, primary visual, which we think is reduced to increases in asymmetries down in areas 44 and 45 in Broca's region.

I'm going to suggest that these basic reorganizational changes took place in the evolution of the human brain, starting with the reduction of primary visual striate cortex with *Australopithecus afarensis* – this taking place 3.5 to 3 million years ago, the evidence being at least AL162–28. Now I think you could add Stw 505 to this and possibly Taung as well. Somehow at the time of *Homo habilis*, perhaps 2 to 1.8 million years ago, or at least with early *Homo*, you're getting reorganization of the frontal lobe. The third inferior frontal convolution in Broca's area is very distinct on KNM-1470, if I were to show you a lateral view of it. It is identifiable as human and not as pongid. We do know that there are cerebral asymmetries, left occipital/right frontal petalias probably in *Homo habilis*. Certainly you see them in the 1470 endocast, but you find them in all subsequent *Homo erectus* endocasts after that. There are three aspects of cerebral reorganization. Here we have refinement in cortical organization. I have no evidence for that. I just assumed that there has been some of that.



... it's not just simply increase in brain size that characterizes human brain evolution. It isn't just reorganization ... but there's an interdigitation through time ...

So, the conclusions: Paleoneurology directly tells us about brain size. It demonstrates asymmetries in Broca's region and left-right hemispheres. Brain endocasts show changes in cerebral organization; both changes in size and organization are present at between 1.5 and 2 million years. The evolution of the brain, then, has been an integration of both size and reorganizational effects occurring at different times and at different rates where both allometric and nonallometric changes have occurred. My point is that it's not just simply increase in brain size that characterizes human brain evolution. It isn't just reorganization that characterizes, but there's an interdigitation through time and the challenge is to unravel that interdigitation. Thank you.



... why would we expect, say, a shrinkage of primary visual cortex (D1) in a species that we antecedently expect to be smarter ...

PINKER: We all take for granted that there is this allometric function relating brain weight to body weight. In one naïve view, you would think that it doesn't really take that much more brain to control the body of a gorilla than the body of a gibbon, nor would you need that much more brain tissue to process visual input from the retina of a gorilla compared to the retina of a gibbon. That would be at least one model, in which case you would expect that the bigger the animal, the smarter – if there was some law of growth that would make the brain grow with some positive monotonic function compared to body size. You would get smarter and smarter as you got bigger and bigger. It would be a very dramatic effect because how much more motor cortex do you need for a gorilla than a gibbon, or, for that matter, a mouse?

On the other hand, I don't think we see that as a strong pattern, and, if not, then why would we expect, say, a shrinkage of primary visual cortex (D1) in a species that we antecedently expect to be smarter – in the other direction?

HOLLOWAY: It's not really shrinkage. It's proportional.

PINKER: So, if posterior parietal gets bigger, then all you are saying is that D1, as a proportion of the total brain, gets smaller?

HOLLOWAY: Probably so.

PINKER: Not in absolute terms.

What I'm trying to show you ... is that you don't need the brain to enlarge at all to get the reorganizational effects.

HOLLOWAY: Now we're getting into directional pressures, and so forth. I would think that the pressures for increasing posterior association cortex were stronger than.... There's no evidence that reduction, relatively speaking, in primary visual striate cortex would have

any effect on the issue of vision and its acuity.

The interesting argument is really between myself and Jerison and Falk, who really thought that the only way you could get a reduction in primary visual striate cortex, or this kind of reorganization, would be to have the brain enlarged. What I'm trying to show you – and them – is that you don't need the brain to enlarge at all to get the reorganizational effects.

PINKER: Has there been any coherent theory as to why there should be an allometric function relating brain weight to body weight at all? If it's just growth, namely, just the developmental program requires you to have more of the other, then why wouldn't all that extra brain tissue be put to use when you have super-intelligent whales and super-intelligent elephants, and so on? Is there any story on that?

DEACON: Lots of stories!

PINKER: Any good ones?



The real challenge is that we still can't agree on how to do the statistics.

DEACON: The real challenge is that we still can't agree on how to do the statistics. This is challenging because what line you draw through those points, although the one that Ralph shows is probably the most robust of all of these, but also simply for brain and body size. While you might think that we would have a good sense of what's going on, in fact, I don't think we do. I can't remember who mentioned that .75 is the accepted number. I certainly don't accept that number because, in fact, it's drawn through *all* mammals.

Now, it's wonderful to put all the mammals together, but, of course, if you look at their embryological development, the primates start, from the earliest point in embryology, being shifted off of that significantly. If you drop them out, the line drops back down to three-quarters. It differs within species. It differs within various groups. We really don't have a clear sense of it.

Let me give you the three standard hypotheses. The first one is that it scales with metabolism. That idea was brought up by Otto Snell in '61 and has been

brought back and forth....

HOLLOWAY: That's 1861.

DEACON: Sorry, yes. Actually, 1891. The second story is that it scales with some kind of surface-to-volume relationship. That idea has been brought back and forth as people have done different statistics to come down with the two-thirds slope.

I, myself, favor one that you mentioned at the end, which is that the nervous tissue is all developed from ectoderm. Ectoderm, when it's set up, divides at a different rate than endoderm and mesoderm. It divides because it's going to be surface on the body. It must have a particular genetic program to do that at a fairly early stage or the body would become very abnormal in shape. I think it's a very, very old program.

The point I want to make is that only one of those stories says anything about intelligence. That's the one that says that somehow surface-to-volume is some sort of assessment of, say, sensory input surfaces. Both of the others – the metabolism story and the surface-to-volume story – don't actually make claims about intelligence and we have to have an independent story about intelligence to sort that out.



Another theory ... is that body size correlates with longevity ... The effect is not through body size per se, but through selection and longevity.

TOOBY: Another theory you could have is that body size correlates with longevity, so an increasing life span may require and allow and permit the beneficial use of information over longer terms.

If you have a larger truck and a smaller truck, both take a truck driver, right? It doesn't take a bigger truck driver. The whole question is, I think, a very interesting and important one, but the only thing that – and I don't find this satisfying – is coherent and semi-functional and makes some sense is the longevity correlation with body size. The effect is not through body size *per se*, but through selection and longevity.

PINKER: It makes a testable prediction. If you did a multiple regression with longevity and body size, assuming that they weren't perfectly correlated, then the brain size would regress much more cleanly on to

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longevity than body size. Has anyone found that?

HOLLOWAY: Sacker did that.

DEACON: Yes, that's right, back about 30 years ago.

PINKER: And the answer is...?



*We actually live too long
even for our brains.*

DEACON: It's slightly better. In fact, a number of people have pursued it. Many organs scale to body size with

longevity. The real challenge is, of course, figuring out what maximum life span really is, which is a challenge in and of itself. Finally, humans don't fit well with that. That makes it even more difficult. We actually live too long even for our brains.

VELAMOOR: Thank you for this presentation, Dr. Holloway.

The Origins of Human Creativity

Presentation by Richard G. Klein, Ph.D.



Orrorin tugenensis, at least as far as I can determine, is the oldest species for which we have evidence of bipedalism. Bipedalism is the definition of humanity ...

KLEIN: This is going to be very different from what we've done so far. I've been very interested to listen to these talks, and I appreciate the opportunity to come here. But I'm kind of like an auto mechanic: I don't have a lot of theory in my head. What I do is go out and dig up stuff and then I try to understand what it means.

Looking into the very deep past, I think it's a kind of storytelling. You have this fragmentary evidence. You have some fossils – human fossils and animal bones that, perhaps, represent the food debris of the peoples who are represented by fossils. You have the artifacts, then you have to weave it together into some kind of coherent story starting out whenever. [Referring to slide] This chart basically outlines the human family tree, at least as I see it, back to about six million years ago. Even this is a kind of story. This is a phylogeny or a family tree. Other people may disagree with the specifics. But one thing that is true, even if you regard this as storytelling, is that it is constrained by evidence, and as we get new evidence, it will get closer and closer to the truth.

I thought I would say a few words in general about human evolution, and then what I want to focus on is the origins of modern humans – people who look and act just like we do. As you'll see and as most people probably know, this is a very recent event. Bill Calvin already spoke about modern humans originating or at least spreading from Africa to the rest of the world only about 50,000 years ago. Down here you have the oldest species that's known to be bipedal. *Bipedal* is the definition of the human group. We used to say the "human family"; strictly speaking, we should say the "human tribe," if you want to get into the zoological nomencla-

tural niceties. But this thing called *Orrorin tugenensis*, at least as far as I can determine, is the oldest species for which we have evidence of bipedalism. Bipedalism is the definition of humanity, in the broad sense.

The general assumption is that chimps went one way; our ancestors went another. But there could have been more than one species six million years ago that became bipedal.

There is a problem that we don't talk about very much. We don't know that back at six million years ago, roughly the time when people and chimps split, that, in fact, there wasn't more than one ape species that went off and became bipedal. The chimps obviously didn't. They went in another direction. The general assumption is that chimps went one way; our ancestors went another. But there could have been more than one species six million years ago that became bipedal. For the moment, we have the one that, I think, right now is probably the oldest for which there's a reasonable consensus on bipedalism, and then you see this sort of bushy tree afterwards. When you move up to here – you can see these question marks – these lines are supposed to indicate ancestor-descendant relationships. They're not very well established; that's why you have all those question marks. When you get up to here – this is roughly two million years ago – the picture becomes clearer and you don't see question marks. If you were wondering about these dotted lines as opposed to the black ones, the black bars indicate demonstrated time spans for a species and the dotted bars indicate what I think are probable time spans or additional time spans beyond the black.

You see here a species called *Homo ergaster*. Some people call it African *Homo erectus*. That's the first human species to leave Africa. It certainly was by 1.4 to 1.5 million years ago; some people would argue for 1.7. After that, you get what I perceive as a kind of branch-

ing of the human family tree. You get a species, which I call *Homo erectus* in the narrow sense – that’s strictly a Far Eastern thing, as I perceive it – that reached the Far East maybe as much as 1.5 million years ago. I put it here closer to 1.1 or 1.2. I’m not going to talk about *Homo erectus* any further in here. We don’t know very much about particularly the final stages of what we might call the *Homo erectus* evolution. We don’t know very much the prehistory of the Far East in the last 100,000 to 200,000 years. It looks as if *Homo erectus* was replaced by people like us roughly 50,000 to 40,000 years ago, but the actual archaeological and fossil evidence for that is pretty sparse.

If you stay on the West, the *Homo ergaster* thing, as I see it, evolved into something called *Homo heidelbergensis*. I was looking at Ralph Holloway’s chart of brain volumes a moment ago, and I see that he perceives it just about the way I do. This is a species that represents another out-of-Africa event. *Homo ergaster* is obviously an out-of-Africa event – the first human species to spread to Eurasia. *Homo heidelbergensis* also spread from Africa, just to Europe, as far as we can tell, and maybe as far east as India. That’s partly based on fossils but the fossil record for *Homo heidelbergensis* isn’t all that impressive. It’s much more firmly based in artifacts.

About 600,000 to 700,000 years ago, there was a dramatic change in the nature of artifacts. [Referring to slide] You see here what are called Acheulian hand-axes. By the way I’ve drawn this chart, it looks as if they span the interval between 1.65 million years ago and 250,000 years ago, and that’s the conventional way of looking at it. But about 600,000 or 700,000 years ago, they changed character dramatically. They got much prettier; they appeal much more aesthetically; they got thinner; they got more symmetrical; many more flakes struck from them. I think it’s as big a change in the archaeological record as we’re likely to detect at 600,000 or 700,000 years. What’s interesting is that when that change takes place in Africa, almost immediately those more sophisticated hand-axes show up in Europe, presumably brought there by *Homo heidelbergensis* from Africa.



Homo heidelbergensis is the last shared ancestor for us, Homo sapiens, and for the Neanderthals.

Homo heidelbergensis is the last shared ancestor for us, *Homo sapiens*, and for the Neanderthals. The Neanderthals evolved in Europe. We can show that now pretty clearly from the fossil record. We have *Homo heidelbergensis* in Europe, say, 600,000 years ago, and then we can see the progressive evolution of the Neanderthals out of *Homo heidelbergensis*. We have fossils that anticipate the Neanderthals by 400,000 years. We have the full-blown Neanderthals by, let’s say, 150,000.

Then in Africa, we have a different evolution toward ourselves. Sometimes when you talk about the origins of modern humans – certainly I have colleagues who believe that this is a chimera, that we shouldn’t discuss this subject, because all fossil humans sort of look alike. In particular, a colleague at the University of Michigan has argued that if you took a Neanderthal – here’s a Neanderthal skull from a place called La Ferrassie in France; this is dated to about 70,000 years ago – if you dress this person up in a coat and tie and a fedora, or whatever, and put him on the Manhattan subway, no one would notice. I think that would only be true – and Ralph can speak to this, as I’m sure he’s taken the subway in New York often enough – if, like most subway riders in New York, people are just minding their own business and aren’t looking at each other. Otherwise, I think that you would notice immediately that this was somebody very peculiar, not just in terms of the way he looks. You can see the big brow ridges here, not much in the way of forehead, but also in terms of the way these people behaved. I think they would have been very peculiar by our standards.

Now over here is an early modern human from France, a young woman who died in France about 22,000 years ago. I hate to resort to anecdote here and one-on-one comparisons, but I hope you can see the great difference in form. She doesn’t have anything like the brow ridge. Now, this is probably a male and this is a female, and there would be some difference between the sexes. But we’ve had male skulls and they

don't have the structure of the brow ridges that Neanderthals do. You can see that she has a lot in the way of forehead. Her skull is relatively short from fore to rear, and high from, say, the ear aperture to the top. His is very long from fore to rear, and relatively short from here to here.

You can see that the face of this Neanderthal is mounted way out in front of the rest of the skull, and particularly the midline of the face, from between the brow ridges or running from between just above the nose down between the upper incisor teeth. If you wanted to be a Neanderthal and your face was absolutely plastic, made of clay, what you would do is put your fingers in your nose and pull out two inches and everything would sweep back. The cheekbones would sweep back. Hers come out this way and then go back, which is, of course, the case in this room today.

... it's not difficult to distinguish Neanderthals from modern humans ... We have no fossils, as far as I'm concerned, that indicate any kind of interbreeding.

My point here is that it's not difficult to distinguish Neanderthals from modern humans. We have a lot of Neanderthal fossils. We have these modern human fossils in Europe. Modern humans appear there relatively abruptly beginning about 40,000 years ago and it looks as if they completely replaced the Neanderthals. We have no fossils, as far as I'm concerned, that indicate *any* kind of interbreeding. We now have Neanderthal DNA – nine different Neanderthals now – mitochondrial DNA. It's interesting for a lot of reasons. There's relatively little variability, like in ourselves. All living humans have, if you look at mitochondrial DNA or other DNA, remarkably little variability in the genes. It seems that that was true in Neanderthals, too, but it's quite different from ours. If you look at the earliest modern humans in Europe, there's a difficulty in extracting the mitochondrial DNA from their bones because if you sneeze in the vicinity of these bones, they're going to have all kinds of modern human sequences from you or me or whoever did the sneezing.

It's one thing to extract mitochondrial DNA from the Neanderthals; it's different enough so that you know when you have it. But when mitochondrial DNA

has been extracted from specimens like that – some of them going back 30,000 years – there are no Neanderthal sequences. You can't be sure the modern human sequences you're looking at weren't introduced by the lab workers or excavators or whatever, but if there are no Neanderthal sequences, then it, again, suggests that there was probably no interbreeding.

Why did these two population groups fail to interact either culturally ... or biologically?

It's a very interesting sort of replacement of the Neanderthals by modern humans in Europe. If you think about European expansions in the age of exploration – Europeans going to Africa and Australia and the Americas, and what have you – wherever they went, European culture became dominant. But there was a lot of interbreeding. We sometimes say the Tasmanians are extinct, for example, but you can still detect Tasmanian genes without any problem. You can't detect Neanderthal genes, even in the earliest modern humans. So, that makes it a very different kind of interaction between human populations of any we have observed historically, and I think that requires a very special kind of explanation. Why did these two population groups fail to interact either culturally – and I can talk about that in more detail later – or biologically? Why was it such a complete replacement without any interbreeding? When I say *complete*, if it was at a very low level, say less than five percent, we probably wouldn't be able to detect it, but right now that's the level it would have to be at if there was interbreeding.

Now, where did modern humans come from? They came from Africa. We have an abundant fossil record to demonstrate this – not, unfortunately, as abundant as the record that demonstrates the evolution of the Neanderthals, but we feel it's still pretty good. Here's a skull that is maybe as much as 160,000 years old. It's certainly more than 50,000 years old. It comes from Herto in Ethiopia. This is somebody who lived in Ethiopia at the same time when the Neanderthals were the sole occupants of Europe. This is essentially a big, robust, modern skull. There's nobody around like this today, but you can see that the face is tucked

in underneath the fore part of the brain, as it is in us. The brow ridges are very substantial and in that sense you would have a hard time duplicating this skull today. There are other features in terms of its general robustness, which you could argue would be difficult to duplicate today, but in terms of its overall form, this is a modern human skull.



The best fossil evidence for the African origin of modern humans comes from Israel.

We have other modern human fossils from Africa that date to more than 50,000 years ago. We also have them on the southwest Asian periphery of Africa. About 100,000 to 120,000 years ago, the Ethiopian fauna, the African fauna, expanded just into Israel – southern Israel – and with that expansion went modern humans, or early, near-modern humans. In fact, that's where they're best known. The best fossil evidence for the African origin of modern humans comes from Israel.

So, we have a kind of paradox here. We have modern humans, at least in anatomical terms, and actually I think that can be over-stressed. That skull we were just looking at, I don't think that *is* a modern human, in the sense of the kind of thing we see after 50,000 years ago. The same would be true of these Israeli things that I mentioned a moment ago. For example, if you take, as an important modern human anatomical feature, the chin, or the size of the brow ridges, these things are enormously variable in these early so-called modern Israelis of 90,000 to 100,000 to 120,000 years ago, so I would argue that those people are not modern. What they're telling us is that it's to Africa that we should look for our origins. They're not our ancestors. Almost certainly, 100,000 years ago we still had those people. They wouldn't look quite modern to us but they're close.

If all we had were the artifacts from Africa, let's say at 100,000 years, and we didn't have the physical remains, we might think that the people who lived in Africa 100,000 years ago were Neanderthals.

Now, we still have this problem: If you have the appearance of people who are anatomically modern or near-modern by 100,000 years ago, why did they only disperse to Eurasia, as I've already said, 50,000 to 40,000 years ago? What causes that gap? It could be that they were already anatomically modern or near-modern, depending on what term you want to use, 160,000 years ago. That would mean that you would have 100,000 or 110,000 years between the appearance of modern anatomy and its spread from Africa to Eurasia. I think the answer is fairly straightforward as to why it only spread 50,000 years ago. There are a whole series of behavioral traits, which distinguish people before 50,000 years ago from people afterwards, and it doesn't matter whether you're in Africa or in Europe. If all we had were the artifacts from Africa, let's say at 100,000 years, and we didn't have the physical remains, we might think that the people who lived in Africa 100,000 years ago were Neanderthals. There is no difference between the archaeological record of Africa up to 50,000 years ago and the archaeological record of Europe. They're essentially identical. Then, at roughly 50,000 years, things change pretty dramatically.

Before 50,000 years ago, people made relatively informal stone artifacts. What I mean by that is: If you think of what archaeology is, what many people think of it as being (and I kind of myself think this way) – you go out and you dig up a bunch of stuff, all the artifacts, and you spread them all out on a table, and then you want to put them in pigeonholes, categorize them, typologize with them. When I was a student at the University of Bordeaux, learning to do this with the Neanderthal artifacts, I found that I had a really difficult time distinguishing between different kinds of Neanderthal artifacts. The technical term is *Mousterian* artifacts; you should separate the people from their artifacts because, as I have already said, the people who lived in Africa made the same artifacts as the people in Europe 50,000 years ago, but they were different physical types.

There was a professor at the University of Bordeaux with whom I went to study who had identified 62 different kinds of Neanderthal stone artifacts. I couldn't do it. I sat in his lab for a year. I think he thought I was a lost cause. I could maybe recognize eight to ten. There were all kinds of other pieces that he could put into one of his 62 types that seemed to me to fall between the cracks. We now know that what he was doing, in fact, was taking stone artifacts that were in different stages in the resharpening or refreshing of a single piece and calling them different types. And it looks as though the Neanderthals made only, say, eight or ten different kinds of artifacts. That's also true of the people in Africa before 50,000 years ago.

After 50,000 years ago, it changes dramatically. I went off to Russia to do my Ph.D. research. I was trying to apply the same system to the categorization of Neanderthal artifacts there, and I couldn't do it. I thought, *I'm not going to get a Ph.D. out of this*. I got so frustrated; I thought I would look at the artifacts that the people made afterwards, the Cro-Magnons, after 40,000 years who were in Russia. I could recognize large numbers of different types without any problem whatsoever. I had been trained to do this in France, too, but it wasn't difficult. Ninety or a hundred different stone artifacts routinely I could recognize. I became convinced then that the Neanderthals had a different mindset than I did, or at least that the people who succeeded them, who I assumed had the same mindset as I did.

Now, what does all this mean? I don't know, but if you think about carpentry, for example – let's suppose you had to build a doghouse on a weekend. You could do this with just a hammer, perhaps. You could use one of the prongs on the back as a screwdriver. You could use the two of them together as a saw. Obviously, you could use the hammer for what it's supposed to be used for. But you would rather have the saw and the screwdriver in addition to the hammer, wouldn't you? I think that's the kind of thing the Neanderthals didn't have. They didn't make special-purpose tools for special purposes, at least not to the extent that their successors did. This was very inefficient.

It is only for the last 40,000 or 50,000 years that the archaeological record looks like the archaeological or material record of people who are hunting and gathering historically.

People before 50,000 years ago rarely worked plastic materials like bone, ivory, or shell into artifact types. Now, why, I don't know. If you look at the archaeological record to see when it is that it comes to look like the material record of historic hunter-gatherers, when we see the easy distinction between stone tool types, when we see the first bone and ivory shell artifacts, and so forth, these are things that are recorded widely among historic hunter-gatherers. It's about 40,000 to 50,000 years ago. It is only for the last 40,000 or 50,000 years that the archaeological record looks like the archaeological or material record of people who are hunting and gathering historically.

Before 50,000 years ago, people rarely, if ever, produced art. Their sites are remarkably unstructured. You go out camping and you put your tent here and you're filleting your fish over here and maybe you do your laundry over here. Neanderthals didn't do that, nor did anybody else before 50,000 years. It doesn't matter where you put a hole in their sites, you get the same thing. You get to the Cro-Magnons and it matters a lot. Their sites are much more structured. We don't have any evidence for housing before 50,000 years ago. I think people had houses but they were too flimsy to leave an archaeological trace. People before 50,000 years ago did bury their dead – both the Neanderthals and these Israeli near-moderns of, say, 100,000 years ago – but there's no clear indication of ritual or ceremony. You could even argue that it was just for hygiene. You've got a dead friend on the surface of the site and you want to stay on the site for a little while, so you dig the smallest possible hole and jam him in. No grave goods, nothing that indicates ritual or ceremony.

Finally – and this is what I studied particularly; I think it is very important – people before 50,000 years ago didn't fish routinely and they hunted relatively inefficiently or ineffectively. The sites I work at in South Africa are all coastal sites. If you look down into the water, you see the fish. If you're going to get them – and after 50,000 years ago, people did in

large numbers – that automatically means a lot more energy, a lot more calories, other things that you can build; it's going to mean more people. The same is true with other aspects of hunting improvements after 50,000 years ago.



What I think is the oldest, widely accepted evidence for art is a volcanic pebble from Berekhat Ram on the Syrian-Israeli border.

Now, let me say a word or two about the art. This is kind of a controversial thing. Not everybody agrees with me that there is no art or, at least, art before 50,000 years ago isn't anticipating art afterwards. What I think is the oldest, widely accepted evidence for art is a volcanic pebble from Berekhat Ram on the Syrian-Israeli border. The lines on it were incised by stone tools. It's been examined microscopically and there seems to be no question that somebody applied the edge of a stone tool to it to make it into something you could call a figurine. Maybe it's a potato made into a figurine. It's a very awkward looking thing.

[Referring to slide] There's a figurine made by Cro-Magnons in Europe. That one happens to be 26,000 to 27,000 years ago, and there's no question about this kind of thing. Is that art? The incised volcanic pebble from Berekhat Ram is probably a quarter of a million years old. Berekhat Ram is a hand-ax site, so maybe an Acheulean or "hand-ax Picasso" started on this and showed it to other people, who said, "What the devil are you doing? What a stupid thing," and that caused him to give up. That's always a possibility, isn't it? I tend to dismiss things like that because it's unknowable whether that's what happened, but it's possible.

Then there are the supposed beads, which Bill Calvin spoke of earlier, from Blombos Cave. These are actually tiny. They are shorter than most of our thumbnails. They have holes in them and those holes are supposed to have been made by sticking a bone point in from the inside and pushing out through the outside. You can do it that way, I've tried it, but most of the time you break the shell and you break the bone point. So, I don't know. My work in South Africa involves looking at bones and shells from a wide variety of sites. I see these things everywhere. I had some sent from South Africa so that I could experiment on them

and when they arrived in the mail, they had holes like that. So, I don't know: Maybe these are beads; that's the interpretation. You can see how irregular the holes are. They don't show any polish from being strung on strings. It's possible that they are beads.

One of the things that must be true about being modern is that new, novel behaviors ... if they increase the likelihood of reproduction and survival ... should spread.

There's one thing that I think is critical if you're evaluating this. There are other things from Blombos Cave that are less compelling than this; this is the most compelling evidence for art or jewelry. This site is one of 25 in South Africa that could be expected to show something like this of how people before 50,000 years ago were behaving, making art or jewelry in a way that anticipates later people. But this is the only one that does. One of the things that *must* be true about being modern is that new, novel behaviors – if they enhance fitness, that is, if they increase the likelihood of reproduction and survival – those behaviors should spread. I think they should. In historic times, and certainly in late prehistoric times, when you have a major innovation, it spreads pretty quickly, if it, in fact, allows people to have more kids and their kids to have more kids. Why has this remained restricted to this particular site for 25,000 or 30,000 years?

TOOBY: Richard, are you saying that you don't think these are beads – that they just happened spontaneously?

KLEIN: Well, I don't know. You could never prove that they're not beads. I could say all kinds of things about the site; I've been involved in it.

TOOBY: But is there any strong, confirmatory evidence that they are intentionally manufactured?

KLEIN: That's a matter of taste, and my taste is *no*.

CALVIN: They are imported, and there are only adult ones that are imported.

KLEIN: That's true. First of all, these things grow on estuarine grass. When we look in the record after 50,000 years ago, they appear and disappear in archaeological sites. It's telling us about the history of sea level and what happens to the estuaries. So,

it's telling us that there was an estuary nearby where more people could get this. Now, at least in late prehistoric times and historic times, people went out and collected this estuarine grass and used it as bedding. They brought it back. The very first site I dug in South Africa was just full of this stuff. There was very nice organic preservation, too. Now you ask: What about the babies? No, the babies aren't there. It's only the adults because when you carry this stuff back in bales, it's only the biggest ones that would stick. So, I don't know. Maybe these things *are* beads. It's quite possible, I suppose. But I would be much more compelled to think that this is something that we should take seriously if there were some other sites.

Prehistory is a matter of patterning ... If we had only one site in all of Europe that had, say, cave paintings in it, what would we think? That the people who made those paintings were everywhere? Probably not.

Prehistory is a matter of patterning, if you're trying to work out the story that I talked about before. The first occurrence of something can be an accident; the second occurrence can be a coincidence; if you get three or more, you begin thinking that you've got a pattern. The record is inherently noisy. I can tell you a lot about this site. I'm prepared to take it at face value, and if you take it at face value, you still have to explain why the other 24 sites in South Africa don't have stuff like this. When you look at, say, the Cro-Magnons in Europe after 40,000 years ago – suppose you're looking for beads; you have to have bone or shell preservation – if there's adequate preservation in the site, they are everywhere. Sometimes the acidic conditions remove things. If we had only one site in all of Europe that had, say, cave paintings in it, what would we think? That the people who made those paintings were everywhere? Probably not. But because we have the cave paintings, and we have the art in the ground, we say: Yes, that's something that people did everywhere after 40,000 years ago. But this is one site. If in Europe in the Cro-Magnon era there was just one site, I don't know what we would make of it, but I don't think we would take it all that seriously. In South Africa, this is being taken very seriously. These beads are on display in the so-called Democracy X Exhibition at what used to be military headquarters for the

Western Cape region.

After 40,000 years ago, we don't have any problem with identifying art. There's a statuette from Vogelherd Cave in southwestern Germany; there's a very famous painting from Chauvet Cave. These are about 32,000 years old, maybe a little bit older. You find it everywhere, if the preservation conditions are adequate. You might wonder how these things got dated. Now with specialized radio-carbon technology, you can scrape off little bits, hardly do any damage, and you can date them directly.

VARKI: What about Australia?

KLEIN: Australia is very relevant to this issue. There was an argument about when people first reached Australia. Maybe it's a matter of convenience for me but I think 40,000 to 45,000 years ago. Most Australian archeologists think 40,000 to 45,000 years ago. There's a modern human burial at a place called Lake Mungo. It's an extended burial with all kinds of coloring matter spread all over it. The coloring matter had to have been brought from 200 kilometers away. It's the kind of thing that people were doing in Europe after 40,000 years ago.

As I say, I think it's only 40,000 or 45,000 at the most. There is a date on it, a highly controversial date, of about 60,000. The date is based on something called electron spin resonance. Now I probably sound cynical, but I think you could go buy a lottery ticket at the drugstore that would give you just as good a date. The method is just whatever you want it to be. Some electron spin resonance dates must be right because there are lots of them, and just by chance a few have to be right. There are plenty of radio-carbon dates for sites that are older than 40,000 years, but it's only at about 40,000 with radio-carbon that you get evidence for human occupation, unless you take the Mungo thing at face value.

VARKI: You said that no one was fishing. What were sea levels?

KLEIN: The site I'm digging was right on the coast. In fact, sea level would have been pretty much as it is today. The coast would have been no more than two or three kilometers away. People bring back vast numbers of intertidal shells and seal bones. I've worked on both coasts. We have the oldest evidence for human exploitation of coastal resources: lots of shellfish; there is a

fur seal that lives on this coast today that they hunted and collected in large numbers; there are penguins that were brought back in large numbers; and then there are coastline birds – cormorants, gulls, and so on.

VARKI: Was the sea level going up and down? What was the range?

CALVIN: A hundred meters is by 22,000 years ago. That's the maximum of water being taken out. In that period, you've got all these fluctuations, but the ice doesn't follow them very fast.

KLEIN: There are a couple things. It's not just sea level fluctuation. It's the nature of the African topography. If it's very steep, sea level can drop 50 to 60 meters and the coastline won't be more than....

VARKI: My question is: Could there be sites along the east African coast that are now below sea level?



People had full control over fire before 50,000 years ago, or at least it's hard to imagine that they could have built fires so routinely if they didn't control them ...

KLEIN: It's possible. I'm sure there are sites out here [referring to slide] that are below sea level. This is Table Bay and there are these early European shipwrecks out there, which are very valuable for their cannons and things of this sort, so people dive on these things. They come up with hand-axes on the sea floor because there were times when sea level was much lower. False Bay is only about 50 meters deep and it just disappeared during most of the last glacial. But I don't think sea level is playing a role in this. If it is, it should affect everything that you collect at the coast, not just the fish. In the sites that we have that date from before 50,000 years ago, they're commonly just chock-full of shells and seal bones.

Klasies River Mouth has provided, again, early evidence for marine exploitation or coastal exploitation, together with some fossils that are considered to be modern or near-modern. Blombos Cave is closer to Capetown. I'm working right now at Ysterfontein.

I probably should have brought a map that could have shown you all the South African sites older than 50,000 years. They're called Middle Stone Age sites. The ones younger than that are called Later Stone Age

sites. I've shown only the coastal ones here but there are a lot of them up in here and they don't show what Blombos does. They don't have all the things that are said to be special that Blombos has.

[Referring to slide] This is the site, Ysterfontein, that I'm working now. It may not look like much. This is a granite cliff here. This forms the base of what was a rock shelter. When the road was widened here going down to a small boat harbor, they cut into this cliff face and truncated what was a rock shelter. Artifacts and shells started falling out and that's how we discovered the site. This is about seven meters above present sea level, so that means that it has to be older, at least the occupation here has to be younger than 115,000 years – 115,000 years ago, the sea would have been lapping right at the base of this shelter. We have a radio-carbon date from near the top of greater than 46,000 years.

[Referring to slides] Here are some of the shells, the limpet shells in place. Down here is a fireplace. There's a whole stack of them in this site. That's a common thing, not only in Middle Stone Age sites in Africa but in comparable or like-age sites in Europe. People had full control over fire before 50,000 years ago, or at least it's hard to imagine that they could have built fires so routinely if they didn't control them, if they had to look for lightning strikes.

These are not chimpanzees, before 50,000 years ago. Whatever they are, they are far more like us than they are like chimpanzees.

You can go too far in talking about behavioral differences between people before and after 50,000 years ago. I don't want to brutalize the Neanderthals and their African contemporaries. They would be very interesting to have around today. They would be so like us and, yet, maybe we wouldn't want them in Harvard or maybe they couldn't survive there. It's a fortunate thing, in a way, that they're not around because it would present a real ethical dilemma. These are not chimpanzees, before 50,000 years ago. Whatever they are, they are far more like us than they are like chimpanzees. The difficulty is trying to understand in any kind of detail what the nature of this behavioral evolution really was. We see differ-

ences but we also see lots of similarities. I mentioned before the burial of the dead. We also have evidence, at least for the Neanderthals, that they seem to have been concerned about the old and the sick – taking care of people when they were debilitated. Yes, they're human; they're just not modern humans. What that means exactly, other than a list of archaeological things that are present or absent, it is hard to say.

Some of what distinguishes sites before 50,000 years ago from sites after, in terms of their animal content – I already mentioned sites before 50,000 years ago have no fish bones to speak of. There are a few, usually very large fish, tuna for example, which the people certainly weren't fishing for because they're deep-water fish. But they would get washed up every once in a while. What might seem to us to be an unpleasant source of food, to Stone Age hunter-gatherers, it was something they could eat.

When you look at the Middle Stone Age sites, before 50,000 years ago, penguins are very common. Flying birds are much less common. After 50,000 years ago, the flying birds become much more common, and penguins become less common. I'll come back to why that might be in a moment. The Middle Stone Age sites are much richer in animal bones from relatively docile species like eland, and much poorer in bones from really dangerous species like buffaloes and wild pigs. I think that what's going on here is that there was a technological change about 50,000 years ago. People came up with projectile weapons and also with the technology needed to fish, and so we see this: There is an artifactual correlate now reflected in the animal remains in their sites.

We have no evidence before 50,000 years ago for projectile points. We're sure that people made spear points but these were mounted on the ends of wooden shafts and they had to walk up right next to a buffalo to kill it.

We have no evidence before 50,000 years ago for projectile points. We're sure that people made spear points but these were mounted on the ends of wooden shafts and they had to walk up right next to a buffalo to kill it. Not a good idea unless you're really, really hungry. On the other hand, if you have something you can throw or shoot from a distance, you might not be all that successful but at least you're not going

to put yourself at such great physical risk. So, something happened: Technology changed and it allowed this change in the animal remains we find in sites.

Now, when you look at Middle Stone Age sites right before 50,000 years ago, you can tell what season of the year the site was occupied. In this environment on the South African coast, it would have been better to be at the coast in the winter and inland in the summer. Plant resources are abundant in the summer. Baby seals, in particular, are abundant on the coast in the winter. So, you should have a kind of seasonal round. This is characteristic of all historic hunter-gatherers: They recognize the different seasons when they could exploit different resources in different places, and they moved around. In the Middle Stone Age, it doesn't look as though they did that. They kept coming back to these coastal sites. I am not saying that they were there straight through the year but they didn't focus on them seasonally. In the Later Stone Age, they were there at exactly the right time to harvest baby seals. There's a particular time of year between August and October when you can do that.

Why might Middle Stone Age people have been more restricted in their movements? Well, maybe they lacked water containers. We have lots of evidence that Later Stone Age people had them. They made these canteens out of ostrich eggshells. We find them abundantly in Later Stone Age sites. We don't find them in Middle Stone Age sites.

The final point is that you can look at certain animal remains – tortoises and shellfish, in particular – and you can get an idea of the average size that was being exploited. When you look at the Middle Stone Age tortoises and shellfish, they're absolutely huge. [Referring to slides] This is a limpet, *Patella granatina*. Here are a bunch of Later Stone Age samples and Middle Stone Age samples. You can see that the Middle Stone Age ones are larger. When gray bars don't overlap between samples, it means that they're statistically significantly different. Sometimes these Middle Stone Age samples are relatively small so the gray bar, which is an estimation error in the median, is very wide. But the Middle Stone Age shells are very much larger.

I took a bunch of students a long time ago to rocks that are not being exploited today, and said, "Go out there, pick up as many of these shells as you can in ten minutes." You can do this without doing any real

Section 4.2.4 | Transcripts

The Origins of Human Creativity

Presentation by Richard G. Klein, Ph.D.

harm to the animals if you're careful about it and put them right back down, but you can measure them at the same time. You can see how big they are. Nobody eats these things today so it's not too hard to find rocks where they're not exploited. The Middle Stone Age ones are much closer in size to those unexploited ones than the Later Stone Age ones. To me, this is telling us that there was much less predation pressure in Middle Stone Age because there were a lot fewer people. That would make sense if they weren't fishing or hunting all that effectively.

You see the same thing with tortoises. The average size of the tortoises is much bigger in the Middle Stone Age than it is in the Later Stone Age. That must be a reflection of collection or predation pressure; fewer people going out there and doing it.



If you accept that there was a change in behavior 50,000 years ago ... there's still the question of what was behind this change in behavior.

So, something happened about 50,000 years ago that dramatically increased human population size. If you accept that there was a change in behavior 50,000 years ago, that's fine. I think most archaeologists would accept that, but there's still the question of what was behind this change in behavior. That's a difficult one. The most popular hypothesis is that there was population growth, maybe beginning 100,000 years ago in Africa, and about 50,000 years ago some threshold was crossed and people had to reorganize themselves. There were so many of them that they just had to do things differently and, in the process, they became much more creative, much more innovative. I don't know. Frankly, it doesn't make a lot of sense to me. In any case, when you look at the actual archaeological evidence for human population growth or shrinkage, if you look at southern or northern Africa, it's very hard to find people 50,000 years ago. Something happened about 60,000 years ago that depressed human populations and we only pick them up again about 30,000 years ago. It's only East Africa that seems to have been continuously occupied between 60,000 and 30,000 years ago. It doesn't seem to have been that dense.

Then there is this other possibility that Terry mentioned, the "hopeful monster" idea: Maybe there

was a genetic change. This could explain why there wasn't that interbreeding. Now, I don't think that interbreeding between Neanderthals and these invading Africans would have been impossible. They had only been separate maybe 500,000 or 600,000 years. That's probably not long enough for the gene pools to have diverged sufficiently that interbreeding would have been precluded, but I kind of think that one side probably wasn't interested because the other side was very strange in the way it behaved and couldn't behave in a fully modern way. So, you get these Cro-Magnons showing up in Europe; they look at these Neanderthals and they say, "Oh no, we're not interested. Too bad. Go away." There may have been even some violence involved.

... we can look into the genome and get some notion from genes and trying to date them as to whether my hypothesis that there was a genetic change 50,000 years ago holds any water or not.

How do you go about testing for a genetic change – point mutation change in a regulatory gene or whatever – 50,000 years ago? Well, I may be overly optimistic, but I think that the only way you can do this is to look into the human genome today and look for genes that underlie language or underlie cognitive abilities, and see whether there are some that changed roughly 50,000 years ago. The only one right now that sort of points the way is something called FOXP2, which is a gene that is implicated in language and speech. There is an excess of rare alleles in this gene today, and it has been shown that the version that most of us have must have been fixed by a selective sweep. This happened sometime between last Tuesday and 200,000 years ago. That's not very satisfying. I would like to say that it happened 50,000 years ago. But at least it shows that we can look into the genome and get some notion from genes and trying to date them as to whether my hypothesis that there was a genetic change 50,000 years ago holds any water or not.

That's all I have to say. Thank you very much.



I'm not sure why it would have to be a single mutation as opposed to just some episode of selection involving some number of genes ... not instantaneously ...

PINKER: I found this entire story very plausible, especially since, unlike other cases where there were sudden or rapid technological changes that were not due to genetic changes such as all the changes subsequent to development of agriculture, we can see what the cumulative dependence was of certain innovations on earlier innovations. You couldn't have, for example, cities until you had a food surplus, so it makes sense that there could have been one magic innovation that led to everything else, whereas the kind of changes that you're talking about seem to be very conceptually independent of one another, such as art, on the one hand, and projectiles, on the other. This much more strongly seems to suggest that the people who created them had a kind of combinatorial creative cognition that manifested itself in a number of independent ways, which all seem to appear more or less together, as opposed to one innovation that led to all the others.

So, I find the whole thing plausible except for the last point. I'm not sure why it would have to be a single mutation as opposed to just some episode of selection involving some number of genes that may have taken place not instantaneously but even over a period of thousands or tens of thousands of years, perhaps not even in the place where you're unearthing these artifacts and bones. This extra assumption that it had to be a saltation or a hopeful monster seems to be less plausible. It doesn't seem to be necessary for the rest of your hypothesis.

KLEIN: I'm looking for what I think is the simplest explanation. Maybe it's simplistic.

PINKER: Let's say FOXP2 was 50,000 years ago. That itself would falsify that particular version of it because we have every reason to believe that, say, the KE family who have the mutant form of the FOXP2 were not like Middle Stone Age people or like the 90,000-year-old Israeli people. I suspect that there isn't going to be one mutation that you would find in any modern human group that would revert them to Middle Stone

Age or near anatomically modern humans.

Moreover, I think more recent findings suggest that there are an awful lot of genes in humans that seem to have been the subject of recent selection. I don't know if it's 50,000 or if it's 200,000 years ago but the genome center at the Broad Center at Harvard and MIT is doing the same analysis done on FOXP2 group but on the entire genome to see which genes seem to have been subject to recent selective sweeps. The problem is that, unlike FOXP2, for the majority of them we won't know what they do, at least not right off the bat. But it seems to me that that would be more genetically and evolutionarily plausible but it would still fit in with the overall hypothesis of a recent evolutionary change.

KLEIN: Yes. First of all, I don't think that Neanderthals had the defective version of FOXP2 that we see in the KE family. Even if you take that 200,000-year date as the basement for the appearance of the selective sweep, that's already after the split of Neanderthals and people. They didn't have it, so if this thing is important in language and speech, that is already interesting, I think.

PINKER: The Middle Stone Age people presumably were not Neanderthal.

KLEIN: No. They might have it. It's possible. When I talk about things like this, people say: Do you think there was an agriculture gene? That's what they hear me saying, that there was a kind of creative gene. Maybe it's much more complex than that. I appreciate that. But the answer is no, I don't think there was an agriculture gene. What you do today is you look at historic hunter-gatherers and you look back to see when they appear, not at agriculturists.

But you can look at it in another way. When did agriculture originate? In Eastern Mediterranean, let's say 11,000 years ago, and I suppose the most widely accepted hypothesis now is that it was a response to environmental change. These people had been hunting goats and sheep, and collecting wild barley and wild wheat, and now the things they have been subsisting on for years are trying to get away. They know about planting seeds and they know that if you take a young animal and keep it by the fire, sometimes, at least, they'll stay with you. So, now they get into that in a big way and you've got agriculture.

Well, we have the same kind of environmental change that happened, let's say 11,000 years ago, many, many times before. Roughly the same thing happened, let's say, 128,000 years ago – but no agriculture. I just don't think the capacity to do it was there. I think whatever was involved in inventing something like agriculture was a change 40,000 years ago. Whatever you want to say that change was, *that* was the basis for it and everything that follows. I don't believe that there is an industrial revolution gene or a computer gene – obviously that's not right.

You can look at it a lot of different ways, because you can take somebody who was born in the Australian outback, an Aboriginal, and, if you get them early enough, you bring them to Bellevue, WA, or Cambridge, MA, or whatever, they are going to become just like anybody else there, in terms of speaking English without an accent, if they're brought early enough; they're going to have the same capacity to become computer programmers, or whatever. To me, that rules out the possibility that there are special genes for agriculture or whatever since hunter-gatherers can become agriculturists or computer programmers without any problem.

PINKER: Everything you say could be true but whatever the genetic change is for – clearly not agriculture or computer programming – it still could be 200 or 500 genes as opposed to one gene.

KLEIN: Sure. The problem with that is that if that's true, we may not know for a very long time. I would like to think that I'm right, but more importantly, I would like to think that *somebody* is and we'll know.

PINKER: Yes. We could know if this scan of the genome for genes showing a recent history of selection could easily turn up ... in fact, I think they already have turned up a couple hundred genes that seem to show signs of recent selection. They don't know what they're for but they can find out.

VARKI: To pick up from what Steve's saying, I tend to favor the idea that a bunch of different genes were selected for, but in terms of the timing, 50,000 is a time that you're picking because that's when you see this apparent explosion of artifacts. But if this story of an effective population size of 10,000 or less is true, that population of 10,000 couldn't have suddenly exploded to the extent of populating everything from

Australia to Europe that fast. When you look at most of the molecular clock estimates, they're like FOXP2. That's 200,000 plus or minus 200,000. That's what you were saying, effectively. Many of the other clock estimates are like 100,000, 150,000 – everything seems to go back a little bit further. The other possibility is that there was a small group isolated somewhere – we haven't found that particular region of Africa yet – and that they were developing separately. They went through these types of selective sweeps with multiple selection, and then they emerged with their new technologies and their abilities and their culture.

My question is: Are you saying that they did not breed with the "Israelis" of 100,000 years ago? They probably didn't. So, that could be a genetic or cultural thing. I favor the notion of not a specific event at exactly this point – or a group that emerged earlier but took a long time to manifest themselves in the archaeological record. That fits the molecular data better, because there are no genes that seem to clock back to...

KLEIN: The latest estimates on the Y chromosome are 60,000.

VARKI: Right. That's the narrowest one.

KLEIN: Yes. Mitochondrial DNA is mostly 100,000 to 150,000 but you would expect that, given its different mode of inheritance. If you're just looking at genetic diversity without worrying about which genes you're particularly concerned with and what their function is, I think 50,000 to 60,000 is perfectly reasonable.

VARKI: Just on genetic diversity, most genes tend to go back on the clock a little further.

KLEIN: Sure, and some are going to go back much, much further. Every gene is going to have its own history.

PINKER: Given the size of the error bars, do we actually know that they were not 50,000 years ago?

VARKI: No. The error bars are big, but you don't see a lot of means that are 30,000 – 40,000 – 50,000. You tend to see things at 100,000 – 150,000 – 200,000.

KLEIN: Certainly for mitochondrial DNA.



It's an extraordinarily strong, surprising, almost astonishing claim and, therefore, I'm systematically open to other explanations ...

TOOBY: The total replacement of the European population is extremely puzzling from a genetic perspective. If you look at other comparable mammals, they can fertily interbreed, or many of them, even though they've been evolutionarily separated for a million years. The idea that human populations that would have been separated for 100,000 years, or something like that, when they met couldn't have interbred is an extremely strong claim against the norm. I've always been skeptical.

You also mentioned that there are many people who say that maybe there was a little interbreeding, but literally that's like being a little bit pregnant. If there is any interbreeding at all, then it's a very different selective model where the new genes are now in new individuals and they're subject to selection. It's a massive infusion of mutations into this other population, and presumably if they're being selected for, it's a better design that's leading to their replacement and they can also be mobilized in this other population. Anyway, I am working that out. It's an extraordinarily strong, surprising, almost astonishing claim and, therefore, I'm systematically open to other explanations for the genetic data that appeared to show it. Secondly, it's extremely unlikely that a single gene change would render two populations mutually interfertile.



I can't imagine that interbreeding was precluded by genetic differences, given the short time they were separate. It's the dog-wolf thing.

KLEIN: Oh, I think they were interfertile. I can't imagine that interbreeding was precluded by genetic differences, given the short time they were separate. It's the dog-wolf thing. When I was a graduate student, I used to take care of dogs and wolves in a laboratory on the University of Chicago campus. When female wolves came into estrus, the male wolves were really interested. When a female dog came into estrus,

sometimes they were interested, and sometimes they weren't. But we know that when there was copulation, it often resulted in infertile offspring.

So, there's kind of an intermediate stage – in this case, I would say there's just a behavioral gulf. The Cro-Magnons just weren't interested. When you look at these archaeological sites, there are Neanderthal layers, and smack on top of them are the Cro-Magnon layers. We can argue about the date because it's right at the edge of the radio-carbon dating range, but it's about 35,000 years ago. If you look at the cultural sequences, it's the same from the Czech Republic across to France. Something very dramatic happened, and it's not like anything historic. I agree that it's an unusual claim.

TOOBY: If there was a replacement then for that reason alone, much less the other reasons you might think of, it's much more likely the kind of model that Steve was suggesting, where there's quite intense selection that leads to 100 or 200 different substitutions. You have a speciation event where there's enough selection such that the groups remained distinct and one replaces the other. That's a lot of selection at a lot of loci for a lot of things. That's not a single FOXP2 or something like that.

CALVIN: There are perfectly good examples of how you can lose a population – for example, what happened to the Native Americans when European viruses arrived. If the people who came into Europe from around eastern Mediterranean and central Asia were bringing with them a lot of viruses picked up by association with animals that the Neanderthals had no immunity to, you would expect the 90 percent fatality rates that we had with the Native Americans without any physical contact between the groups at all.

TOOBY: These processes are intense, and there is a big drop-back in the population. With the North American Indians, it wasn't a replacement; it was hybridization.



... the mitochondrial genome is inherited as a whole, and you're not going to get any kind of admixture.

DEACON: I'm always troubled by discussion of the Neanderthal mitochondrial DNA when people talk about it as though one could get admixture. Of course, the mitochondrial genome is inherited as a whole, and you're not going to get any kind of admixture. If we found a Neanderthal-looking skeleton that had any kind of linkage with an anatomically modern, it would be within our group; it would not be a little bit of something or other. One of the problems with that is that, of course, mitochondrial DNA is inherited in one direction. I can easily imagine especially a dominant group in which males are mating into one group but not in the other direction. It makes it really difficult to sort this out because we're not probably going to get any of the other DNA evidence. All we can hope is that if it happened, one set of mitochondrial DNA crossed over.

If that's the case, if that's all our evidence, we don't really have good evidence that it didn't go the other way, that we didn't get genes floating. It's almost impossible to do that, especially if there's strong linkage between some of the traits that show up in the fossils. It would be very hard to pick them out. What I'm saying is that on that question, I think, even though we've got the data, what it tells us is when the group split but it probably doesn't tell us much about the interbreeding story, and I think that's a real problem.

KLEIN: It would have to be modern human females and Neanderthal males. What are the chances of that happening? There might be a chance for that. We now have nine Neanderthal mtDNA sequences. If we get 100, eventually, and every Neanderthal looks different from every modern human and all these early modern humans failed to provide mitochondrial DNA sequences – yes, there are other explanations but it seems to me they're terribly uneconomic because of the way mitochondrial DNA is inherited. Admittedly, I think it's a stretch. You could do it, if you really want to put mitochondrial DNA evidence away.

DEACON: One other thing: We've been talking about lots

of genes changing, and, of course, the word *selection* comes up. The co-assortment story can happen very fast. In Waddington's story, he created co-assortment in 30 generations of quite a number of genes. Even hundreds of genes could be co-assorted rapidly if they're already in the population. The combinatorial effect is not necessarily dependent on a mutation effect.

KLEIN: Don't you think the problem is to figure out what actually happened? We can imagine lots of things. I enjoyed your presentation, but we have the example of the finches; we have the fruit flies; and we see things happening there that you could imagine happened in human evolution, but did they? And how would we go about trying to find that out?



The internal curvature of the prefrontal lobe in the Neanderthals is exactly the same as it is in modern Homo sapiens.

HOLLOWAY: I think that if I dressed up Australian Aborigines and put them on the subway, I might notice them quite well. Neanderthals, incidentally, though they look as though they have a sloping forehead, really don't have a sloping forehead. The internal curvature of the prefrontal lobe in the Neanderthals is exactly the same as it is in modern *Homo sapiens*, as Bookstein has shown.

One of the questions I have, though, is on the logic of using sophistication of stone tools, and so forth, to make these kinds of jumps about behavior and selection. What would you do with the Clovis people? What is the tool kit of the Clovis people that populated the New World 12,000 to 15,000 years ago, in terms of stone tool technology?

KLEIN: It's complicated. You have to take a kind of multifaceted approach to the understanding of the archaeological record. Clovis people made these wonderful fluted points, mounted on the ends of spears, and they took small blades out of the base on either side of the point, which presumably made it easier to insert it in the end of a wooden spear. The spear probably was hurled with a spear thrower. We have the spear throwers. We have other wonderful bone artifacts that they made that look just like ones that people were making in Europe.

HOLLOWAY: You don't have any art; you don't have any burials; you don't have any red ochre.

KLEIN: We do have some burials. You can do much better than that: What about the Tasmanians at the time of historic contact? These are people who arguably had the most impoverished material culture on the planet. Interestingly, if you go back 19,000 years in Tasmania they were doing much better.

HOLLOWAY: I was going to add the Australian Aborigines because their social systems have wracked modern anthropological brains despite some of the most miserable stone tools that you have ever found.



Why is it such an impoverished stone artifact record?

KLEIN: It's difficult. Definitely where people are recorded historically, some prehistorically, who don't fit into what I call the post-50,000-year picture, they look more like people living in Australia. The kinds of stone artifacts that people were making 40,000 years ago look like the ones people were making in Africa 2,000,000 years ago. Why is it such an impoverished stone artifact record? In all other respects, we had the boomerang back there at 15,000 years. We have other things going back before that. For whatever reasons, when you look at the stone technology, it looks remarkably primitive.

Before 40,000 years ago, everything was sort of the same wherever you look. After 40,000 years ago there was a lot of variation. Some of that variation does look like what was happening before 40,000 but a lot of it is quite different. I think what that's telling us is that before 40,000 years ago we're dealing mainly with a difference in the genes – that's just my perspective – and after 40,000 years ago we're looking at history, environment, things of that sort, leading to differences in material culture.

HOLLOWAY: The recent BBC Horizon program on Neanderthals did a tremendous job at looking at the whole skeleton. One of the hypotheses that came out of that is that the recession of the glaciers – or the advance of the glaciers, however you want to look at

the weather changes that took place there – really had tremendous effects on the overall bodily proportions of Neanderthals versus Cro-Magnons. Neanderthals, basically, were in forest kinds of conditions, whereas the Cro-Magnons were out in more open kinds of territories. If the boreal elements retreat, and you have very small population sizes to boot, you can lose Neanderthal that way as well.

It seems to me that it would be a remarkable coincidence to have the Neanderthals disappear just as modern humans were invading Europe, if climate was the reason.

KLEIN: Bill [Calvin] showed his slide with the Greenland ice sheet fluctuations in temperature, which were pretty dramatic. It's been argued that those things caused the Neanderthals to become extinct. Some of those fluctuations, one way or the other, occurred within a human lifetime. It's hard to imagine people adjusting, but they continued after the Cro-Magnons appeared and if they had an effect on the Cro-Magnons, it's not clear that it was different from the effect it had on the Neanderthals. It all looks the same.

Most of what we call Neanderthal sites are as much carnivore sites, places where cave bears were living, as they were human-occupation sites. That's true of European sites before 40,000 years ago. Then suddenly at 40,000 years you get these modern humans appearing. The cave bear becomes extinct and the sites are just chock-full of stuff. You no longer get any indication that the people are competing with carnivores for their living sites. Something very dramatic happened and it might be that the climate is somehow implicated, but then why 40,000 years ago just at the time when modern humans appeared? Those rapid fluctuations in temperature were occurring before that. They had a particular impact on the North Atlantic region. It seems to me that it would be a remarkable coincidence to have the Neanderthals disappear just as modern humans were invading Europe, if climate was the reason.

HOLLOWAY: I would have no doubt that they were out-competed by modern *Homo sapiens*. I think that's clear, but the reasons why they were out-competed

are not clear. There is no evidence that it was the brain that failed them.

KLEIN: This is a conference largely about the brain, so I'm looking at what the brain has produced and then inferring back to the brain or back to biology. There's a lot of circularity in that and you can argue that we have to actually know something about the brain. That's why I got into the genome data, but the archaeology itself, the behavior, is not a proper proxy for the biological change.

VARKI: I have to agree with Terry that if you get a Neanderthal skeleton and you get a modern human mitochondrial DNA, you have to discard that because you don't know about contamination. There could be an ascertainment bias. So, the number we need to know is: If you have nine Neanderthal mitochondrial preparations that are completely different, how many times would we also find human? At the moment, anyway, it's nine to none, but, of course, negative results don't get reported.

The second point is in regard to the interbreeding, if it occurred, and it might well have occurred. We're not considering the possibility of social isolation. Look at what happened in North America. There's extensive breeding between Africans and Europeans, and there was almost a complete exclusion of

those peoples that had any "contamination" – cultural appearance or whatever – of one group by the other group. So if, in fact, by some historical process, the Civil War had not occurred and that whole group had been wiped out, you would have said: There is no evidence for interbreeding. But it's purely a cultural isolation mechanism. So, I don't see why it could not have been a cultural isolation mechanism.

TOOBY: There is some recent evidence that in modern human mitochondria, there are some specializations for cold weather areas and that there's a different trade-off from the mitochondria of keeping warm and muscle strength. So, it's not at all implausible that Neanderthals would look very much like a periglacial adapted subspecies. That kind of mitochondria might disappear with the ending of the ice age, so to base the notion of genetic contact or admixture across very broad classes of human subpopulations based on just Neanderthal mitochondria seems very weak evidence to me.

KLEIN: It's very controversial as to whether mitochondria are under selection. Doug Wallace at Irvine has probably been the major proponent. I just don't know. I don't think that it's widely accepted.

VELAMMOOR: Thank you, Dr. Klein.

Can We Change Human Nature?

Presentation by Steven Pinker, Ph.D.



*... I often get the following question ...
Is human nature going to change? ...
Are we going to change it ourselves?*

PINKER: I'm going to give part of a talk that I've given a couple of times called "The Past, Present, and Future of Human Nature," but in deference to the name of this foundation, I'm going to concentrate on the future.

When I lecture about human nature, I often get the following question, and I bet many people in this room get it as well: Is human nature going to change? Or even more specifically: Are we going to change it ourselves? There are a number of ways of answering this question. How *could* we change human nature? Well, there have been a number of attempts in the 20th century. There was coercive social engineering, such as the idea of the New Socialist Man tried out in Stalinist Russia and in Maoist China, based on something like a blank slate – that since human nature is a function of the environment, you change the environment and you could change human nature. I think the results of that experiment are well known and not something we want to replicate.

There's eugenics, where the actual genome would be changed, either through negative eugenics, namely, sterilization or even genocide, or positive eugenics, government subsidies for high-IQ people to have more children or people with a college education, as we see in Singapore. I think most people in most parts of the world would not be terribly receptive to that means of changing human nature either at this point in history.

What I'm going to talk about is a third way in which human nature could change, namely, voluntary genetic engineering, so-called "designer babies" or genetic enhancement, something we've heard a lot

about in the last five or ten years. It's ethically controversial. There have been a number of jeremiads against it from Francis Fukuyama, Michael Sandel, Leon Kass, and other bioethicists. But there also have been authors welcoming it: Gregory Stock, a past winner of the Kistler Book Award, in fact, and others.

But the common assumption among people who dread designer babies and people who welcome them is that it is inevitable, that if current progress in genetics continues, designer babies are around the corner, leading also, at least among the people who think this is a bad idea, to the idea that we should intervene and regulate now, pass laws against genetic enhancement, perhaps curtail research in human reproductive physiology, in human genetics, and genetic engineering in general, because left to its own devices it would lead to germline enhancement, and since that's such a terrible thing, we had better stop it in its tracks right now.

... genetic enhancement of human nature is not inevitable. In fact, I think it's highly unlikely in our lifetimes.

I'm going to challenge the common assumption underlying both the fans and critics of designer babies and suggest that the genetic enhancement of human nature is *not* inevitable. In fact, I think it's highly unlikely in our lifetimes. It's foolish to say that anything will *never* happen but one could look at the current state of the technology and make some guesses. One can certainly challenge the idea that something is inevitable. Why? Just to give you a preview: the fallibility of predictions about complex technology in general, impediments from the science of behavioral genetics, and impediments from human nature itself.

Let me start off with some of the limitations of predictions about our inevitable future. Here's a quote, "Fifty years hence we shall escape the absurdity of

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growing a whole chicken in order to eat the breast or wing by growing these parts separately under a suitable medium.” That was a prediction from Winston Churchill in 1932. Fifty years would have been in 1982 but we’re still growing the whole chicken. “Nuclear-powered vacuum cleaners will probably be a reality within ten years,” said Alex Lewyt in 1955. He had a company that manufactured vacuum cleaners. These and many, many others can be found in a delightful book called *The Experts Speak* by Victor Navasky and Christopher Cerf [subtitle: *The Definitive Compendium of Authoritative Misinformation*, Random House, 1990], which ought to be a humbling experience for anyone who talks about what’s inevitable.

Here are a few others. These I remember from my childhood; it was confidently predicted that they would be in place in 1980, 1990 – 2000 certainly: domed cities that would control the weather; commuting by jet pack – remember that? Mile-high buildings – you crowd an entire city into one apartment building. Artificial organs – this is probably closer to fact than anything else – but would anyone have predicted around the time of the first heart transplant, which I think was 1966, that the year 2005 would come and there would be no artificial heart, let alone an internal artificial kidney or an artificial eyeball?

Routine consumer space flight – remember the Pan American flight to the Moon in the movie *2001: A Space Odyssey*? Maybe it’s because PanAm went out of business. Interactive television where you would choose the ending to your sitcom or drama; people would decide on their remote control how they wanted the plot to end. The paperless office – remember that from the early 1980s? Did any of you know what the word *ream* meant before you got a computer? The Internet refrigerator – this is only five years old: We were all going to have these, where the refrigerator would have an Internet connection. When you were running low on milk, a sensor would detect that, call up the supermarket so you would get milk delivered. Then, of course, the dot.com revolution and the end of bricks-and-mortar retail. There weren’t going to be any stores anymore.

Why do predictions so often go wrong, wildly wrong? One of them is just the fallible human habit of linear extrapolation of progress, the so-called fallacy of climbing trees to get to the Moon, the failure of many futurologists to consider the costs as well as

the benefits of new technology, whereas the actual users consider both the benefits and the costs. Just to take one example, the Internet refrigerator. It would be nice not to run out of milk but, on the other hand, do you really want to have to reboot your refrigerator or get on the helpline to Microsoft when it’s freezing all of your food, to be put on hold for 47 minutes, or when you go on vacation, to have to go to the manual to try to figure out how to disable the function that automatically orders the milk? The costs – given the trends in user interfaces with complex technology – would far outweigh any benefit.

Also, futurology itself has an incentive structure. You get attention both for announcing a brave new world of enhanced technology, but also for being the prophet, the Jeremiah, the person who warns about an impending catastrophe. There have been a number of bestsellers – for example, Bill Joy had a manifesto of how we had better stop technology now, otherwise we’re going to be engulfed in gray goo as the nanobots take over. Whereas if you were to say, “Well, the future probably in most respects is going to be an awful lot like the present except for a few respects that no one can predict right now,” then you’re unlikely to get much notice in *Technology Review* or *Wired* magazine.



If I were to identify one Achilles heel of genetic enhancement, it would be the rarity of single genes with consistent beneficial psychological effects.

A second reason for skepticism is that what we know about behavioral genetics and neural development throws some cold water on the idea of genetically enhanced humans. If I were to identify one Achilles heel of genetic enhancement, it would be the rarity of single genes with consistent beneficial psychological effects. That is, when you read about the inevitability of designer babies, you always hear: What yuppie parent could resist the temptation of inserting the gene for musical talent into his child? The question is: Is there going to be a gene for musical talent? Here, we run up against an enormous paradox in current behavioral genetics, which is that we know that tens of thousands of genes working together have a large effect on the mind. We know that from twin and adoption studies, the most dramatic examples being the uncanny

similarities among identical twins separated at birth. There's no question that the genes have a substantial effect on individual differences both between normal and pathological humans and within the normal range, but we found few or no single genes that have a consistent effect on the mind. Even though there is no doubt, except maybe among some members of the Harvard faculty, that schizophrenia, autism, OCD, and so on, have an important genetic component, no one has found the schizophrenia gene, the autism gene, the OCD gene, and so on, let alone genes for musical talent or likeability. I say "let alone" because *a priori*, you would be much more likely to expect a single gene, hypothetically, that could cause schizophrenia than something like musical talent because any complex system can be damaged by a single hit, whereas it's harder to imagine a single hit that would suddenly give a complex system a new talent.

So, if we can't even find a single gene behind defects like autism and schizophrenia, it's even less likely that we'll find them for talents like music, intelligence, and so on. There have been reports of single-gene discoveries for things like bipolar illness, sexual orientation, and higher IQ, but they have a notorious history of not replicating when larger samples are examined.

Now, this isn't an irresolvable paradox because we know, just based on our knowledge of developmental biology, that the human brain is not a bag of traits with one gene for each trait. We know that neural development is staggeringly complex with many genes interacting in complex feedback loops. We know that the effects of genes are often nonadditive. We know that the pattern of expression of genes is as important as which genes are present. The pattern of expression can be affected by the products of other genes, by other aspects of the extracellular environment, by the environment outside the organism having an indirect effect through messenger molecules and other cues. So, don't hold your breath for the musical talent gene to be discovered any time soon, if ever.

An analogy would be: We certainly know that the content of computer software determines how easy the program is to use, but it's not as if there's going to be one line of code that implements user friendliness. It's going to be distributed over the structure of the entire program.

Even if we could insert all 22,000 genes, our predictability would be on the order of 50 percent.

There are some other genetic impediments to genetic enhancement and one of them is an upper bound on how much we can hope to enhance our children, imposed by the probabilistic effect of all the genes. This is a remarkable statistic that people almost never call attention to: You all know that monozygotic twins reared apart are highly correlated, but monozygotic twins reared together are not perfectly correlated, nowhere near perfectly correlated. You often get correlations on the range of .5. That's really, really high. That's much higher than zero, but on the other hand, it's much, much less than 1.0, which is significant given that these are two kids who have pretty much identical genomes. There may be mutations that arose after the split of the zygote, but they're a small fraction of the genome. They have the same parents, the same home, the same neighborhood, same school, same peer group, same number of TVs in the house, and so on. Yet, one of them can be gay and the other one can be straight; one of them can be schizophrenic, the other one not; one of them can be more intelligent than the other. Again, they're much more likely to be correlated than ordinary siblings, let alone strangers, but they're far from perfectly correlated, even given identical genes and virtually identical environments. So, that puts an upper bound on the best that we could do. Even if we could insert all 22,000 genes, our predictability would be on the order of 50 percent.

There is also the phenomenon of pleiotropy, where one gene has multiple effects or dominance, where the effect of a gene can depend on the complementary allele.

There is also the phenomenon of pleiotropy, where one gene has multiple effects or dominance, where the effect of a gene can depend on the complementary allele. Most genes probably have some degree of pleiotropy, and what evolution selects for is the best compromise, not necessarily a gene that only has a

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desirable trait. We know of some examples pertaining to the traits that would be targets of genetic enhancement. The famous “Doogie Howser” mice, reported about six years ago, that had extra NMDA receptors knocked into them, which enhanced their learning and retention of how to find a submerged platform in a water maze, also turned out to be hypersensitive to inflammatory pain. That’s probably not a combination that anyone would want to insert into his/her unborn children.



... I have heard, at least informally, that most genes that are associated with higher IQ are also associated with some enhanced susceptibility to various neurological disorders.

I’ve read that there is a condition called *torsion dystonia* caused by a single gene that on average gives a 10-point boost in IQ but also a 10 percent chance of being confined to a wheelchair with uncontrollable muscle spasms. There isn’t a lot published on this but I have heard, at least informally, that most genes that are associated with higher IQ are also associated with some enhanced susceptibility to various neurological disorders.

This combines with another problem, namely, the impediments to actually doing the research in this area that would get us from here to there. How could one try out possible genetic enhancements on an experimental basis, given the risk of a deformed child? Can anyone even imagine a path toward common use of genetic enhancement, given that the research is pretty much undoable?

Another genetic impediment is that most traits are desirable at intermediate values. Wallis Simpson famously said you can’t be too rich or too thin, but most traits aren’t like that. Maybe you can’t be too smart but let’s take something like self-confidence or assertiveness. You don’t want a shrinking violet for your child, but you don’t want Vlad the Impaler either. You want some intermediate level of assertiveness or aggressiveness. Likewise, conscientiousness: You don’t want a psychopath for a child, but you also don’t want children who are so self-abnegating that they can’t do anything in their own interests. You don’t want a child who is completely averse to taking a risk, who just cowers under a desk the whole time,

but you don’t want a candidate for the so-called Darwin Awards either.

So, let’s say that you had a gene, even hypothetically, that would enhance risk-taking as a personality trait. What would be desirable in your child would depend on what the other 19,999 genes are doing. That is, are they placing your child below the mean or above the mean or at the mean? Until we know what *all* of the genes are doing, it’s not clear that any gene that simply increments a trait is going to be desirable.

The third part is that I think there may be strong impediments in human nature to enhancing human nature. In parental psychology, it’s always pointed out in these discussions that parents, especially in this culture of young, urban professionals, would stop at nothing to help their children. If they drive them to umpteen lessons after every day of school, arrange play dates, play Mozart to their pregnant bellies, play *Baby Einstein* videos, what would stop them from inserting genes that would enhance IQ, musical talent, tennis skill, and so on? Well, it’s true that there is a strong desire to help children, but there is also, I would think, a much stronger aversion to harm children and that is a force pulling in the other direction, given that the effects of genetic enhancement would not be certain.

If it’s a hard sell to get people to accept genetically modified soybeans, it might be an even harder sell to get them to accept genetically modified children.

We also have intuitions about contamination and naturalness that might play a role here. We see this in resistance to technologies that, on strict cost/benefit grounds, would seem to be completely desirable but against which there are very strong qualms, such as genetically enhanced foods. Even though in this country they are unexceptionable, in Europe they’ve made no inroads at all. One could argue that nuclear power has a similar status. Nuclear power is probably the only practicable energy technology that won’t contribute to global warming, but there hasn’t been a new nuclear power plant built in this country in 30-odd years. These come from intuitions – you can argue about how reasonable they are – that there is a pure state of affairs and that there is a process of con-

tamination or pollution, such as genes inserted into your tomatoes. If it's a hard sell to get people to accept genetically modified soybeans, it might be an even harder sell to get them to accept genetically modified children.

Then there's another practical problem that probably all technologies of genetic enhancement would require some form of *in vitro* fertilization, which is certainly a less desirable method of creating a baby than the old-fashioned one. So, the parents' choice is not, as is often said in these discussions: "Would you opt for a procedure that would give you a happier and more talented child?" Rather, it is: "Would you opt for a traumatic and expensive procedure that might give you a slightly happier, more talented child; might give you a less happy, less talented child; might give you a deformed child; and probably would do nothing?" For human nature to change, for us to actually take control of our biological evolution, not just a few but billions of people would have to answer *yes* to that question, and I don't think that's obvious at all.

To sum up, I think that changing human nature by voluntary genetic enhancement is not inevitable because of the complexity of neural development and the rarity or absence of single genes with large, consistent, beneficial effects, because of the trade-offs of the risks and benefits of enhancement, both by researchers in doing this research ethically and by parents' intuitions of what is an unacceptable thing to do to your child.

... bioethics policies should acknowledge the frailty of long-term technological predictions; should be based on fact, not fantasy; and, if predicated on the inevitability of genetic enhancement, should be rethought.

I want to be clear: I'm not arguing that genetic enhancement will never happen, just because no one should argue that *anything* will never happen. Rather, I think that bioethics policies should acknowledge the frailty of long-term technological predictions; should be based on fact, not fantasy; and, if predicated on the inevitability of genetic enhancement, should be rethought.

Another way of putting this is that this is not a pessimistic assessment, one that would be skeptical or even negative about effects to alter our future – quite

the contrary. I think that the biggest threat to beneficial technological change is the mindset that would say that as soon as we start on that path, there will be a juggernaut, a runaway freight train that will lead us to horrific ends, so we had better stop it now. We had better stop the runaway freight train before it gains momentum. We had better nip this in the bud, which is definitely the argument of people like Leon Kass and Francis Fukuyama in trying to curtail progress in biomedical research. Their position is that the costs of designer babies ethically would be so huge that we have to shut down the enterprise now, have a moratorium for five years until we understand it or ten years before we let it get going again – with, I think, quite disastrous consequences for human health and human well-being, given the possible benefits of this research.

The state of ignorance is so huge that any decision you make right now is bound to be the wrong one ... but we shouldn't cut off a whole branch of inquiry based on assumptions that the worst case is the inevitable case.

Rather, if you say that we really don't know benefits or costs on that great a timescale, it's not like stopping a runaway freight train but, rather, it's like making decisions about where your great grandchildren ought to live. The state of ignorance is so huge that any decision you make right now is bound to be the wrong one and, therefore, when a hazard comes up we can deal with *when* it comes up, but we shouldn't cut off a whole branch of inquiry based on assumptions that the worst case is the inevitable case. Thank you.

DEACON: Steven, great talk. The only thing that troubles me is totalitarian government. It does seem to me, especially if you take the Foundation For the Future long view of a thousand years, if we *do* have the technology – it is readily available; it can be mass-produced; cloning technologies can be mass-produced almost certainly; stem cells certainly can – totalitarianism is a risk. There are lots of reasons where if you had no real compulsion, you could do the selection, you could do the eugenics, but you could do it one better with genetic engineering.

This doesn't mean that we should stop doing the research, of course, but my bottom line is that if it

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happens, I don't see that changing human nature will be for beneficial purposes. I think you're right that people won't choose it, but it might be chosen for us. I do worry about that.

PINKER: That sometimes raises an objection against other kinds of enhancements, such as drugs that change the functioning of the brain, that enhance memory. Are they going to put it in the drinking water? Are they going to force everyone to have it? Are they going to have mandatory Prozac® to pacify us so we won't challenge the government, and so on? It seems to me that in all of these things there is a question: Will we have the kind of totalitarian government that could force that on us? Then there's the question: Would such a totalitarian government have access to even greater methods of control, such as drugs, genetic enhancement, and so on?

It seems to me that the horror of having that kind of totalitarian government, with or without mind-improving drugs, with or without genetic enhancement, so overwhelms the extra increment of badness that having enhancing drugs or genetic enhancement would give them that the biomedical technology is a red herring. It's a strong argument for never having a totalitarian government of that sort. But I have often heard the argument that we shouldn't allow this kind of biomedical improvement because what happens if it gets into the hands of a totalitarian government? I think the answer is: Let's make sure we don't have that kind of government.



... when we study the genetics of identical twins, they not only have the same genes; they have the same combinations of genes. They have exactly the same synergies of genes.

DEACON: Let me add one other thing. We have talked about twin studies a few times. One thing that is seldom brought up is that when we study the genetics of identical twins, they not only have the same genes; they have the same combinations of genes. They have exactly the same synergies of genes. Since the numbers of combinations are vastly more than the numbers of genes, the amount of similarity is remarkable. What astounds me is how little concordance there is, given that fact.

PINKER: Right. That's a very significant point. There are some traits that are what behavioral geneticists sometimes call *emergenetic*, where you have known linearities. For example, heritability is a very crude statistic because it's a linear statistic, but the estimate that you get from twin studies is much higher than what you get from adoption studies simply because having 100 percent genes in common gives you all of the high-order interactions, so you get much more similarity than you would predict, say, based on the difference between biological and adopted siblings. It's more than twice the similarity. There are some things like political orientation: Conservative/liberal orientation is pretty heritable but highly *emergenetic* in that identical twins would be very similar but fraternal twins, not particularly, compared to adopted siblings.

As you say, it also underlines the ignorance that we have of development that allows there to be half the variance that's unaccounted for by most of the environment. All of the additive effects of the genes, all of the nonadditive effects of the genes, and we still can't predict everything. It's humbling.

HOLLOWAY: There are different forms of monozygotic twinning. The implantation in the placenta has effects, and I would imagine that epigenetic effects during development would really kick in and give possible differences, even though, possibly, the genes are the same.

PINKER: Yes, there are monochorionic and dichorionic monozygotic twins.

HOLLOWAY: And almost none of these studies on twins really differentiate between these different kinds of monozygotic twins.

PINKER: Some of them do. There are a lot of cases where monochorionic twins can actually be more different because they compete over placental real estate and, hence, can get more or less blood supply, and so on. So, there are some ways in which some of the estimates from the monozygotic/dizygotic comparisons might actually underestimate the genetic effect, to the extent that that is true.

Another one is that there are mutations that can make monozygotic twins *not* genetically identical as well. In fact, Chris Walsh at Harvard had an idea that there could be a new behavior/genetic technique that could be very powerful: If you could get identical

twins and since they aren't identical in their behavior, psychology, and so on, if you could measure those differences and see if there were genetic differences between them – they would be few and far between, but that could, in principle, be a very powerful way of doing gene/behavior correlations because they would be against a common backdrop.



... there's something else called somatic nuclear transfer ... and it has nothing to do with cloning humans, although theoretically it's on the path to doing that.

VARKI: I want to resonate with everything you've said and add a couple of things. One is that when you introduce foreign DNA into the genome, the genomes of mammals are highly specialized to shut off anything that comes in, so somatic gene therapy has yet to succeed. We are at that stage.

Second, having spent many years making knock-out mice and modifying mice, and so on – you hear about the “Doogie Howser” mouse – but what they don't tell you is that this was successful after many, many tries and hundreds of embryos. In other words, the effort barrier is not just individual fertilization; it's going to be a huge effort for the parents.

The last comment: As you correctly said, we don't want this to stop the good biomedical research, but I think we need to be careful to further define this constant mixing – unwittingly, actually; we all do it – of the idea of creating designer babies or cloning humans with somatic nuclear transfer, which is really what people want to do to provide tissues for other people. This constantly gets mixed up. We almost need to always have a disclaimer that there's something else called *somatic nuclear transfer* that's not the same thing, where you're taking a nucleus and putting in an egg because you're trying to make something that you can then put back into the human from which the nucleus came, and it has nothing to do with cloning humans, although theoretically it's on the path to doing that. Somehow we need to keep them separate.

PINKER: I agree. I actually think that most bioethicists are a menace. They're actually making society much less ethical.

VELAMOOR: Why would a free market not resolve all these issues?

PINKER: It might, and if these arguments have merit, I would say that the free market would not create much of a demand for human genetic enhancement.

VELAMOOR: Wherever the chips fall – would that not be the best way to go?

PINKER: You would not get high consumer demand from most parents once they were informed what the costs and benefits would be.

*... this is not just somebody's kids.
This is the genome of the species.*

DEACON: One of the real challenges is that we're talking about the human genome. Let's say that the free market keeps all but .001 percent of the population from fiddling with their children's genomes. Those genes are in the population. Those genes will proliferate in future generations. The question is really an open end. We have to be more careful than to just let it sort itself out. As much as it is right that it will work that way, this is not just somebody's kids. This is the genome of the species.

VELAMOOR: So, it comes down to a question of information and more information and more information, unbiased as opposed to simply casting prohibitions by those who presume to know.

CALVIN: Just look at how effective information has been in influencing the people that utilize untried medical treatments by buying all their drugs in the health food stores. People will have enthusiasms for doing things that are irrational by other standards and they'll try them out. Now, this might not be putting a particular gene in or taking it out, but it is going to help bias the population, after a while, because there are going to be a lot of things you take that will turn out to produce, for example, more spontaneous abortions in certain gene types than others. You can get shifts of population out of much more subtle effects.

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Can We Change Human Nature?

Presentation by Steven Pinker, Ph.D.



Is this frontier any different from any prior revolutionary technology in terms of how it got to be adopted?

VELAMOOR: Is this frontier any different from any prior revolutionary technology in terms of how it got to be adopted? Is it radically different? Are there patterns, for instance, for innovating jet aircraft – or riding a bicycle, for that matter? Is it the same or is it not the same?

PINKER: Jet aircraft is a nice analogy. Steven Weinberg pointed out, as an example of how improvements in technology are not inevitable, that commercial jet travel is a case where there's been virtually no change of the experience at the consumer level for probably close to 50 years. If anything, it has gone downhill. The idea that things just get better and better – they do get better in some ways; jets are more fuel-efficient now, but in terms of how long it takes to get from Boston to Seattle, and how enjoyable the trip is, from 1957 to 2005 there's not a whole lot of improvement.

In general, I think there *is* a difference in that people have much stronger moral intuitions about the case of improving the technology of the human constitution, as opposed to improving the technology of jet travel. Some are valid, some are not so valid, but my point is that both sides are based on overestimates of how easy this would be to do.

VARKI: I would second what Terry said, that this one is different. Changing the genome of the species is a very serious matter because of the downstream potential consequences for generations, which are highly likely to be negative rather than positive, based on the many things you said, even if we were successful. In the few cases of gene therapy that have actually worked, all those trials have been stopped because those kids are getting leukemia now. Those are the unanticipated consequences you get when you go messing around. And those are treatments of somatic cells; they're not germline.

PINKER: I would not be surprised if somatic gene therapy will eventually be successful ethically, simply because these are often kids who are very, very sick in the first place and so the risks could be outweighed by

the long-term benefits.

VARKI: The experiment ends when the individual dies.

PINKER: That's another matter, yes. But I think the ethically more relevant criterion is what happens to the individual child. The risk that therapy might end with death in the case of someone who has a severe illness to begin with could make it justifiable, whereas if you are having these deformed children, Doogie Howser-mouse-type children, there the price would so far outweigh the benefit that it's less likely that that research would ever get done.



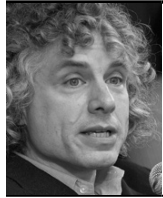
What would you need to do to be able to ethically do this kind of thing?

TOOBY: What would you need to do to be able to ethically do this kind of thing? It would mean that you would have to have an inventory with all the functional interactions and systems in human development and the brain at such a level that you could do predictive computations. You could predict in advance the effect of the intervention and all the costs and benefits on all the different systems. That's a kind of science that is a millennium away, or 500 years away. It certainly falls beyond anything we have on the horizon.

Regarding what you were saying about why predictions don't pan out, the reason is the rise of competitive things that are cheaper. With changing human nature, you have to control the developmental process throughout the life cycle, which means computations with all the interactions. Computationally, that is just immensely intricate.

On the other hand, making an intervention in an adult is something where you don't have to deal with all the developmental complexity of that. Something like installing a chip in the brain to have higher intelligence, which is something that is not so far away – whether you could have a chip that would increase all types of intellectual activity, that's a much more complicated thing, but having some sort of direct sensory feed into the Internet or something like that ... I'm just saying that there are all sorts of installation technologies that don't require such dauntingly com-

plex developmental information, which are much more plausible. They are going to out-compete it on a technological level on the 100-year scale rather than the 500-year scale.



... we don't know the code of the brain anywhere near well enough to know how to have it interface with our chips.

PINKER: I'm skeptical about the brain implants as well, but it is still an order of magnitude less complex than genetic enhancement. I'm skeptical about it except for cases like, perhaps, paralyzed or blind people where even a crude brain/machine interface would be better than none at all. Just the fact that we have ten fingers means that with something like a keyboard we can have such a high throughput of information. So, a Palm Pilot, I think, would always be better than a chip in the brain with 60 little prongs, given all the technological problems of the brain pulsing with every beat of your heart and sites of infection and scar tissue, and the fact that we don't know the code of the brain anywhere near well enough to know how to have it interface with our chips. Nonetheless, as hard as that is – I'm guessing impossible – as you point out, human genetic enhancement is even more complicated.

OBSERVER: To the extent that human nature is controlled by our interactions with the environment, it is possible to modify human nature with genetic manipulation of other creatures, starting, of course, with agriculture and animals, but even designer pets and strange things like that.

PINKER: Whether you would want to call it *human nature* if you just have cuter pets or more easily trainable pets – I think it wouldn't have such strong effects on our lifestyle that we would call it a change of human nature. But just to throw something out, one could argue that there are social changes, cultural changes that lead to such widespread and pervasive changes in our lifestyle that one could almost call them *human nature*.

One could say, for example, that the change in the status of women in the last 30 years – if someone were to do a global history of *Homo sapiens*, both the sexual revolution and the gender revolution might be

severe enough that you would call that a change in human nature. The decline in force and violence in Western democracies compared to the time span of human history is strong enough. The Flynn Effect on IQ, where we seem to be gaining three IQ points a decade, is another, and possibly the increase in anxiety, which seems also to be a secular trend that's linear over a number of decades.

So, there could be cultural changes that are pervasive enough that they would almost count as human nature, although I suspect that genetically engineering plants and animals would be a small part. I guess the agricultural revolution could almost be considered that, given that it did involve genetic modification through selective breeding, so that might be an example of what you had in mind.

OBSERVER: Although we might get used to requesting certain traits and having them made – in our pets, for example. It changes the initial barrier to curiosity in modifying children.



... in the last century ... we have changed something that's been constant for about 65 million years in primates ...

DEACON: We also overly play out the story that human nature is in our heads, because our biology has expected certain things from the environment, and when the environment changes, we physiologically are different creatures. I think that's also true with our brains. My own suspicion is that in the last century or so, since we've begun to leave young babies away from parents in cradles and on floors and in playpens, we have changed something that's been constant for about 65 million years in primates, which is being moved around constantly after birth. We know that in other species of primates that has a very troublesome consequence on social behavior. We're trying this experiment right now without knowing that we're doing it or what the consequences are, nor has anyone even looked at the consequences. So, I think it's also a mistake to think that human nature is just in our heads.

PINKER: You could consider human nature, rather than a fixed set of traits, a fixed set of "if-then" rules

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in response to the environment – that that’s fixed, but then when the environment changes, the outcome is going to change. A lot of it depends on how you take the folk term *human nature* and map it onto some sort of scientific construct.

DEACON: The only problem with the “if” is that it’s really big.

PINKER: Yes.



If selective breeding is repugnant to people, they should consider the experiment that started about 100 years ago in exactly this direction.

CALVIN: If selective breeding is repugnant to people, they should consider the experiment that started about 100 years ago in exactly this direction. We don’t call it that, but when you have co-educational colleges, and the colleges have a substantial entry-level requirement, then you’re putting high IQ males and females together at a time when mate selection is at its maximum. That experiment, to some extent, has run.

I don’t know that it’s changed anything very much, but you can clearly have a society that believes that it shouldn’t happen, and it could be implemented without talking about genes at all.

PINKER: Right. I don’t know what the population genetic prediction of that would be, but I think that if there was an increase in assortative mating, you would get greater variance on the traits that are being selected. Is that right?

CALVIN: Yes.

PINKER: So, it wouldn’t account directly for the Flynn Effect except, perhaps, if it leads to a higher positive tail and then the negative tail doesn’t get entered into the statistics, for whatever reason.

TOOBY: It would go against the Flynn Effect. High-IQ people have fewer children. If you are bringing together both sexes of high IQ and they are mating more commonly together, they’re going to have fewer children and then the population average will drop.

PINKER: Yes, that’s true.

VELAMMOOR: Thank you, Dr. Pinker.

Evolved Neurocognitive Programs as the Foundations of Cultural and Social Phenomena

Presentation by John Tooby, Ph.D.



What I'm interested in doing is seeing if we can map some of the brain's computational devices.

TOOBY: Many of you know that you can look at the brain in two ways. One is as a set of physical structures of which we're really only in infancy, because the thing that does what the brain is important for, which is computation, happens on such a fine-structured level that the gross level at which we can explore the structure is not all that informative. It's beginning to be informative but it's not truly yet informative for describing what happens in the brain in terms of detail in computational operations that change information from one form into another.

What I'm interested in doing is seeing if we can map some of the brain's computational devices. Though I'll be using the word *brain*, I'm really talking about the information mapping, and then ultimately one wants to cash that out in terms of the physical structure.

I'm interested in "widget mapping." We're robots; we're physical structures that came about by evolution. There's a random component to evolution. The nonrandom component to evolution is natural selection. Any time you find functional structure, that's caused by natural selection; therefore, it's really informative to look at the detailed adaptive problems that our ancestors encountered on a day-by-day basis, not just things that are important and very interesting and very worth doing, like looking at what happens when an ice age comes, but what about looking at what happens every day to a hunter-gatherer and asking: What computational circuits does that hunter-gatherer need in his head?

The other quick thing is "Just So" stories. A Just So story is a *post hoc* explanation of how you got a phenomenon already known. It is exactly *not* what

evolutionary psychology is, because you take models of selection pressures and our understanding of the ancestral environment, and you make predictions about neurocomputational architecture that should be there that nobody has ever thought to look for before. Then you go and you find it. You can't have a *post-hoc* explanation for a phenomenon that you found that nobody knew was there before. It's just a wrong temporal order. Therefore, a Just So story is probably the most inappropriate criticism of this kind of research.

The last of these preliminary remarks is: Another kind of difference, perhaps, is that a major problem that people are centrally interested in with humans is: How do we have this spectacularly interesting human-unique phenomenon that you might call "improvisational intelligence," the ability to do things right the first time? That's not what I'm going to talk about. There is so much discourse about this, and it's not that I criticize that discourse, but it seems to me that somebody ought to be looking at all the rest of the stuff in the brain, which is doing incredibly important, detailed things.

The traditional *blank slate* notion was that you have a blank slate and then you have improvisational intelligence. Everything important about behavior comes out of the improvisational intelligence. It might be that even our whole understanding of what improvisational intelligence is will shift when we find out that we are an artificial intelligence system with 200 or 500 – some large number – of little computational devices in there and they're doing a lot of the important work that we now attribute to improvisational intelligence. If all of our research effort continues to be exclusively devoted to looking at intelligence and rationality and these big-picture items, we may never, in fact, come to a correct description of them, but instead, come back around to looking at widget mapping. If you map enough of the widgets, you might end up with a description of the architecture that really is informative.



... our design necessarily reflects the structure of the ancestral environment and the selection pressures that acted within that environment.

The basic idea is that we're a highly improbable physical outcome and what has caused this highly improbable tower is natural selection, given a certain set of ancestral environments. Just like the key necessarily reflects the structure of locks, our design necessarily reflects the structure of the ancestral environment and the selection pressures that acted within that environment. So, by looking at the structure of the lock, you can figure out what the key is like.

We have this brain with this population of hundreds of billions of neurons – really too complicated to look at as a whole system very well, at this point in our history. Instead, we can start to identify substructures in their subcomputational subsystems by thinking really carefully about this functionality. If you do an analysis of the long-term statistical and causal structure of the ancestral world and look at what states of affairs natural selection favors, this tells us about the likely characteristics of machinery that evolved to solve adaptive problems and how the subcomplements are coordinated with each other to achieve solutions. This is really like the keys to the kingdom. You can use these kinds of ideas and drill down in any area of psychology and really quickly come across stuff that nobody had found before.

By *computational structure*, I'm talking about natural selection. Our bodies, our brains are there to solve problems. Most of these problems are regulatory in nature. The brain is there with regulatory structure to change inputs into outputs, and so we're interested in getting at what set of variables – environmental and endogenous variables – the system is designed to take as input, the operations that are performed on these inputs, the regulatory variables and representations they produce, and the evolutionarily designed effects these regulatory variables and representations have on all sorts of things – outputs that regulate behavior.

The other thing I think will happen is that when we start to get really good maps of the computational structure, this will allow us to come back and make discoveries about the physical structure that you

couldn't have done otherwise, and about the genetic processes that lead to the realization of computational structure.

What you have with humans and designs in organic systems is engineering – human universal pieces of machinery.

I want to see how many examples I can get through to give you a sense that it's an engineering kind of thing. What you have with humans and designs in organic systems is engineering – human universal pieces of machinery. These are important. I like thinking on a large scale and this is the largest possible scale.

What's the importance of this kind of thing? We heard, to some extent, the importance last night from Steve [Pinker] that the traditional way of thinking in the social sciences is you have a blank-slate model. What he didn't talk about so much but which is really key to all this is the next step in that, which is: Durkheim said that the social sciences are causally disconnected from psychology because if all you have is a blank slate, then nothing about the individual mind determines anything or has an impact on any social phenomena. This is a core, fundamental thing that's taught in sociology. It's taught in anthropology that the human sciences are autonomous, disconnected from biology, from psychology, all these other levels – evolution has nothing to do with human behavior because the blank slate is there. It intervenes and it tears the fabric.

Now, some people in the room might smile and shake their heads that this is a silly belief. It is so regularly taught, so universally believed, that all of the research efforts in the social sciences are carried out within that paradigm. On the other hand, if you have a different model – that the brain has, in fact, important pieces of circuit logic that have to do with things like human conflict and cooperation and family structure, and so on – then these pieces of circuit logic form crucial components to social theories. I think we have lost sight of the fact that we *could* have a natural science of the social sciences that looked really like natural sciences. We are accustomed to human sciences being impressionistic, particularistic, not telling us anything very useful in any particu-

lar case, so that we're just used to it as being failures as sciences, however much it might be enriching in other respects, more like humanities.

... if we really can map the human universal neurocomputational architecture, that will be a foundation for a set of social sciences that really look like sciences, so that we could do something important about the human problems that face us ...

But now we're at the point where, if we really can map the human universal neurocomputational architecture, that will be a foundation for a set of social sciences that really look like sciences, so that we could do something important about the human problems that face us, if we understand the circuit logic that is governing human behavior in complex circumstances.

A series of examples: The first one that we've been working on is the architecture of the Human Kin Detection System and its relationship to motivational output systems. There was intense selection to avoid mating with close relatives. A blank-slate mind can say nothing against mating with your sister, mother, brother, children – they're just people like anybody else. But from a biological perspective, there is intense selection against it. Your deleterious recessives are expressed. There are some other costs to it.

A second important thing that is known from evolutionary biology is that another strong selection pressure is to take into account the welfare of your relatives when you act. That is, the closer the genetic relative, the gene has an effect on its own frequency when it's found in close relatives. All other things being equal, you should be selected to have mechanisms to make you nicer to your close relatives than to more distant relatives and to nonrelatives. That presupposes that the brain can identify who is a genetic relative and who is not a genetic relative.

So, you have two behavioral adaptive problems here of quite different payoff structure. One is: Don't have sex with your relatives; the other is: Otherwise, be nice to them. They both presuppose a certain cognitive ability to track a certain kind of information. That predicts the existence of a regulatory solution, a neurocomputational system that's well-engineered, given the structure of the ancestral environments, to detect the genetic relatedness of others and to compute a behavior that regulates sexual attraction or

repulsion to the individual and what we call a *welfare tradeoff ratio*: the degree to which the other individual's welfare is weighted against your own. That shows up in a lot of different adaptor problems, but in this one, it regulates love, caring, an intrinsic interest in the other person's welfare – and, on the negative side, neglect and abuse.

What was the ancestral world like? You can't see DNA directly. The question is: What kind of reliable cues – generation by generation, over thousands of generations, over a diverse set of environments – would there have been to genetic relatedness? Our research started out on siblings because we have undergraduates and our undergraduates don't have children yet, and we don't have the money for research so we're doing Kin Detection System for siblings – sibling detection. One thing that's a reliable cue is – we're assuming, but there's very good evidence for this – that you know who your mother is. And especially your mother also knows who you are. If an organism comes out of your body and you're a female, well, that's your offspring. So, there's an initial kin detection that happens there. A mother's behavior is organized to invest in that offspring. She keeps in close association with that offspring for a period of time. That leaks information to observers: Those people are connected; there's relatedness. If you know who your mother is and you see your mother in close maternal perinatal association with another individual, that's a strong cue that that's your sibling. So, that was a prediction about one source of information. In our dataset, it actually turns out to be a predictor at .88 [$r = .88$]. But we're talking about the long-term evolutionary rate, and we believe that, given the structure of foraging environments, that was a pretty reliable cue.

I want to point out, before we go on to the secondary cue, that this can work only for older siblings looking at younger siblings. If you're a younger sibling, you weren't around when your older sibling was being nursed by your mother; you didn't exist yet. It's a complex problem in information engineering. The integration of multiple cues comes up with an estimate of kinship.

Another kind of cue – this one was proposed a long time ago – was from Westermarck. He thought that the duration of childhood co-residence was the primary factor that caused sexual disinterest. If you think about that in a more modern context than the hunter-

gatherer fusion/fission structure in which parents stay with children and siblings co-associate to some extent, the more often you're in the presence of somebody because of the way families aggregate and disaggregate for foraging and for food and seasonal types of things, visiting among relatives across bands – overall, you would get a relationship between how often you saw somebody and how related they were to you.



*... for every individual you know,
 there's a Kinship Index ... It regulates
 these two things: your sexual
 attraction to the person and how much
 you care about them ...*

A prediction notion is that we have something internal in our brains that is computed, which is that for every individual you know, there's a Kinship Index. It's in your brains and it's not a declarative, consciously accessible thing like your episodic memory, but it's a variable that is part of person representation and it indexes the degree of genetic relatedness. It regulates these two things: your sexual attraction to the person and how much you care about them, love them.

[Referring to slide] Here's an overall mapping of the structure that you have. Over on the left, you have cues that the system is designed to take in from the external environment. We don't think we have necessarily exhausted the cues, but we have very strong evidence about the co-residence monitoring system and maternal perinatal association monitoring system. How we get this evidence is we take our subjects, who are undergraduates here and subjects on an island called Dominica; we're going to do it in Japan and South America, also. You take how long they've lived with people when they were children, other kinds of variables and information, and then you see how that maps onto these two output variables: intensity of disgust at the notion of having sexual contact with the person, and what kinds of things they would do and to what extent they would do them in terms of acts of assistance to other people.

The idea is that you can take those and you can see what things in the environment may increase or decrease those predictive functional output variables. Then you can recover the architecture of the system.

The Kinship Index operates independent of your formal, declarative beliefs because the emotions track these things like how long you lived with somebody when you were a child ...

There are the two inputs of the co-residence monitoring system and the maternal perinatal association monitoring system, and we believe there are possibly other things. Some people have speculated about MHC monitoring from olfaction, but things like that can't be all that strong, from our dataset, because we have people in our datasets who are adopted people. The Kinship Index operates independent of your formal, declarative beliefs because the emotions track these things like how long you lived with somebody when you were a child and did you observe them breastfeeding or taking care of your younger sibling? Those are the things that govern the intensity of the emotion and not formal beliefs about whether they think the person is a sibling or not. That does not control or predict the intensity of these emotions.

So, we have these inputs, which go into something that integrates them, the Kinship Estimator. The Kinship Estimator produces a Kinship Index for person "I" – I to my brother, or my sister. Then there are two output systems. We all have a sexual psychology, and it's a complicated one, so there are things like attractiveness and all sorts of other things ... sexual value or how attractive somebody is to you. But one of the things that affect it is the Kinship Index: Did you receive cues when you were growing up that they are related to you? Not any cue at all that they're related to you? There are certain ones that are evolutionarily stable, long-term cues. That has a negative effect on the Sexual Value Estimator, and the Sexual Value Estimator is passed out to the programs that guide sexual attraction and sexual avoidance. People who were raised with a person or who had a period when they saw their mother taking care of a person, even if they were subsequently separated from that child, the idea is that when they are adults, the notion of having sex with that person is disgusting to them. It's at least uninteresting and, more often, it's positively repugnant.

There's a separate system that has to do with how much you are predisposed to spontaneously trade off your welfare for somebody else's. That's a variable that

is a constituent of love and caring, and various kinds of close social attitudes.

We're talking about only one aspect of psychology here, which is: How is the Kinship Index related to the welfare tradeoff ratio? This system computes the Kinship Index between yourself and somebody else, and then that has a positive effect on the Welfare Trade-off Estimator and that feeds out into programs regarding altruistic behavior. There's a real piece of engineering here. It's complex; it's important; you can map important pieces of it by doing careful task analyses of what information was available, the nature of the ancestral environment from a cue basis, and so on.

There are reasons to think that the sexual psychology will be different for males and females. Females lose more by incest than males do, so we analyzed the data separately for males and females. The point is that it was a prediction and it's confirmed here that if you're looking just at co-residence, which is one of the variables – people have believed from Westermarck that it might be a variable in, at least, incest avoidance. Here, you can put it as part of a larger system including altruism and you can show that co-residence makes a big difference with respect to altruism and personal disgust at the idea of having sex with a sibling as well as your moral attitude toward third-party situations, if you're a younger sibling. If you're an older sibling, co-residence doesn't make nearly as much difference. Basically there's a big drop-off systematic in all the categories, but it is a less important cue because there is this other more informative cue that trumps it, which is that you were able to observe your mother taking care of your sibling. If you have that information, you don't need co-residence information. The co-residence information is not used nearly as much.

We have a similar mapping system with anger. Anger has internal-specific logic that has a computational architecture – what variables trigger it, and so on.

I'm going to skip over to race. There's a separate system that regulates coalitional cooperation and conflict. One of the classes I teach is genetics. I did a lot of evolutionary genetics for a while. We teach undergraduates that race, as a genetic concept, makes no sense, and that we can't do any kind of mapping from the underlying genetic distributions to what people think are the racial groups that they seem to see every

day and everywhere. So, after you teach them that there's no such thing as race in quite the way they're thinking about it, they look at you in the same sort of patronizing way that undergraduates do when you tell them something clearly false. Who are they going to believe – the professor or their lying eyes? They see race in the world.

The question is: How come people see race in the world when the underlying biology doesn't support it?

The question is: How come people see race in the world when the underlying biology doesn't support it? Social psychologists for 30 years have found that when people meet new people, they're automatically processing in codes certain kinds of information that's part of their personal representation that they've formed. One of these is sex or gender; the second one is life stage or age; and the third one is race. This kind of information is automatically and mandatorily encoded. The psychologists found this very distressing because they wanted to create a race-free world. Why is race information so salient to people? They attempted to find manipulations that would reduce or eliminate people's racial awareness and they found nothing that they could do. All sorts of manipulations were tried over 30 years.

We looked at this, starting from the genetic basis that one theory you could have about race is that race is really out there. It's like: Why do you see apples as different from nectarines? Because apples *are* different from nectarines – they're really there. Your perceptual system just sees something different. But there is a *kind* categorization that goes on. There's not a smooth distribution between apples and nectarines, whereas in the human species there is an interpenetration of all sorts of different dimensions of variation in a way that doesn't come out into just three kinds. And yet the imposition on the actual perceptual network of a *kind* perception is very interesting.

Social psychologists don't necessarily think in terms of evolved systems but they thought they found an evolved system that was specialized for encoding race. Well, gender makes sense because that would always have supported a lot of very important things

behaviorally for hunter-gatherer. But the notion that we have an evolved system for detecting race makes no sense because hunter-gatherers never would have been in a world where they would have walked far enough on a regular basis to regularly encounter people who would be genetically different enough to qualify as being from a different race.



Race is a cue to coalitional affiliation, and it is encoded because our minds are designed to sift for coalitional affiliation in the world on an unconscious basis ...

This was coming together with a different kind of work we were doing, which is that there are evolved cognitive specializations for dealing with groups and dealing with coalitions. So, if our race-encoding system is not there with the evolved function of racial categorization, why does it exist? The alternative view would be: Race is a proxy for something else that *did* exist among our hunter-gatherer ancestors. Our hypothesis was that that would be coalitional affiliation. Race is a cue to coalitional affiliation, and it is encoded because our minds are designed to sift for coalitional affiliation in the world on an unconscious basis – in the same way that there’s a whole layer of cognitive object construction that’s going on in our minds, such as the kinship identifiers. There are lots of specializations that are giving our consciousness access to concepts that have been preprocessed because of the evolved functions that these devices, these widgets, were designed to serve. We have been mapping a lot of features about this.

There is a cartoon from Gary Larson with the notion that there’s this miracle product called *StopIt*. You can use it to stop your faucet from leaking; if you want a taxi to stop for you, you spray it; if you want your spouse to stop smoking, you spray it on him; if you want your baby to stop crying, you spray it on the baby; if an elephant is charging, it will work for that. The notion is that this is our model of the human mind – that general intelligence is just one thing – and that’s not what it really looks like.

... our perceptual systems are being trained by an underlying nonvisible characteristic, which is coalitional affiliation.

Categorization happened over all the dimensions that you could discriminate. But you don’t have to categorize that way. You could do equally well to categorize in a different way. There are lots of different physical features that people have. It is, in fact, extremely hard – though our brains can possibly do it – to come up with just that exact set of things to discriminate in order to sort what we think of as our racial categories. The point is that there are a lot of options that the perceptual system could be using and the claim is that our perceptual systems are being trained by an underlying nonvisible characteristic, which is coalitional affiliation. It’s not race *per se* that is being picked out, but it is any appearance cue that would predict coalitional affiliation in the world.

The experimental design we did is a very interesting one. Nancy Etcoff was one of the people in this very clever research paradigm called the “who said what?” paradigm, where you infer what categorization people are using from how they confuse one person with another. For example, if you were to confuse Eddie Murphy with Steve Martin, the principle might be that you were encoding *comedian*, as a dimension of social categorization. If, on the other hand, you were confusing Eddie Murphy with O.J. Simpson, it wouldn’t be *comedian* that was the categorization; it would be *race*, plausibly. The targets have a conversation and you see a picture of somebody with a little sentence underneath it, indicating what the person said. Another picture comes up, another sentence; another picture, another sentence. Then, at the end, you see a whole series of these sentences of what people said, then the subjects are given a surprise recall task in which one by one the sentences come up and they have to say who said what. If they correctly do it, it doesn’t tell us anything and we hate it, but when they make mistakes, it tells us what their principles of categorizations are. It’s an unobtrusive measure of all sorts of categorization, including racial categorization. You couldn’t control it if you wanted to. People are not aware that they’re leaking this information, so

we know when race is a dimension of their categorization and when it's not.

If they make an error and they attribute it to somebody else of the same race, that tells us that they do it more often than chance, and that tells us that race was a dimension of variation. On the other hand, if the pictures show people in different jerseys of basketball teams, then in this scenario the person might be categorizing by team and not race. So, we can get a measure of the relative intensity of their disposition to make categorization errors – to categorize people by race, by gender, by team, by a number of different things.

The underlying idea is: What coalitions is this person a member of, so that the mind automatically picks up this information? There's a variable assigned to a personal representation that indexes the person's coalition membership. There's a specialized coalition-mapping device that infers coalitional alliances. It sits there in the world, in your mind – you're not aware of it – and in the social world it detects acts of cooperation and acts of conflict. It also sifts and sees if there are some predictor values. For example, if you're going to be a well-defined hunter-gatherer, you have to know: *If I'm going to propose this in this group, can I get away with it? Will enough people come in on my side of the issue?* You have to have a map of the social world in which you can anticipate the likely consequences of various types of activities, and who is going to come in on what side of what issue is very important.

... groups aren't really there at all. Groups are a mental construct, so one has to keep track of the alliance structure in the world.

There are in-group conflicts and conflicts between groups and, of course, groups aren't really there at all. Groups are a mental construct, so one has to keep track of the alliance structure in the world. If you have appearance cues that are correlated with alliance, then you can detect somebody's alliance without having to always be present exactly when they reveal certain types of intentional acts that would reveal their alliance. You can know in advance how things would turn out. Even though social psychologists hadn't been able to find a way to drop racial awareness, our notion was that if what racial awareness really was,

was a proxy for coalitional affiliation, then if you created a social world in which coalitional affiliation no longer maps onto racial affiliation, then subjects should stop encoding race. The notion is that you could reduce it, and potentially, if you understood it enough, maybe eliminate it.

We created an experiment in which the people are racially mixed, but the conflict that emerges in this group that they're seeing the story of doesn't map onto a racial division. It's two different sports teams. We didn't know whether we would detect any effect at all, but in the course of four minutes of this, a very short period of time, we were quite astonished that the effects were so big, particularly because there's prior history among social psychologists: They've never been able to find anything that decreased racial coding at all. But if you put people into this environment where people are having a dispute but the dispute doesn't map onto racial alliance, what you find out is that within that context, subjects seriously reduce the degree to which they encode race of subjects, so that they will no longer be mistaking what one person said for what another person said by race. Racial awareness or race consciousness, as an organizing feature of personal representation, diminishes.

So, we have a very rich, complexly structured piece of machinery. When you add the shared appearance cue, which predicts coalitional alliance, you create an artificial model race. People spontaneously start to encode that and the degree to which they encode race goes down. We created this artificial world, only four minutes long; it was a striking effect and we now replicate it in a lot of different contexts. The underlying point I'm trying to make is that there are a lot of these widgets in there. You can find out their properties by modeling adaptive problems carefully.

VARKI: In terms of the group that you're defining as the ancestral state, if you're studying things that are universal to human population, I suppose you're defining this as being some time period before 50,000 or 60,000 years ago, before people started out across the world. In other words, when you said *hunter-gatherers*, were you using that as a proxy for what we think that people were doing between 100,000 and 50,000 years ago? If you're dealing with things that you think were selected for that would be the same in an Australian Aborigine and a Native American, then you

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would have to be talking about selection that occurred prior to the diaspora of these peoples.



... environmental evolutionary adaptiveness is intrinsic in the Darwinian notion when you talk about things that are more than single-locus things.

TOOBY: There's a lot to say about your question. It's a very big question. The thing is that it's such an under-utilized approach that we can pick things that are adaptively significant that were endured for a long period of time.

The other thing is that we're interested in complex cognitive systems – that's the notion that it takes a long time for natural selection to operate, so it's unlikely that simple things can happen fairly fast. For example, the ability to digest milk – in a few thousand years you can get that. But if you're talking about a complex thing with a lot of inputs and outputs, that takes a big chunk of evolutionary time. That's 100,000 years or something like that.

You're also looking at it from the point of view of the adaptive information-processing problem. Environment is not just a physical place; it's a structure of causal relations and informational relations. Australian Aborigines had alliances. They had disputes. The notion is that at a certain abstract level, there's a uniformity. This notion of an environmental evolutionary adaptiveness is intrinsic in the Darwinian notion when you talk about things that are more than single-locus things. Something drove an allele towards fixation. It either went there by random walk or it went there under selection, systematically. If it went there systematically, that causal aspect of the world that drove it there is what we're talking about as the environment of evolutionary adaptiveness with respect to that adaptation.



My point is that if you're talking about something that is local to a particular region and impact, then it was recently selected.

VARKI: My point is that if you're talking about something that is local to a particular region and impact, then it was recently selected. But if you're talking about something that's universal to humans, then you're talking about, actually, this time period that Bill [Calvin] was alluding to where there doesn't seem to be any evidence for anything. There aren't any fossils; there aren't any peoples. My point is that we don't know what that environment was.

TOOBY: Again, if you're talking about gizmos, a lot of these things will be true for extremely broad lengths of time – things like: space is three-dimensional. Even though we don't know what happened to Atlanteans, or if UFOs landed in that particular period, still, space was three-dimensional. In gender, there were two genders. So, with the notion that we have an automatic system that assigns gender categorization and does powerful inferences on it, we can reconstruct certain aspects of the environment of evolutionary adaptiveness with certainty at this compositional level. Some aspects of it we have no idea about, in which case we are back with normal psychological research, which is to say that you don't know where your hypotheses come from.

But, yes, you do a lot of work thinking about the structure of foraging environments and foraging people's use, primatology use, research on hunter-gatherers in paleoanthropology.

DEACON: I have a question about just how you do this. In coalitional assessment and race assessment, of course, one could come up with 500 possible competing ways that you could get a conflict of assessment of categorization here, which was indicated with your initial categorization story. How do you then go about picking out the ones that you're going to utilize? Do you just have to walk through the ones that you best-guess, or is there a more statistical way that says: I only have to do three of them and I've done it?

Race only appears to be significant because it arbitrarily cues a coalitional thing, and clothes will do that just as well. And hair styles.

TOOBY: The question is: Have we exhausted the kinds of computation systems that are in there? – as opposed to: Have we identified some? For example, sex is really not affected by coalition, so we did that as a control. People almost never make these cross-gender errors. If a man says something, you don't confuse it with something a woman said. If a woman says something, you don't confuse it with a man. It didn't have to be that way. It means that it's incredibly robust. Its effect sizes are almost unheard of in certain aspects of psychology – social psychology, certainly. It's very important that people don't make the gender error, for example. Here we have positive information about what *does* happen.

That's not to say that there couldn't be other kinds of categories, so we're also doing other work now on whether people pick up kinship information in this way. It's an experiment, so we control what things we vary. We can affirm that certain variables are being processed. As I said, we don't know that others are not, although we do know that a lot of things aren't; for example, arbitrary clothing doesn't get processed. That's the thing about race: Race only appears to be significant because it arbitrarily cues a coalitional thing, and clothes will do that just as well. And hair styles.

So, in terms of this kind of processing, there's no preference given to something that is biologically part of the development, over things that are put on for the day. It's not a different kind of thing, in terms of the mind's categorization system.

DEACON: My question was about the broader methodology. In some sense, this is a positive fishing in which you pick out a couple of things that are your best guess, then you plot them against your best-guess competitors.

TOOBY: I prefer to say that we make theoretically principled predictions.

DEACON: That's fine. So, the question is: What do you do with all the negatives. You say, "I think it's coalition," so you come up with markers that you think are coalition and set up this assessment. You come up with sex being an interesting counter that might be something different from coalition, but coalition is an assumption to begin with. You've created that. How do you subdivide that? How do you go in and analyze that?

TOOBY: How do we operationalize our theoretical concepts? That is one part of your question. Here, we invent a new coalition. We don't tell the subjects that there's a new coalition there. It just emerges in the course of the conversation. They didn't have to encode. All they're being asked about at the end is: "Who said what sentence?" There's nothing in there to divide this into two teams or anything like that. That's something that the subjects themselves have brought to the task. There's nothing about the instructions that forces them to do that, but they backward-infer from the structure of the conversation that there's an argument going on, and pick up on who is on what side of the argument. We also have a verbal-only part in which there's no shared appearance at all.

Men are more coalition-activated than women are. It's an extremely hard task. You've never seen these people before; you don't care about the conversation, and so on, but, still, something shifts there and you are interpreting that this is an interpersonal thing in which there are two groups. That's something that is being brought by the mind to the task; it's not intrinsically in the task.

DEACON: I guess my point had to do with the operationalization of *coalition*.

TOOBY: It's operationalized by the structure of the argument. You notice that some people are agreeing with other people and disagreeing with other people. That's how coalition appears in the stimuli.

VELAMOOR: Thank you, Dr. Tooby.

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Evolved Neurocognitive Programs as the Foundations of Cultural and Social Phenomena
Presentation by John Tooby, Ph.D.

What Is Future?

Presentation by Endel Tulving, Ph.D.



... future exists solely by virtue of a certain kind of consciousness of the evolved human brain, not duplicated anywhere else in the known universe ...

TULVING: I wish to talk about an idea that has to do with *future*. The idea is that future exists solely by virtue of a certain kind of consciousness of the evolved human brain, not duplicated anywhere else in the known universe, and that this kind of consciousness was one of the necessary conditions for the initiation and development of human culture. I came here, actually, to try out this idea, which I have tried out in other quarters, and I've asked people to tell me exactly where I've gone wrong. I have not succeeded in getting people to say, "You're totally off base here." I thought that this particular audience will tell me where I'm wrong.

I made the "discovery" about the future in my own life relatively recently. I came to it in two ways: from my own research in human memory, on the one hand, and then, on the other, the question: What is consciousness all about? A known problem with people who are interested in consciousness is that they usually just talk about it. When I read a paper or book on consciousness, I say, "Beautiful, but what is the evidence? How can I tell that your story is a better story than that of the other person, who came to exactly the opposite conclusion?" So, that's one problem.

The other problem lies in the difficulty of objectively studying something as intangible and fuzzy as consciousness, something that many hard-nosed scientists and other experts think is an epiphenomenon to begin with. Indeed, if one goes by the rules of the 19th century science, the problem appears to be real. But if we accept a few new rules, still compatible with the basic foundation of science – of empirically verifiable and replicable observations – then consciousness

becomes a tractable object of study, and the issue of its epiphenomenality can be addressed objectively. The primary question then becomes: What exactly is it that humans, with their consciousness, can do that a nonconscious machine, or a "nonconscious" animal could not? It's an interesting question. When Deep Blue beat Garry Kasparov in the famous chess match, there went one big idea that humans can plan for the future in a way that machines cannot. Chess was supposed to be the prototypical planning, thinking-about-the-future game that requires the kind of intelligence that "lower" animals or "mere" machines do not possess. And Deep Blue seemed to prove that supposition wrong. Or did it? Perhaps all it proved was that chess is not the kind of game that we thought it was. We were wrong about the game, not necessarily about the human mind.

If so, there was a possible answer to the query about the epiphenomenality of human consciousness: Humans can consciously think not only about their own past but also about their own future, whereas nonconscious machines, or animals with different kinds of consciousness cannot. This kind of ability should manifest itself in human achievements that are beyond the powers of other creatures and machines.

I actually believe that everything that we know today ... all of those things are going to be wrong. It's only a question of how long it will be before humankind has figured it out ...

I actually believe that everything that we know today – I teach my students this – all of those things are going to be wrong. It's only a question of how long it will be before humankind has figured it out: "Oh, the silly ideas they used to have back in 2005." So, all of these ideas are wrong. The question is not whether they're right or wrong; the question is *how* are they wrong? In what sense? How can we change it so that

the next step that we take will be a little closer to what eventually will remain from all the activities that all kinds of scientists engage in?

So, I make this outrageous statement: Future is one of the most powerful ideas ever to emerge from the human brain/mind. You can prove me wrong by giving me a better idea. I'll accept many other equivalents, but I would like to get a better idea, a more important idea, a more powerful idea. I'm not saying it's the *only* idea. I'm going to argue that the future is a very important driver of human culture, for instance. By no means does it mean that there are no other determinants. It's one necessary condition. One enabling variable – one of zillions, perhaps.

The future, of course, is disputable and subjective; it has something to do with time, but it's not time. Time is all over us. Time is something that surrounds everything that happens in the universe. Cosmic evolution all happened in time. All physical laws run their course in time; all behavior takes place in time; the lowliest organism operates in time. Time is a discriminative variable. It's something that controls people's behavior, an organism's behavior. I mean by *subjectively apprehended time* something totally different.

You apprehend time in a way that, I will argue, other organisms, other animals, do not. For example, you can close your eyes, plug your ears, turn off the nose (if you can), and think about yesterday's evening celebration. What happened? You can play that tape in your own mind, in any way you want, either taking snippets or playing from the beginning or going to the highlights, or so on. You can revisit the past in your own mind. Now, it is possible that there is somebody in this room who cannot do that. I will argue that this ability of mental time travel is a relatively recent evolutionary happening on the scene, and, therefore, it is not unlikely that there are perfectly normal, intelligent human beings, successful in our society, who do not have this ability of mental time travel. Later on, I'll introduce the concept of autonoetic consciousness. There are probably people around who do not have that. These are people who become mystified when we tell them about it. It's like color-blind people who listen to others who have color vision talk about different hues and have to make some sense of it, but they cope and adjust and figure it out.



... conscious awareness of subjective time is made possible by something I call *chronesthesia* – time sense. This is an evolved neurocognitive capacity probably unique to humans.

If you're normal, you can travel back into the past in your own mind. This is what *subjectively apprehended time* means. You have to have some ability of subjectively getting your mind on what happened at another time in another place. By the way, very little of what is known as memory is concerned with that. Most kinds of memory that people have studied have nothing to do with the past – nothing more than anything else in the universe has to do with the past. Now, I am going to argue that this conscious awareness of subjective time is made possible by something I call *chronesthesia* – time sense. This is an evolved neurocognitive capacity probably unique to humans. I am not saying that other animals, including our closest relatives on the evolutionary tree, do not have that time sense of chronesthesia. I'm simply saying that there is no evidence that would satisfy me, as a relatively objective observer, that they do.

Chronesthesia is a recently evolved capacity that enables us to mentally travel in time into the past as well as into the future. This is where the future comes in. The past and future are connected, in the sense that they are enabled by the same mental capacity. I will also argue that mental time travel was a critical driver of culture. It defined culture. I like to think I'm not capable of thinking complicated thoughts. I like very simple thoughts. Chronesthesia provides one of the most telling illustrations of the function of consciousness. Chronesthesia is an example of what an organism that has this higher level of consciousness can do that organisms without it cannot. Otherwise consciousness, like everything else, is distributed continuously in nature.

I always get a chuckle out of these arguments: Is this organism conscious? Or is this species conscious? Are cats conscious? Are worms conscious? Of course they all are, although in different ways. Even the tree outside my house in Toronto is conscious, in a way. How do I know? It reacts to the environment in a way that a rock does not. I've seen it. It's a fir tree that has been growing there in front of our eyes for the last 20

years. Its seed certainly did not have that information genetically implanted that *as I grow older, I had better keep toward the east because toward the west there is a mountain ash that steals my light and I am better off with more light*. That's consciousness: awareness of what's happening in one's world. It is consciousness ("anoetic" or non-knowing consciousness) but it is not the same kind of consciousness that is involved in your or my mentally traveling back into our own personal past or "forward" into our personal future. Consciousness covers so many things. To talk about consciousness as an all-or-none phenomenon – or even *self-consciousness, self-awareness* – is like talking about, "Are you a sick person or are you a healthy person? Are you an old person or are you a young person? Make up your mind. You have no more choices." I don't understand why people do that, but I've been puzzled about what people do for a long time.

***Without this chronesthetic consciousness,
the future could not exist, nor would culture.***

The bottom line, then: This hypothesized, hypothetical entity called *future* that does not exist in the physical world but it does exist in the more important world of human consciousness. As such, it is very much a part of reality. It is made possible by chronesthesia, a kind of consciousness that only humans possess. Without this chronesthetic consciousness, the future could not exist, nor would culture. I'm happy to tell Walter Kistler that your Foundation owes its existence, among other things, to something you did not even know about: chronesthesia.

When I "figured out" that future plays an important role in shaping human affairs, I sat down one day and wrote down things that human beings do in their organized activities. I ended up with a very long list, organized under category names such as education, science, art, literature, religion, communication, construction, trade, commerce, banking, and many others like these. I asked, What do all these activities require? What are things without which none of those activities could occur? The answer is that they all require large brains and intelligence and creativity and inventiveness and abstract problem-solving activ-

ity; they require language. Then I said, Yes, of course, no problem with that – all of these above plus many others. But every single one also requires chronesthesia. You take away the human ability to imagine the future, being aware that there's a tomorrow after today – take that away, and they will not engage in any of these activities. It's one of these thought experiments; it's very simple to sit down and imagine: Would you take your money to the bank if you didn't know that there is a tomorrow? Would you send your children to school? Would you buy a newspaper today? Would you go and buy yourself a new car if you did not know that you would be using it for a while?

How does someone like me who has spent most of his life doing tightly controlled laboratory experiments on undergraduates' ability to learn and retain this and that, under these and those conditions, get to lofty thoughts about consciousness and future? In 1972 I wrote an essay about what I called *episodic memory*, the kind of memory involved in remembering personally experienced events. (The concept as such was old – many others had played with the thought that there is something special about this kind of memory – but the term was new.) And ever since I myself started to take seriously the possibility that there was a real difference between episodic memory and all the other kinds, I was haunted by the question: Why did it evolve? What is it good for? If it is true that the rest of the world can do without episodic memory, if it is true that all the animals that have ever lived, all the species that have ever lived, and all the millions of species that are alive too, are doing exceedingly well at the main business that they have to do – namely, to survive and procreate, and so on – without having something called *episodic memory*, why did it switch in, in humans? What is it good for? What does it help? What's the adaptive value of it?

Then at one point I started wondering if there is something wrong with that question: What is episodic memory good for? Where have I gone wrong? But perhaps this is the wrong way to look at it. Perhaps remembering is something derivative of something else.

In 1983, I met a young man whose name is Kent Cochrane. I don't hesitate saying his name because he has been all over TV in Ontario and elsewhere. [Referring to slide] Here he is in a wedding photograph of his brother, who is standing next to him, and

the young bride is in the middle. His mother sits in the front with father and another brother. This is 1979. He had made a surprise for the other people by getting himself an Afro haircut. He was an object of admiration and attention throughout it. He now looks at this picture – he's over 50 years old now – and you ask him who these people are, and he says, "Oh, that's my family." He can tell you all about it. You ask him when this picture was taken, and he says, "I don't know." You ask, "Do you know these people?" "Yes." "But when?" And nothing. The reason is that in 1981 he suffered a closed-head injury, traumatic brain injury, as a result of which he became deeply amnesic. That means that he does not remember ongoing experiences from his regular life. He's like H.M., the famous H.M., in terms of severity of anterograde amnesia.

One interesting feature is that also he does not remember any personal happenings that ever occurred to him in his life. For personal experiences that you and I have no difficulty with, at least mostly, of any kind, he has none. His blankness of the mind when it comes to personal happenings goes back to Day One. Otherwise he's perfectly fine. He speaks; he writes; he reads; he thinks; he plays musical instruments; he plays chess – he's not a great chess player, but he knows the rules; he's learned it. Now he spends his time mostly playing computer games. But if you ask him, "Kent, before you came here..." he doesn't know.

If I had brought him with me, I could ask him, "Where are we?" and he would answer, "I don't know." "Well, describe the room." He would say, "It's a room full of people and you are making one of your speeches, I suppose, and you are showing my picture here and they seem to be paying attention to what you're saying." He has a dry sense of humor. But *you* know where you are; *I* know where I am. Have you been here before? No. Then how do you know where you are? You know where you are because you remember how you got here, and that's the only reason. Take away the memory of personal happenings and you do not know where you are. This ability to orient in time is made possible by episodic memory and auto-noetic ("self-knowing") consciousness, remembering what happened to you.

Earlier I suggested an "outrageous," and possibly wrong, hypothesis about future being the most powerful idea of the human brain/mind. Part of the hypothesis is the idea that chronesthesia, which

makes future possible, evolved because it allowed human beings to deal more effectively with vagaries of unpredictable environment. Instead of adapting to the world, chronesthetic humans began to change the world to fit their needs.

Culture is the difference between the world as it actually exists and as it would have existed, as a natural product of evolution, if there had been no changes wrought by the creative human intervention. The initiation of culture was, and its continued development is, critically dependent on auto-noetic consciousness and pro-spective (forward-looking) chronesthesia. The kind of culture that *Homo sapiens sapiens* has created over the last 40,000 years or so can be produced only by individuals whose intelligence includes conscious awareness of the existence of the future in which they and their progeny will continue to live and survive. We take this ability of our awareness of time, both backward and forward, so much for granted that we don't give it a second thought. But I say it's one of the greatest miracles that evolution and nature have produced.

PINKER: Would you remind us of what *auto-noetic consciousness* means?



Humans acquired auto-noetic consciousness some time after their line split from the one that ended up with chimpanzees.

TULVING: Auto-noetic is the one consciousness that you and I have that has to do with self and time. This is a necessary component of episodic memory. Episodic memory is a conjunction of self, subjective time, and auto-noetic consciousness. The way it works is this: Humans acquired auto-noetic consciousness some time after their line split from the one that ended up with chimpanzees. We do not know when, but probably quite recently. This difference from chimpanzees and all other primates, and all other animals, ought to be potentially discoverable at the level of physics and chemistry of the brain. Chronesthesia allows us to create auto-noetic conscious awareness of the past and conscious awareness of the future, so that we have an idea of the future. And because we have a future, we can think about future the way Kent or an amnesic patient cannot. He does not know any more what he's

going to do after he leaves here than he knows what he did just before he got here. He does not know and cannot tell you what he's going to do next summer or next week.

We have a paper just coming out, a long, long paper on Kent in *Neuropsychologia*, the whole story with particular reference to the nature of his brain damage. The damage is diffuse, consisting of multiple lesions, so Kent's case is not very informative regarding anatomical localization of brain regions involved in his memory impairment. But even so, his case can be seen as teaching us that if one can imagine the future, as all healthy humans can, then one can choose to act now in preparation for the future. Animals without autonoetic consciousness and ability to think future act only in response to present stimuli and need states.

I have recently proposed something called a spoon test, which essentially is a test of future thinking in chimps. If your chimps pass this test, bring me the evidence and I'll say that I was wrong and your chimp has chronesthesia. The chimp doesn't have to talk; it just has to act in a particular way.

The point is that you change your environment if you have some idea of what this environment is going to be and continue to be. If you don't have any idea, you simply adapt to the environment as it exists. Darwin knew all about it. It is what evolution has been all about – always making sure that you fit into the environment as it exists. There are always exceptions, but I'm talking about the large scale. Then you change your environment. It may start with burying your dead. But I'm not too sure whether that really requires any future thinking. What does require future thinking is if you bury your dead and grave goods to go with it, to be useful in the hereafter. Is there a hereafter? Of course there is, but only in your mind, and only if you have autonoetic consciousness that enables you to think future.

Tool use: I am not impressed about this fact. If *Homo erectus*, for instance, used tools but did not really improve them for a million years – used more or less the same tools – then just making and using tools is not an impressive achievement. What is more impressive is if the tool users carried their tools with them as they moved from one location to another, and stored their tools out of sight for long periods of time that they were not needed. Getting the materials for

making tools at a faraway location and transporting them “home” where the tools are made is also more interesting, because it requires forethought, imagining the future.

What is future? One of the most powerful ideas ever to emerge from the human brain/mind. The important thing is that future does not exist in the physical world.

So, that's the end of my story. What is future? One of the most powerful ideas ever to emerge from the human brain/mind. The important thing is that future does not exist in the physical world. If there were no human beings around, if you could look at the universe as it existed for the first 11 billion years, there was nothing like humans around. There was no future in that universe. Anyone who argues differently has a job.

Future comes in only as a manifestation of the human brain and not hardware manifestation but something that goes beyond it, that emerges from the brain: consciousness. And that is why consciousness is necessary. That's why it has given us the current world in which we live and that's why we have a conference here of this sort, and that's why there's no telling what will happen in another thousand years, if humans, somehow, manage to keep themselves alive until then.



What do you think the role of forgetting is?

HOLLOWAY: That was a really fascinating talk that has so many tendrils in it that I would like to talk about. You might be interested to know that toolmaking goes back at least 2.5 million years ago, and there's very good evidence that there was planning and future anticipation because some of the materials that were used to make the stone tools were clearly being transported from one place to another. As you get into about 1.8 million years, 1.5 million years, those distances become quite large.

I wanted to ask you: What do you think the role of forgetting is?

TULVING: Highly overrated. Forgetting is something that happens naturally in the human brain, as all biological organisms are machines; they wear down. That's very simple-minded. You probably have in mind: Why is it important for the brains to be instruments that are programmed, not only to soak up information but also to forget information? That's why I say that it is overrated. Too many people think that somehow the brain gets full and then in order to make room for new information in there, you throw some stuff out and just forget. It's so naïve I don't even want to....

HOLLOWAY: That's too rational for me.

TULVING: Forgetting is one of these natural phenomena. It also makes possible the study of memory by psychologists. If there is no forgetting, then psychologists have no business saying anything about memory.

HOLLOWAY: My question was more: Do you think there is remembering to forget?

TULVING: No.



... these phenomena, I think, exist in warm-blooded animals, but what needs to be explained is how it got enormously amplified ...

VARKI: I'm not an expert on this topic but from my reading, my understanding is that there are some birds that can store things and come back much later, even knowing whether they are perishable or non-perishable. Chimps actually *do* carry their stones for cracking nuts some distance, and they can remember when the fruit tree fruited last year, and so on.

What I'm getting at is that I don't think there's a great rubicon, but I think there's some kind of quantum jump. In other words, these phenomena, I think, exist in warm-blooded animals, but what needs to be explained is how it got enormously amplified and made so much more complex, as opposed to a bright line saying that only humans are capable of thinking about the future.

TULVING: There is something called *episodic-like memory*. I have been involved watching it and supporting

these young people, particularly Nicky [Nicola S.] Clayton, who is one of the major players in Cambridge, England, and whom I met some ten years ago at UC Davis. When I was there, we talked about it. She wanted to call it episodic memory in her scrub jays, but had the good sense to call it *episodic-like* memory. Yes, sure, there are always these exceptions. What is tool use? What is language? Where does language end and nonlanguage begin? Where does language end and nonlinguistic communication begin? Nature doesn't work like this. It doesn't come in packages.

I'm simply saying that I have no evidence that any other – particularly, we're talking about these great apes – that a chimp would be able to think about the future and take action now in preparation for the future in the absence of currently active drive or stimuli or hormonal states or even changes in the light and dark cycle. In the absence of those, I don't see that any one can do what a three-year-old or four-year-old child can do. Not a two-year-old – two-year-olds also have no future. Three-year-olds probably don't have future. Future comes in somewhere around age three, four, or five; this is what developmental psychologists tell you. Young children, like all other animals, have a "sense of time" in several senses, but they do not have it in the same sense that they will have when their brains mature and they begin acting like chronometric creatures. Young children do not sit around and think about what they are going to do ten minutes from now, or tomorrow.

If you ask a four-year-old child: "What is this color called?" The child says, "Green." "No, no, no. It's chartreuse." Then you test the child ten minutes later, "What is this color called?" These three-year-olds are fast learning machines, very clever, very intelligent. They soak up information about their environment. You ask them, "What is it called?" What does a child say? "Chartreuse." "Good!" Does that mean she remembers where she picked up that information? No. You ask her, "How long have you know it?" "Forever, always. Everybody knows it." Exactly like my patient, Kent. I can teach him things that have nothing to do with himself. He can learn. "Kent, the dog confronted what?" He says, "Bullfrog." I said, "Dog confronted bullfrog?" He said, "Yes." "Why do you say that?" "I don't know." Now he's getting smart enough that he can think and say, "Hey, perhaps it is unusual. Perhaps you taught me." But whatever you know,

you take for granted. Remembering where or when something happened or where or when you picked up some information is not a very important part of human life. This is episodic memory, and the question is: What good does it do?

My mistake was trying to answer this question thinking only about the past. This was a mistake in the sense that it does not allow one to claim human uniqueness of episodic memory. This is why the insight (hypothesis) of a common subjective-time-related sensibility (chronesthesia) that covers both the past and the future was more promising. Chronesthesia can be (hypothetically) denied to all kinds of animals, and machines, that otherwise have excellent ability to learn and retain skills and knowledge. And there are tests, such as the spoon test that I mentioned, that can be used to prove the hypothesis wrong.

VARKI: I basically agree with you. My point is that if you set a line in an area or level of this issue where, in fact, it turns out that there are many exceptions in nature, you're going to be accused of "moving the goalposts." I think it's much better to set the goalpost somewhere in the middle of where humans are, rather than at the minimal, otherwise you always run into this problem where people say, "Yes, but look at scrub blue jays or chimpanzees." I agree with your general principle. I would say that humans have this ability in far greater excess than other animals do, but we may not have studied enough animals to know how much of it does exist in other parts of the animal kingdom.

TULVING: As a matter of fact, I talk provocatively mostly to specialists because I want them to, as I said, tell me where I'm wrong. Now if you tell me that, yes, there's evidence about tool storage and tool carrying earlier than 40,000 or 50,000 years, fine, I accept that. I'm not going to argue with specialists who know. But it's still inferential evidence. I would be much happier to take our close relatives and see them, whom we can actually follow. Jane Goodall is supposed to have described an incident where some of her chimps carried a stick around. I said, "Fine, great." Now, next time let's not just have Jane Goodall's word on it, but let's have a videotape. Let's have a videotape of another chimp or two on another occasion, and then we will find out whether this is a cultural acquisition in that particular group, or whether it's really a general thing. Then I'm persuaded. But until then, I need hard evi-

dence they can do certain things.

Biology cannot have any laws because every single organism that you study in biology is different from every other single organism. That's a kind of problem that physical scientists do not have. An atom of helium or hydrogen in outer space is exactly the same as here in your bottled water, right? You can study it, and that's why you can make up laws. But everyone here – we may have 99 or 99.5 of the genome parallel sequences in common, but every one of us here is as different as you can make us, *if* you want to look at differences. That's not meaning that there are no similarities.

I am not one of those people who say, "It's only differences." I am talking about differences because the received wisdom right now in neuroscience and brain sciences in general is that we are just big monkeys or big apes, nothing much different. And, as a matter of fact, I've had heated arguments with people who are supposed to be in the know. I've said, "Look, it is our duty as scientists to study both similarities and differences, not just similarities." Some of them tell me, "No."



... for the future ... you have to piece things together that probably have never been together before and you have to make judgments ...

CALVIN: I like that summary. One of the problems with both looking into the future and looking into unique aspects of the past, as opposed to annual migrations to fruit trees, is that you have to piece this stuff together. That is to say, the *what* is likely to be in the temporal lobe and the *where* in the parietal lobe or hippocampus. In piecing together unique stories like that, you make a lot of errors. You wind up probably with things that look a lot like our nighttime dreams of people, places, occasions that do not hang together very well.

But since we speak unique sentences every day, all the time, we get a great deal of practice in finding coherent collections of things. It's this quality-control problem that makes it hard to do what's in the past very well, unless it's been repeated and tied together very well. But for the future, you have this creativity problem – you have to piece things together that

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What Is Future?

Presentation by Endel Tulving, Ph.D.

probably have never been together before and you have to make judgments such as: Does this hang together well enough to act on, or to speak about? It's that quality-control problem that makes planning of all sorts difficult, and it certainly is what makes difficult-to-piece-together stories pass decently. It seems to me that that's the kind of thing you start seeing with higher intellectual function and that may not be very old in human evolution.

TULVING: You are right, but note that you are talking about mental activity and its contents. You are talking about the message, and here I have been talking about the medium. You're talking about ships and voyages that the ships are on. I'm talking about the water on which these ships float. Voyages are important, and water makes them possible; thinking about *your own* future (and *your own* past) is important, and chronesthesia makes it possible.

CALVIN: That's what I would really like to get at: What are the processes in the brain that allow us to do this coherence-finding? I think that's what enables us to do what you are emphasizing.



... we have tried to get rid of final causality – that is, causality in which the future somehow plays a role in causing what goes on in the present ...

DEACON: A phrase that I've fallen in love with about this comes from Charles Sanders Peirce, the philosopher at the end of the 19th century. He called us the creature that lives *in futuro*. That is, we don't live in the present – in fact, we live in the future.

I think it really makes sense. He connects it with something larger and I wanted to carry you back on this because I think it fits with Ajit's question, which is somewhat like mine. I always find it very interesting, once you look at a phenomenon and you struggle with it, to find out what's the special case of the general rule. The special case, of course, is this living *in futuro* that we can do, and we almost can't do without it, as you pointed out and I think rightly so.

I look back at it related to a very much older philosophical idea – Aristotle's idea of final causality. In biology, of course, we have tried to get rid of final causality – that is, causality in which the future somehow

plays a role in causing what goes on in the present, which sounds like nonsense in any realistic philosophical framework, but of course it's what we do all the time. In biology we often talk about something less than that, but that looks a lot like it. It's been now given the name *teleonomy* by Pittendrige back in the 1950s. That is, we have, in effect, over time become more and more capable of something that has a very old ancestry though it was much simpler.

TULVING: Good point.



Are there interesting interrelations in the patterns of dissociations with planning and imagining the future?

TOOBY: Now that you've been reborn as this utterly different thing, a cognitive neuroscientist, let me ask a cognitive neuroscience question about this, which is: It's an interesting claim that there is a computational faculty for the apprehension of time and that episodic memory might not be entirely spun off as a unique thing but as an expression of this larger faculty. With Kent and whatever other cases you have, can you get a disassociation, people who lose the ability to plan but are perfectly okay with episodic memory? Are there interesting interrelations in the patterns of dissociations with planning and imagining the future? I remember one time you talked about remembering the future.



In general, the literature on these sorts of issues is largely nonexistent; the game is barely starting.

TULVING: There are lots of cases described in the literature showing that people with normal memory (episodic and otherwise) are not capable of making plans for the future. This kind of a dissociation frequently occurs as a result of damage to prefrontal cortex. It underscores the fact that chronesthesia is not a sufficient condition for future planning or future thinking; it is only necessary.

Talking about dissociations, however, more inter-

esting is a case described by Stanley Klein and his colleagues at UC Santa Barbara (John Tooby's home institution). They tested a patient with four kinds of questions, conforming to a two-by-two design. One factor was the direction of time: past versus future. The other one was personal versus general. The patient did much better answering past- and future-related questions having to do with the world in general than he did with similar questions about his own personal past and personal future.

In general, the literature on these sorts of issues is largely nonexistent; the game is barely starting. When I talk to neuropsychologists and other clinicians concerned with neurological and psychiatric conditions, I suggest that they talk to their clients not only about the clients' personal past but also personal future. Not everyone likes such new radical ideas, but the message is spreading.

VELAMOOR: Thank you, Dr. Tulving.

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What Is Future?

Presentation by Endel Tulving, Ph.D.

Explaining the Human Condition: Problems and Prospects

Presentation by Ajit Varki, M.D.



There's extensive molecular evidence now showing that our closest cousins are the rodents, not dogs or pigs or whales ...

VARKI: The first point that I was going to make was actually already made by this Foundation, and that is that if you want to know where you are going, you have to know where you came from. We need to know what makes us what we are, how we got here, and where we came from. It's the totality of this information that's going to, eventually, allow us to try to answer this question.

I also realized that the Foundation had a broad view when I picked up this quote from your brochure where Walter Kistler says that "the purpose of the Foundation is to bring some light into the dark cave, so that humanity really sees and understands its surroundings and its own place in the universe."

Let's just zoom right into that region of evolution that gave rise to us, the origin of primates. There's extensive molecular evidence now showing that our closest cousins are the rodents, not dogs or pigs or whales or anybody else, but the rodents. So, we actually picked the right species in terms of research – mice and rats – next to primates. Then, of course, we have common ancestors with prosimians, New World monkeys, Old World monkeys, lesser apes, and great apes. My work is focused on the hominids. It's pretty clear now that we shared a common ancestor with the orangutan about 13 million years ago, with the gorilla about 8 million years ago, and with the chimpanzee and bonobo, or so-called pygmy chimpanzee, about 6–7 million years ago. Now, the remarkable fact is that while we classify all these species as great apes, the mean amino acid difference between our proteins – between humans and the bonobo/chimpanzee clade – is less than 1 percent, and we're closer to the bonobo

and chimpanzee than any of us are to the gorilla.

In fact, the correct classification now is as follows. I won't go into details, but basically we are classified as *Homo* along with *Pan* – these two species under hominids. So, is it wrong that we call all these species "the great apes"? I've always wondered about this, and I feel that we've gone too far overboard in the other direction, going from saying that humans are totally unique and different to saying that the politically correct view is that we're just a third chimpanzee (although I really like that book by Jared Diamond of that title).

Over the years, then, I have collected these features of humans that seemed to me to be somewhat different from great apes. This is just a part of a very long list, an amateur list – I'm not an expert on this kind of topic. You all know about brain size, the adductive thumb, and body hair, but some of you may not be aware about the chin, skeletal muscle strength, the descended larynx, the penis bone, concealed ovulation, breast tissue in virgin females, a different chromosome number, ear lobes, frequency of third molar impaction (wisdom tooth impaction), and so on. This list does not have cognition, consciousness, language, or any of those things on it. Chris Wills saw this list of mine sometime in the late 1980s when he was writing a book. He took this information and put it into one of these phylograms. And he put it in his book [*Children of Prometheus: The Accelerating Pace of Human Evolution*, Perseus Publishing, 1998], saying, we stick out like a sore thumb, or like a fishing pole.

There is something unusual about us ... How do you have a group of species that are a relatively conservative clade, then you have this unusual species emerge?

There is something unusual about us, and I don't think it's purely anthropocentric. I think it's an interesting

question of evolution. How do you have a group of species that are a relatively conservative clade, then you have this unusual species emerge?

[Referring to slide] This is my daughter when she was born in 1984. About ten years later I was flying across the Pacific on a long flight with her and trying to keep her busy, so I took out a dictionary that she happened to have and I said, “Check entries in the dictionary under each letter from the top. Stop when you reach the first one that you think is unique to humans, and I’ll help you out.” In very short order, we came up with *abbreviating*, *bag-making*, *calculus*, *darts*, etc., and hit *zeroing* pretty soon. We finished up in an hour. Then I said, “All right, take the letter S and scan all the entries under the letter S and record all the ones that you think are unique to humans.” And we started with *sacrificing*, *sack-making*, *saddling*, and went on and on. By the time we reached the middle, *spending*, we were already tired so we jumped to the end to *surfing*. The point of all this is that there is something unusual about us humans, and I think it’s worthy of study and it’s not an anthropocentric point of view. There is something to be studied and it’s quite big.

The most obvious difference is cognition. There are many areas of cognition: the arts, the humanities, and the sciences. My expertise is in the sciences. [Referring to slide] Here we see C.P. Snow’s great divide of the natural and social sciences, but actually I see the sciences somewhat differently: that is, engineering and computing sciences, physical sciences, and biological sciences being quite distinctive, and I’ll explain why. Over the last century, all of these sciences have made major inroads into each other, although I would daresay that while the social sciences and biological sciences are beginning to merge, there’s still somewhat of a gap.

Now, I had the good fortune, as I mentioned, of having come from a background in biomedical sciences. This is a “shotgun marriage,” the one field where we cannot afford to say there’s social science or natural science or physical science or biological science. There’s only one science – it’s medicine – and we have to use information from all the fields. This gives me the advantage of having a central view in terms of many of these problems.

If you look back at these different sciences, engineering and computing are highly precise. Well, we created these sciences; we know the rules. Unless

somebody loses the code, we know exactly what we’re doing there. In the physical sciences, we didn’t plan it that way, but it turned out that there are almost universal laws in most of the physical sciences. So, there’s a tendency to believe that biological sciences fit in here as a form of a highly precise type of science, as opposed to, as some people would try to argue, the social sciences. I would say that’s wrong. The central dogma of molecular biology that Francis Crick enunciated in 1958 is: “DNA makes RNA makes protein.” It’s a wonderful and almost digital dogma, but there’s a tendency to then think, as this student put out on the Web recently, that DNA makes RNA – she recognized various kinds of RNA – makes proteins; add some chicken fingers, and you get *me!* In other words, protein makes cell makes organism. In other words, DNA makes the organism.

I organize some meetings on human origins in San Diego, and the last time I heard Francis Crick speak, this is what he said, “There are no laws in biology – only widgets.” Widgets, as you know, are little mechanical devices that are useful for little things. What Francis was saying is, “Now I see that biology is just a huge collection of widgets.” We have all these little things that do little things. We conglomerate them in various combinations to achieve things that seem to work. So, really, I think the physical sciences have to get used to the idea that there are no laws in biology. But perhaps there is one and that is this famous statement of Dobzhansky: “Nothing in biology makes sense except in the light of evolution.” But I think we need to be very careful. I like the statement of John Coffin: “Although no biological explanation makes sense except in the light of evolution, it does not follow that all evolutionary explanations make sense.” So, you have to be very careful, but that should not inhibit us from speculating and thinking along those lines.



... most medical students think that evolution results in optimal design ... when in fact, what we are right now is a snapshot in the history ...

The other point I’ll make, since I’m in Seattle, is that we have our creationists and we have our evolutionists, and we think that they are in two different camps altogether. Of course, the creationists now

have come up with the idea of Intelligent Design. I realized in medical school that we train people how to take care of one species – humans – but we teach nothing about the evolution of that species. Actually, most medical students think that evolution results in optimal design, that everything is perfectly designed and optimal, when in fact, what we are right now is a snapshot in the history of this complex process called evolution. “Survival of the fittest” was not coined by Darwin, and “survival of the luckiest” could happen just as well.

Let’s go back to the central dogma [DNA → RNA → protein → cell → organism], and I’ll give you a couple of other reasons why the dogma is inadequate. Obviously, DNA is meaningless unless you express DNA, and the physical environment has an impact. The biological environment – there’s a huge impact of microbes, particularly, on the expression of our DNA. And in some species, we have cultural environments where we can alter each other’s DNA expression. In the case of humans, we’ve expanded this cultural environment to take over all these other environments, so I daresay that humans are a major cause of gene expression on the planet today, in many, many species, including ourselves.

But there’s another reason why this paradigm is incomplete, and that’s a molecular one, which is really my area of research. Besides DNA, RNA, and proteins, there are two other major classes of micromolecules that got left out of the molecular biology revolution. One are lipids – fats – that form membranes, without which you don’t have a cell. The other very major one is called glycans, or sugars. This is not carbohydrate diets and energy, and so on. If you were to approach a cell, it would look like the Amazon Jungle, and everything that was green would be sugars. That entire area of biology just got left out of the molecular biology revolution because it was too hard to study. I stumbled on it coming from a background in hematology and stuck with it, and it now has a name. It is called glyobiology, which is really a variant of molecular biology.

[Referring to slide] Here I’m showing you two cells, and it’s not an exaggeration that I’ve drawn there in terms of the thickness and complexity of these glycans. So really, we have proteins and enzymes, glycans and lipids, glycoproteins and glycolipids, giving rise to cells and matrices, tissues and organs, organisms. Of course, things do signal back to DNA, although

it turns out that a lot of what we thought was “junk DNA” is, in fact, very, very functional. But, of course, don’t forget diet, microbes, parasites, physical environment, and, of course, in an organism like ourselves, cultural environment.

This is an overview of my thinking about the human condition. Our own specific research had to do with a finding that there was a molecular difference between humans and other animals. Basically, there is a molecule that’s on that cell surface that sticks right out, called Neu5Ac – it’s a molecule called sialic acid. We found that the other major variant of this, called Neu5Gc, was missing, specifically in humans, though present in all the apes and other animals. The reason for this is a specific genetic mutation that occurred about three million years ago in one chromosome in one individual somewhere, and is now fixed in the worldwide human population. We actually have evidence now that it was probably fixed a few hundred thousand years after the initial mutation.

Essentially, what we found is that as Ac is the precursor of Gc, so we’re actually mutants, being unable to make this, but like any metabolic precursor, we accumulate this other molecule. So, we have two differences – one is a missing Gc on our cell surface, and the other is that we have an excessive Ac. This has raised a huge number of questions that we have been pursuing over the last decade: how, why, what, when, where, etc. I’m not going to go through any of this except to say that it ranges all the way from studying fossils with Meave Leakey and Svante Paabo to studying the brain with Rusty Gage to studying stem cells, or studying infections or malaria with people at CDC. We’re finding that a lot of this has had some impact on the human condition.

This slide is from a review [“An Anthropocentric View of Primate Gene Evolution”] I wrote recently about known genetic differences that have emerged over the last decade between humans and great apes. This is an anthropocentric view, starting with rodents and coming down to humans. These are genes that have undergone these types of different classes of changes. We initially found one genetic difference in sialic acid biology. The entire field of sialic acid biology involves about 55 genes, and out of all of these, we have now found 14 genes in which there have been significant changes in sialic acid biology. We think that this means this is a signature of some event that

occurred in human evolution that left its scars, so the sialic acid system has been shaken up in humans. That's what we're trying to study now.

So, how do you approach this kind of problem? Unlike most other fields of science, when it comes to humans, or, for that matter, great apes, 99 percent of the experiments you would like to do, you cannot do. You're left with taking a very different approach, for which I realized that my training as a physician was extremely useful – that is, the approach of making a diagnosis. If you went into the emergency room with a coma, the worst possible thing that can happen to you is to have the neurologist arrive immediately. The neurologist will immediately go to your brain and miss the fact that you've got a murmur in your heart or a spot on your toe and what you've really got is bacterial endocarditis, because you've had some infection that came from somewhere else and that's why you happen to be in a coma.



The right way to proceed is to collect every possible piece of information and put it together before you try to make a conclusion.

The point is: How do you proceed? The right way to proceed is to collect every possible piece of information and put it together before you try to make a conclusion. So, my view of approaching the human condition is that. It's fine to follow Sutton's Law and go for the brain, and to those that do it, I think that's wonderful; I commend you for doing that; but I think we may just as well find clues in the skin that lead us to the brain or elsewhere. It's not a surprise that Arthur Conan Doyle was a physician; in fact, many murder mysteries are written by physicians. Physicians are accustomed to being detectives, basically. I think that Richard [Klein] would say that sometimes it is sort of like a detective story that we're trying to figure out. So, this is our detective story for sialic acid biology.

Coming back to this issue of the different sciences, when I got interested in what makes us human, obviously I had to try to learn some anthropology and I tried to educate myself from Anthropology 101 onwards. As I said, my medical school education didn't teach me any of this. I found to my surprise that, as you all know, most of anthropology is classi-

fied under the social sciences. It seemed strange to me until I read the history of anthropology and realized that that's the way the field evolved. So, I would like to suggest that rather than anthropology, which is a broad study of humans in every context, maybe we need to go back to what Haeckel called "anthropogeny." Anthropogeny is the investigation of the origin of humans (explaining humans). It's only a subset of anthropology, but I believe anthropogeny should be sited right in the middle of all the sciences. We need to use all the sciences if we're going to get anywhere because of this problem of not being able to do every experiment we want.

We need to make comparisons between great apes and humans and other animals – obviously everything we can find out coming from a common ancestor ...

Here would be a very ambitious and broad agenda for what we need to do. We need to understand great apes and humans. We need to make comparisons between great apes and humans and other animals – obviously everything we can find out coming from a common ancestor, all of the environmental influences of all levels on both groups of animals and intraspecies interactions: male versus female, adults versus infants, etc. All of these things need to be studied.

When I started thinking this way about ten years ago, I would walk around San Diego talking to friends – who happened to be a linguist or an anthropologist or something or the other. One day, one of the neurobiologists, Rusty Gage, said to me, "How many people are you talking to?" I said, "Oh, about 20 people. And it's too bad: They'll never understand each other. They all speak different languages, and I can't understand half of them." He said, "Why don't you ask them to get together?" I said, "They are not going to do that." Lo and behold, they did! We formed something called The Project for Explaining the Origin of Humans. We have a broad-based view of this and try to take many, many areas into account. We hold meetings and discussion groups. My biggest fear in getting this group together was that these are all very famous people who are well known to have big egos in their own fields. This seemed to me to be a problem, and, in fact, I think this is one of the big problems in human

evolution research. When we study humans, we are studying ourselves. We're talking about ourselves. Much more than in any other science, we have a tendency to hang on to our beliefs because we're talking about "me." So, one very important aspect of human origins research is that we need to cut out the egos.

... a hypothesis I have come up with ... is that the major diseases of a given species are likely to be related to maladaptations during the recent evolutionary past of that species.

The other thing I got involved in is that I realized that here we have the closest evolutionary relative, the chimpanzee, and there's very little information about the chimpanzee. So, in one of the few areas of scientific lobbying I did, I decided to ask for the chimpanzee genome – not just to explain "human-ness," but to explain biomedical differences between humans and chimpanzees, and to improve the care and conservation of great apes, keeping in mind that we need other primate genomes to interpret differences, check differences in multiple individuals, and pay attention to ethical, legal, and social issues.

When it comes to the biomedical issues, I decided I needed to learn about chimpanzees so I spent a month and a half at the Yerkes National Primate Research Center, just learning the chimps. After interacting with the chimpanzees, I sat down with the veterinarian who takes care of chimpanzees, and found that he's using *Harrison's Principles of Internal Medicine*, the same textbook we use for humans, to take care of chimps. We went through chapter by chapter, and it turns out that there are a lot of biomedical differences between humans and great apes – many, many more than you might think. It turns out that the chimpanzee research community downplays those differences because they think that it somehow means that they don't have a good model. In fact, I think those differences are the amazing things. If somebody is interested, I can tell you a list of all these differences. But a hypothesis I have come up with, which may not be novel, is that the major diseases of a given species are likely to be related to maladaptations during the recent evolutionary past of that species. A corollary is: The comparison of disease incidence between humans and our closest evolutionary relatives should be useful.

We managed to convince the powers-that-be to put money into the Chimpanzee Genome Project. We held a symposium last year when the information in the draft sequence came out. It's still coming out. The bottom line is that things are far, far more complicated than we thought. There are many, many differences, many of which may be neutral. We are going to be searching for many needles in a very large haystack.

The other issue related to this is that apes are not mice. Having spent time with apes, I've come to realize they are very special creatures. So, we've argued ethical, legal, and social issues regarding this. We – my colleagues Pascal Gagneux and Jim Moore, who are primatologists, and I – have written an article entitled "Great Apes in Captivity: Ethical and Scientific Challenges in the Post-genomic Era," which will come out in the same issue of *Nature*. [Editor's note: "The Ethics of Research on Great Apes," by Pascal Gagneux, James J. Moore, and Ajit Varki, was published in *Nature*, 437 (September 1, 2005), 27–29.] We are sitting on the proverbial slippery slope where neither end likes us, but I think that is the place to be on issues like this. You have to be on a slippery slope sometimes.

... phenome ... our original definition is: complete information about an organism's phenotype and relevant environmental influences.

The genome, of course, is a diploid set of chromosomes. We know exactly what the genome is. We know how to go about defining it. A few years ago we published an article in *Science* suggesting that while we knew so much about humans, we needed to know more about chimpanzees and great apes, and we suggested the term *phenome*. It's still not in any dictionary but I just checked this morning and there are 113,000 entries in Google for *phenome*. It's now being used in many different ways, but our original definition is: complete information about an organism's phenotype and relevant environmental influences. Here is the problem we face: We have the human genome at a 10X coverage. All that remains to be done is to find the differences between individuals, mostly. And we have a huge amount of knowledge about the human phenome. Over the millennia, we've accumulated so

much information in so many fields of endeavor, so this makes sense. We can look at the genome and the phenome and its influence on the environment, and compare to the genotype and the phenotype.

The chimpanzee genome, by the way, is not complete. It's not polished. It will be polished in the next few years, and it will come up to the same preciseness as humans, although there's more genetic diversity among chimps. When it comes to the chimpanzee phenome, it turns out we know very, very little. So, we have suggested that this is where the big hole is, in terms of interpreting this matrix. One of the things we're trying to do is to create what we would like to call a Museum of Comparative Anthropogeny, where we will take all areas from ecology, complete including culture, to try to identify those things where either people *know* that there are differences between humans and great apes or that there are potential differences between humans and great apes – including the ones where it has been *incorrectly* claimed that there are differences between humans and great apes. This, we hope, will be a resource, although we're just beginning on this and it will be quite a while. The San Diego Supercomputer Center is helping us with this.

The second project is to try to develop materials and databases – just simple things like if you want a piece of chimpanzee skin to find out if there are genes that are expressed that are different from humans. It's not available. If you want a library of genes expressing a given tissue, it's not available, and so on.

[Referring to slide] This is Bernard Wood's version of the emergence of humans from a common ancestor after the common ancestor of the chimpanzee. But as you all know, modern humans are a very recent success story. While it's not clear exactly when things happened back here, the point is that a lot of things happened very recently. Why is this? Again, it seems to me that innovation and imitation are critical features. We have a very small number of innovators, but despite our common phrase "imitating like a monkey," we are the greatest imitators of all. Cycles of innovation/imitation can go a long way. Of course, this is not a novel concept.

[Referring to slide] Here is the diffusion of hybrid seed corn across two Iowa communities. There are 2.5 percent innovators and the laggards who didn't do it even after a long time, but it diffuses pretty fast. There are additional factors: population, communication,

and instruction. As you increase your population, you can obviously greatly increase the availability of the actual number of innovators. Suppose we had two billion chimpanzees. I don't think it's fair to compare the studies we've done on five chimpanzees with four billion humans to see what their potential is. We do know that a chimpanzee doesn't have the capabilities of imitation that humans have, but this innovation factor can be great. Then, of course, you've got communication and instruction or teaching, which amplify this whole thing further.

Finally, I want to conclude with my favorite ... we all read Darwin and Wallace, and so on, and I'm still struck by this and somehow other people don't necessarily feel that there's a problem here, but I think there is one. As you all probably know, Alfred Russel Wallace was the co-discoverer of evolution, but toward the end of his life, he lost favor with science and sort of faded from history. A lot of that was because he wrote this article, "The Limits of Natural Selection as Applied to Man." What Wallace said is: "It will, therefore, probably excite some surprise among my readers to find that I do not consider that all nature can be explained on the principles of which I am so ardent an advocate; and that I am now myself going to state objections, and to place limits, to the power of 'natural selection.'" So, he became a bit of a spiritualist. Essentially he said, "I can explain everything except humans by natural selection. The origin of consciousness that developed into humans – there's something different about this." Again, what he's talking about is this phenomenon: How do you have an exaptation that somewhere back here gives you a brain that is capable eventually of ... I saw my daughter a few years ago sitting in front of a computer typing, talking on the phone, listening to music, and talking to three people on AOL Instant Messaging – all of this at the same time. Granted that times were tough 50,000 years ago, but where did this come from? I'm not suggesting that there's anything more than normal biology, but there may have been some other kind of selective forces.

So, Wallace says, "These can only be met by the discovery of new facts or new laws of a nature very different from any yet known to us." He lost favor because of saying this, but I think he was just being honest, saying: This is unusual. We need to go beyond simple natural selection to explain these phenomena.



The great majority of differences between humans and apes are in favor of apes, apart from our brains, our upper arm coordination, and maybe our striding, bipedal gait.

One thing would be that we seem to have relaxed selection for physical attributes – as Terry [Deacon] says: We're a degenerate ape. The great majority of differences between humans and apes are in favor of apes, apart from our brains, our upper arm coordination, and maybe our striding, bipedal gait. In everything else we are degenerate; we are much worse off than apes. Maynard Olson and I have written articles on the idea that throwing away genes may be a much better way to get sudden change than tweaking existing genes. Maynard likes this analogy: If you had a Lexus and the weather changed and you had to survive, you are not going to survive by tweaking the air conditioning and tinting the windows. You're going to rip the top off, throw away the air conditioner, and get a Jeep. That's how you're going to do it. Maybe something like that happened.

[Referring to slide] Here's a little thing I made up, just off the top of my head. This is definitely part of the story, but when it came in, I don't know: Prolonged Helplessness with Extended Nurturing Occurring with Maternal input during Extended Neotony Of the Nervous System [PHENOMENON]. I think this is one of the features that contribute to our abilities.

I've barely talked about the brain at all, but I would say that we need to take a holistic view of the human condition because that will eventually lead us to the brain and, in the bargain, will help us in many areas of human endeavor. And when it comes to genetic modifications, I would say: Do what you like to yourself, but don't do it to the germline, because you are going to affect other people. Thanks.

VELAMOOR: Thank you, Dr. Varki. Are there any questions from either participants or observers?

OBSERVER: When you had your tree with the humans sticking up like a sore thumb, based on attributes, what would happen to that tree if you filled in from the fossil record all these other hominid species? Does it become a little more uniform?

VARKI: No, not really. Many of those attributes we

have no evidence for, one way or the other, so it would be difficult. But I think you're making an important point that what we need to do is try to fill in as much information as we can on the other fossil hominids. The orangutan is so far away from us in molecular, genetic terms and in terms of speciation, and yet I would argue that classifying the great apes as a group is still a very useful thing to do because they have a lot of similarities.

The other reason human evolution is interesting is not just a case of studying *human* evolution, but how does one get evolutionary novelty out of a relatively conservative clade of creatures? That's my feeling. You can look at it from the physical viewpoint. Obviously, the moment you get into cognitive issues, there is no end to the number of things you can list.

VELAMOOR: Even though it's estimated, as you pointed out, that the difference between the bonobo and the human is about 1 percent or 1.4 percent, do all the differences you have listed add up to being within that 1 percent, even though it appears, when you consider the spectrum, that it is far greater than 1 percent?

VARKI: This whole 1 percent story was a useful thing to focus attention, but now I think we need to get away from it. As I said, mice and rats are our closest cousins, not whales or dolphins or dogs. The percent difference is no longer that interesting to me. It turns out, actually, that the percent difference that has been touted for so long is based on alignable sequences. If you have two pieces of DNA, you couldn't align them, you just had different parts of the genome. Now that we have the whole genome, it turns out that in the alignable regions, it's actually less than 1 percent in protein sequences. Twenty-five percent of our proteins are identical. But if you go to other regions of the genome, there are huge chunks present in a chimp and not in a human, and visa versa. There are all sorts of insertions and deletions, so the actual number is more like 4.5 percent, if you take the total. So, the number of differences is huge. A lot of that is in areas called "junk DNA," but as we've been hearing recently, a lot of that junk DNA is very active. In fact, in our system, two of our genes were taken out by so-called junk DNA landing there and killing them.

VELAMOOR: Given the fact that these are the differences and the magnitude is not great, taking all of the

junk DNA into account, what are the risks of the same argument being co-opted by Intelligent Design?

VARKI: I realize that it's an inadequate position, but I don't stay awake at night worrying about the Intelligent Design people. Sometime – maybe in my lifetime, I hope – they will go away.

VELAMOOR: Not likely any time soon.

VARKI: I have this view that bad ideas reach a crescendo before they collapse and right now we are facing a huge crescendo of fundamentalism in all areas. I think that's the prediction of a collapse. The question is *when* it happens, and hopefully it happens soon. The fact is that we shouldn't go exactly by numbers and percentages; we should go by actual genes.

One of the things the Genome Project has found is that there are so many differences, they don't know where to start. Meanwhile, we had a system of 55 genes and we had found eight that were different. Then we found a few additional differences. It turns out we found most of them just by nosing around in a gene-centric way. So, what should happen is people should pursue their little areas and make inroads into the genome as a resource, and that's how it will happen, I think.



I always find it curious that we're terribly worried about the simplification of the chimpanzee genome when ours is such a vastly smaller variation.

DEACON: You mentioned the very big difference between gene variation within the chimpanzee clade, for example, and the human clade. Unfortunately you didn't show one of the nice tree pictures that give that sense of how incredibly small our variation is genetically compared to a species that has maybe 100,000 or so individuals in Africa. I always find it curious that we're terribly worried about the simplification of the chimpanzee genome when ours is such a vastly smaller variation. I think there are significant consequences for our future because of that. I would be interested in what you think.

VARKI: Pascal Gagneux did his post-doctoral on this and his thesis work was to show that one group of chimpanzees in West Africa had more genetic varia-

tion than all the humans on the planet. That's true – chimpanzees have a much wider variation. So, we are an unusual species and this fits the idea of some very small, common origin of peoples that spread out and, by sexual selection and environment, and so on, selected ourselves into so-called "races." I personally would advocate the complete abandonment of the term *race*, going instead to looking at peoples of different origin, which is a very interesting concept. If you want to talk about our future, I think that *race* is one of the most damaging words that is used.

The fact is it's not a matter of being politically correct. Everybody in this room is genetically more similar than a few chimpanzees in West Africa. That's just how it turned out. Now, having said that, on the other hand, when you take a particular gene and you look, you find many more polymorphisms in humans. You say APO-E, the worst allele to have for Alzheimer's Disease and heart attacks, both of which chimps never seem to have had. Here's the allele in chimps. We have APO-E2 and APO-E3 and various other things. Partly it's population size, but partly we came from a very narrow bottleneck and then subjected ourselves to enormous selection over a very short period of time.

So, I think we're going to see both: on the one hand, overall incredible similarities and yet we're going to see all sorts of little selections that occurred. It makes a huge difference whether you live on the Equator or in the Arctic – it's going to make a difference in how you get selected. There's been rapid evolution over the last 50,000 years but, because of the rate at which humans migrate and copulate with each other, a lot of that has been partially rehomogenized, which creates a big mess if you're trying to figure out what's going on.

CALVIN: Regarding the Intelligent Design problems, and, for that matter, creationism, these are beginners' mistakes. I think beginners' mistakes are always going to be with us because most of the population – even if they had the time that we have to study the issue, some of them will do that, but the people who are only ten years old or they stopped reading in this area at age 20, or whatnot, are going to wind up with much simpler analogies to work from.



... the way I would speak to Intelligent Design people is to say, "Boy, you call this 'intelligent design'? What a mess!"

VARKI: The point I was trying to make is that most biologists are unwittingly falling into that trap. We like to think that the systems that we study ... the system I study is wonderful! It's amazing in its precision and balance because it was honed by many years of evolution. But that somehow translates into biologists thinking everything is perfectly honed, and that gets co-opted by the Intelligent Design people. Instead, the way I would speak to Intelligent Design people is to say, "Boy, you call this 'intelligent design'? What a mess!"

CALVIN: The other thing I wanted to say was that in terms of a lot of selection going on in the period of, say, the Mind's Big Bang 50,000 years ago or in that vicinity, in this period there's an enormous amount of the climate flipping around. When you go from a warm and wet climate to a cool and dry, dusty, windy climate, and then pop in five years back up to the other, what this means is an enormous amount of drought, an enormous amount of shrinkage of populations down into confined areas where there are not enough resources to make the trip to another population. So, you wind up with a lot of inbreeding, a lot of loss of alleles – and all different in each of the different groups. Even when they come back together, you've still got a lot of loss.

VARKI: There's no question that there's huge variation.

CALVIN: Particularly with the spread out of Africa at this time, you have a perfect setup for squeezing the populations down, reexpanding them, and when you squeeze them down, you lose a lot.

... my point is that the way that humans were classified was a social construct ... the convenience of using these old classifications is detrimental to society and our future.

VARKI: My point is not that there's incredible diversity in the human species; my point is that the way that humans were classified was a social construct. I

think if you want to reclassify humans according to our current knowledge, I have no problem with comparing groups. The biggest problem I have is with the concept of *white*. I have no idea what *white* is. You could have a man from North India who comes to the United States and changes his name and has fair-enough skin and he suddenly becomes a *white*, whereas some blonde-haired, blue-eyed Scandinavian gets called a *white*. I think that if we got rid of that, to begin with, that would help a great deal.

Now, if you want to say, "My ancestry is primarily of Scandinavian origin or West African origin," that's very useful information, extremely useful biologically. I just think that the convenience of using these old classifications is detrimental to society and our future.

TOOBY: I was just wondering if you would talk a little bit about having identified the eight genes that might have glycobiological differences. I know that all the consequences would come to a huge list, but do you have, from what you have studied, a functional interpretation of any of them? What would have been the selective force that would have driven it?

VARKI: Yes. One thing for sure: We have changed our susceptibility to certain infectious diseases because these are the targets for things like malaria and various livestock diseases, and so on. That is pretty clear.

The second thing that's pretty clear is that we are missing a molecule from our bodies that we are eating in our food. It turns out that it's getting into our bodies, incorporating into ourselves, and we're making antibodies against it. And it's also in stem cells, which is why our recent work on stem cells got all this attention because these animal molecules are getting into stem cells and antibodies are reacting.

From the point of view of the brain, it's all indirect right now. We have one molecule that has turned on in the human brain and it is not in ape brain, but we don't know what it does, so we're in the early days in that. The other is the particular molecule that is present throughout the body of the chimp and missing in humans. There's only one place where it's hard to find – it's the brain. If you go back all the way to whales, you find the same thing. There's some reason why you don't want this molecule in the brain; we find tiny amounts in every brain we look at except humans. So, our fantasy is that we finally "got rid" of it. We've been trying for three years to make a mouse that overex-

presses this molecule in the brain to see what's so bad about having this molecule in the brain. We've been unable to get a mouse so far, which is interesting, but unfortunately I don't have any definite statements to make.

This has impact on biotechnology, on many other things: food, various diseases of humans, and so on. But it's still in the early days.

TOOBY: So, one of them might be because bigger brain evolution, greater brain functioning in humans requires a lower level for that one?

VARKI: The timing is right. The mutation occurred and got fixed about two and a half million years ago, presumably by some infectious agent. It would have actually resulted in an immune system that is hyper-reactive, which we think is still not settled down. A by-product of that could have been some selection for some brain process. But we have a mouse now that has the same defect as humans, the exact same defect, and it's certainly not walking around talking. It has a few funny changes – actually surprising things like balance – not things that we would have thought. The problem is that you're talking about something that happened a long time ago, and we're seeing the outcome right now. I think it's too early for us to say much more than that.

HOLLOWAY: I'm interested in the possibility that the loss of the gene or the molecule that you were talking about might have to do with rationality. I find whales quite rational. I find even chimpanzees to be rational, and moose and caribou and all the rest. But I do wonder about humans.

VARKI: You're wondering if we became irrational by losing this thing. That's an interesting idea.

HOLLOWAY: In your talk, you mentioned Francis Crick and widgets. Do you really subscribe to the idea that there are no biological laws?

VARKI: When I say *laws*, I mean universal laws. In physics, there are universal laws; in chemistry, there are universal laws that, at least in this universe, are not going to change.

HOLLOWAY: With regard to the relationship between brain and body, there seems to be a very, very lawful constraint in which the exponent comes out to be .75, suggesting a relationship to metabolism.

VARKI: But I'm sure it won't be very difficult to find exceptions to the rule, like humans. Take a law in chemistry: An oxygen atom, unless it's in very, very unusual circumstances, is going to behave like an oxygen atom, and you can hang your hat on that certainty. That's my point. Maybe I should change that to say that what Francis is really saying is that there are no *universal* laws in biology. There are little laws you can make when a certain bunch of widgets get together and do a certain thing, then you get a law of those widgets, which works for that zone, but won't work in another biological circumstance.

VELAMMOOR: Thank you, Dr. Varki, and thank you all very much. I think it was an extraordinary set of eight papers.

Critical Question Theme

Emerging Knowledge of the Brain and Its Long-term Implications for Humanity

Following the individual presentations on Day 1, participants returned the following day to focus their attention on group discussions of critical themes related to the evolution of the human brain. Rather than adhere to a set list of questions, the scholars chose to engage in an open-ended discussion on emerging knowledge.



What might be the most important issues to discuss further, going forward, specifically related to the human brain and the future?

VELAMOOR: This morning is intended for the group to have a conversation on the question: What might be the most important issues to discuss further, going forward, specifically related to the human brain and the future? I want to make sure that we stay with those aspects: the future and the human brain.

Take a moment, each of you, and think about what two issues should be put on the table in a conversation, and we'll see if there is a consensus that emerges.



... attempts at genetic modification and the dangers of doing so.

VARKI: For my top two, the first would be, basically following up on Steve's talk from yesterday, this whole idea of attempts at genetic modification and the dangers of doing so.

The second for me would be something we didn't discuss a lot but which I think is really critical, which is the major changes that are being made in how babies and infants are being managed. It's a major change from our evolutionary background. How do we handle that and understand the consequences of that, negative or positive, for the future of the human

brain? It's that postnatal input ... when you make a major change in something that's been working in a particular way, how do we handle that in the face of wanting very much to continue the so-called women's liberation movement and have equality of women in all spheres? There are a lot of unknowns there that are very important.



... the use of addictive electronic devices in the particularly sensitive period of childhood.

CALVIN: I phrase that as soft-wiring in childhood, encompassing both the instinctive stuff and the way it has changed, as in Terry's example yesterday. Also, the game machine – that would be the modern manifestations of it – the use of addictive electronic devices in the particularly sensitive period of childhood. It is the sort of thing that we could use to train for handling more things at a time or doing them quicker, the preschool versions of those that people will surely try out and that will surely have some lifelong effects, in some cases.

VELAMOOR: Should we call that “risks of electronic babysitting”?

CALVIN: Electronic baby *training*.



... flexibility with respect to adaptation to alternative social and technological environments.

DEACON: Those are probably the top two, but I will add another one. It could be phrased: How flexible are we? How flexible is our species? It's really an evolutionary psychology question. Are there some things

we can't do? Some places we can't push? Some ways of organizing human societies we cannot do because of predispositions that we have inherited and are not modifiable? So, this is flexibility with respect to adaptation to alternative social and technological environments.

In other words, the top one is the dangers and risks of actually moving ourselves, which we've already done to an extensive degree, into a very atypical rearing environment. We are also, of course, because of this, in a very atypical adult environment, and the consequences of that are significant. So, the first one is about pushing us. The second one, which I'm suggesting, is that there may be a push too far that we simply can't do. There are certain societies that will not form simply because of the way we are. I think that's a possibility.

CALVIN: There will be side effects.

DEACON: Right. What I want to say is that it would be nice to be able to identify that ahead of time, not that we will. The first one is possibly a "what could happen" issue. The second one is a constraints issue: What are our constraints and biases?

CALVIN: You can use modern society as a brief example. People these days are living in a society where 90 percent of the people they meet every day they'll never see again. It's completely different.



What would be the impact on our species of having a social science that was based on the circuit logic in the brain, as opposed to the present social sciences ...

TOOBY: Before we get to quite such ambitious topics, let me try some other still-too-ambitious topics. The first thing is: What's the functional circuit logic mechanism in the human brain? The second thing is: What's the developmental genetic instantiation of that, which would give us insights into questions like flexibility, and so on. Then the third thing would be: What would be the impact on our species of having a social science that was based on the circuit logic in the brain, as opposed to the present social sciences, which are in contradiction to what the brain is going to be like and, therefore, hopelessly weak?



... the brain, human nature, and its relationship to political realities ... what is missing here is any overview of what is happening in the world ...

HOLLOWAY: What I would suggest is probably involved in all of these. What I would suggest is something like the brain, human nature, and its relationship to political realities, because what is missing here is any overview of what is happening in the world, not just what's happening in foundations and academic circles. The fact that we're growing to about 9 billion people in a very few decades is a reality that I think has to be put in context when we're talking about the brain and human nature – whether we can change it or can't change it – and that fits in exactly with Terry's issue about how flexible we are as a species. I would like to say something about political realities.

CALVIN: I would modify that slightly to say that it's not only how flexible we are as individuals, but as a society, what we permit individuals to have. We're getting a lot of reaction at the moment to evolution in various parts of the country, to concepts of the newly fertilized ovum having a soul, for example.

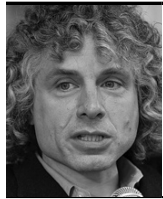
There is a batch of societal concerns about things that in the future will buy us academic concerns. It's not just a matter of what the brain is capable of. It's a question of how political reality will guide it.

DEACON: I would like to expand our first issue also. Genetic intervention is, of course, not the only kind of intervention, and, certainly we are going to see in the very near future lots of attempts to come up with prostheses of various kinds. We're seeing it now only with respect to sensory and motor processes, but that clearly is not the end of the issue, and the question then becomes: What are the consequences of expanding our ability to directly access computational resources and that sort of thing?

Now, in a sense, the boundaries of what we call human nature are going to be different. The more we directly connect in with this – and I think this is also true of the social connections we're talking about – it really changes the boundary of what we are. That's a significant issue because I don't think we know how to think those processes through. I don't think we

know what the consequences are going to be.

CALVIN: For example, suppose you do have training machines for the sensitive period in childhood. And suppose that those are largely developed by groups – religious groups come to mind – that will have a very distinctive agenda of “give them to me when they’re young and I’ve got them for life.” All the things that we can imagine to do to enhance intellect can also, presumably, work to do other things like that.



*What makes us what we are? ...
find out when in life and from what
sources in life we turn into what we are
– that is a significant question.*

PINKER: I’m interested in all of these topics. I have a couple comments on some of them.

I tend not to think that the first issue is going to be a big problem, just because of the practical limitations. I don’t think we’re going to face the ethical dilemma of human germline engineering. I am also very skeptical of implanted chips or interfaces in the brain, simply because of the physiological problems such as a brain that pulses with every heartbeat and floats around in the skull, our lack of knowing the neural code, the crudeness of any interface.... Since we have, already, such a rich interface through our eyes and voice and hands, I think that the cost/benefit ratio is always going to go towards a better Palm Pilot rather than an implantable chip.

There may be an issue with drugs that enhance memory, intelligence, attention, and so on. I tend to think that those are minor ethical problems, and they’ll be worked out as people find a balance of costs and benefits.

Regarding the second issue, I’m also skeptical that this is going to be a big problem because I think the developmental program is buffered against a lot of variation other than extreme neglect and abuse. It certainly is a significant question – what socializes people? what gives them the certain set of values and skills of their culture? – but I think that, as a result of over-interpreting some of the findings of plasticity in neuroscience, we’ve thought way too much about the first few years of childhood, whereas what we really ought to look at is adolescence, which is when a per-

son adopts his adult identity. It’s when they get a lot of their values, and when peer-to-peer influences are likely to be much more significant than parent-to-child. But, again, it’s an empirical question.

As a sign of how important it is, the fact that we’ve looked only at one possible solution – probably the wrong solution – suggests that this *is* something that we need more research in. In particular, the fact that an enormous amount of variation in intelligence and personality is not predictable by either genes or families (up to half the variation) means that there’s an enormous set of causal processes that we have no understanding of. I suspect it is some kind of small or random events in either brain development or early lifelong experience, for that matter. A broader version of Question 2 is: What makes us what we are? And not prejudging it by saying that it’s neo- or postnatal, but to find out when in life and from what sources in life we turn into what we are – that is a significant question.

I think Question 3 is interesting but I think we should remember that the kind of people around this table are probably not the best ones to address it, but rather social historians. There is a lot of interesting data from experimental societies that were set up in the late 19th and middle of the 20th century. The Kibbutz; the socialist societies of the Soviet Union, China, Cambodia; the various utopian rural communities in the United States; the Oneida community; and so on. There are very interesting social histories on how these attempts at reforming human nature ran up against human nature, which provides a lot of insight to Question 3.

Question 4: John’s point about whether the kind of science that many of us think ought to be done will be unacceptable for political and emotional reasons, I think, is a very significant issue. Bill mentioned creationism. Many of us around the table in the corridors and over dinner have talked about postmodernism within academia as a significant barrier to biological anthropology. The fact that both the right and the left, large segments of them, would rather see this not happen is something we have to deal with, which is why I wrote *The Blank Slate*.

I would like to add another issue that is perhaps a sub-issue of Question 3: How flexible are we? Another way of looking at it is: We know that there has to be some degree of flexibility because there are cross-cul-

tural differences and historical change. Ironically, the people who have pushed the malleability of culture have very few explanations as to where these differences come from and what causes them.

To give one example that I think many people ought to study and very few people are studying, there's an enormous secular trend over the past couple of millennia away from violence in the following senses. I should say force in general. Slavery used to be the norm and now it's rarer and rarer – not, of course, that it's eradicated but it's gone from the Western democracies. That wasn't true 150 years ago. Torture as a sanctioned form of criminal punishment; bodily mutilation as a sanctioned form of criminal punishment – cutting off an ear or a finger; corporal punishment as a sanctioned form of criminal punishment – we don't put people in stocks or hang them from chains legitimately. The fact that there was such outrage over Abu Ghraib proves this point. The lynchings and ethnic riots: A hundred years ago, if a black man was accused of a crime in a town, that would have been an excuse to go out and burn the homes of all the black people. That doesn't happen any more. Wars, even in the last 50 years: There used to be the generalization that no two countries with a McDonald's ever go to war. It turns out that there is an exception now, since the Americans bombed Sarajevo, because there is a McDonald's in Sarajevo. But, still, if France and Germany have a dispute, they wouldn't invade each other, and that is something we take for granted now but which couldn't have been taken for granted 100 years ago. Human sacrifice, corporal punishment of children – there's a long list of cases that, as awful as these times are, by a lot of measures they're much better than they were 100 years ago, 500 years ago, 2,000 years ago.



Human nature, in the sense of the biological given of emotions and self-deception, hasn't changed, but something has changed. Can we bottle it and get more of it?

So, what happened? Human nature, in the sense of the biological given of emotions and self-deception, hasn't changed, but something has changed. Can we bottle it and get more of it? What are the candidates? I talked briefly about Peter Singer's notion of an

expanding circle. Somehow you take a capacity that we all have, in some degree of empathy, and you try to expand its range of application. How does that happen? One hypothesis from Robert Wright is that it's through trade. When you have expanding networks of trade owing to advances in technology, you just make it easier to ship goods or services over greater distances. More and more of the world becomes more valuable alive than dead and you're in a positive sum rather than a zero-sum situation.

Another hypothesis is that it's other technologies of empathy: history, realistic fiction, journalism, enough knowledge of what it's like to be someone else that it's harder to dehumanize them because you are tempted to think, *there but for fortune go I*. Maybe Hobbes was right, and it's having a Leviathan, that as we have better police forces, better criminal justice systems, people not only have less temptation to commit aggression but they have less temptation to commit preemptive aggression, worrying about the other guy getting to them before they get to him.

So, these are a few hypotheses. I know of very little work, other than Bob Wright's nonzero, that systematically identifies this trend and tries to isolate its causes. Likewise for other secular trends I mentioned yesterday, such as the Flynn Effect.

VELAMMOOR: Could we state the issue as: Can we think in terms of the limits to the expandability of our identities?

Do we know the antecedents, the causes, that would make one culture a culture of vendetta and another one less so?

PINKER: We don't know what the limits are. I would rather put it as: Do we know what the causes are of long-term historical changes? That is, how can there be long-term secular changes given a constant brain, presumably, or constant genome, assuming that we haven't seen any genetic changes in the last 100–500–2,000 years? It's a version of Terry's Question 3, but more on the positive than the negative. It's not: When will we bump into a wall? But rather: What's been the motor that's pushed us around so far? It can be asked cross-culturally as well as within a culture.

Another example, partly relevant to this, is instead of looking diachronically, to look cross-sectionally. A work of Dick Nesbitt and Dov Cohen on cultures of honor.... We know that different cultures have more or less of a sense of honorable displays of force and retaliation, and displays of bravado and toughness. Not all cultures are the same, even though I assume that it's a feature of human nature that you find in all cultures, but some ramp it up more than others. Do we know the antecedents, the causes, that would make one culture a culture of vendetta and another one less so? They claim to have identified several factors. But hypotheses as to where that flexibility comes from and what drives it are surprisingly missing from our social sciences, probably because, as John points out, unless you have a theory of human nature that includes what the parameters of variation are that it allows, what inputs it's sensitive to, ironically you can't do the social science. You have to have a good understanding of the innate structure, which is going to have lots of inputs, lots of ways of responding facultatively to changes in the environments. If you simply assume that cultures vary arbitrarily without limit, just by the throw of the dice, then one change is as likely as another change and you'll have no insight as to what causes particular changes and, therefore, no lever in which to nudge it in that direction more in the future.



... all of the violence and force committed by almost all societies can be accounted for by the Y chromosome.

VARKI: What we're really talking about is the use of violence and force. What we've not mentioned at all – in fact, all of the discussants here are male – is that all of the violence and force committed by almost all societies can be accounted for by the Y chromosome. You can almost say that civilization is the process of taming the human male. How can we bottle that and proceed in that direction? I think we need to acknowledge that.

I remember about ten years ago there was a lot of discussion in *Science* with Letters to the Editor about the genetic basis for aggression. Finally, there was a short letter from a woman scientist that said, "I don't

know what all this discussion is about. More than 95 percent of all the violence on the planet is due to one piece of DNA – the Y chromosome. Why don't we first do something about that?"

PINKER: This, by the way, maps onto Question 4. If the President of Harvard mentioned that, his head would get cut off. You would get violence from the other side.

VARKI: Yes. We've reached a difficult situation where the people who try to bring up the issue on either side get pilloried by the Left or the Right. I think these issues need to be brought out into the open. Essentially the process you're describing is a gradual process going from 50 percent of all deaths being male-on-male violence to being less than .1 percent. In a sense, that's the picture that has occurred. And that's what we call civilization. Everything else that comes along in civilization is possible because of that. If you just remove that one plug, then you lose most of what we call civilization.

PINKER: Although a lot of the changes occurred within what we call *civilization*. It's within civilization that you have disemboweling as a form of punishment and slavery.

VARKI: Yes. I am using *civilization* as a positive term, not as a general phenomenon.



... there's a great mystery in brain science as to how knowledge is converted into behavior ... people know exactly what to do and they do not do it.

TULVING: I am agreeable to everything you people say. At the same time, I also told you that I frequently tend to be out of sync with the rest of humanity and the rest of society on occasions like this. I know it's not going to make you very happy. It's going to be upsetting, but I feel that I have to say what's on my mind.

My question is: What are you people doing here? Exactly what is it that's going on? What kind of exercise is this? I've been sitting through all kinds of scientific meetings and faculty meetings; it reminds me of a faculty meeting – people get up and start making wise statements about everything. First of all, the topic was supposed to be "Future of the Human Brain." I look at that list of issues we have developed, and I ask: Exactly

where is the brain there? Are you going to engineer a change of the future human brain?

Why does brain matter? Why does brain play a role in it? Answer: Brain is behind behavior. You can change your brains as much as you wish, but unless it somehow expresses itself in what the people who own the brains do with the new brains – genetically modified or artificially filled with knowledge – then when it comes to behavior there's also knowledge. There's a relation between knowledge and behavior. Are we talking about changing behavior? Are we talking about changing knowledge?

Right now, as it happens, there's a great mystery in brain science as to how knowledge is converted into behavior. There are instances after instances where people know exactly what to do and they do not do it. That, to me, is a kind of mystery that requires attention.

The point here, in general, is that we have so many really hard, unsolved, fundamental problems having to do with the brain, behavior, mind, and then the third level – my specialty, my love object – consciousness, which is separate from behavior and cognition. Very few people want to acknowledge it. I don't mind. I hope that a hundred years from now they will have come to that conclusion.

The problem is what we could call individual differences, variety, Darwinian diversity, the one fact about nature that drives all of evolution ... What are you going to do about individual differences in your plans for the future of the brain?

My point here is that I will be quiet during your discussions. I'll let you change your world. But there's only one thing that I want you to keep in mind – and this is my contribution to that list there. You have overlooked one of the most basic facts about humanity and biology in general, and I wish that in your discussions you would at least think about it. The problem is what we could call individual differences, variety, Darwinian diversity, the one fact about nature that drives all of evolution, everything. One of the most important problems – you don't have to have a Ph.D. in anything to realize it – is that there's a tremendous variety of individuals in every imaginable way, right here in this room, and this is a highly selected, small segment of society. Just go outside: in northern Wash-

ington State, then in Washington, then in the United States, then go to the rest of the world. What are you going to do about individual differences in your plans for the future of the brain?

I'm sorry to sound so negative, but that's the way I am. I like people who really try to identify problems that exist and then say: Okay, is there anything we can do about that problem? If so, how do we go about it? This kind of dreaming about.... I hope I'm not offending anyone. I don't want to offend anyone. I'm simply speaking my mind. This is the way with academics, too; this is very normal behavior, as I said. You get together; you take an academic interest in something; then you generate ideas; then you argue about them. These grand visions about changing the world: What is human nature – as if there is one thing called *human nature*? What is our future? What is our brain? Who is this generality? This is, by the way, the mistake that you find most frequently made in our daily media: generalization. Americans think that way. The Muslims think that way. The Palestinians are all like that. Men are like this; women are like that. Used car sales men – you know what they are like. Mothers-in-laws – they're all the same. That's good for general conversation but when you actually tackle the problem, it's silly. You don't think that way.



... a lot of what's going on in brain sciences today involves telling people something they don't want to hear – that the brain is physical, that we evolved.

DEACON: This has to do with, not exactly the moral, but the spiritual side of what's going on here. Over the years, I've been invited to many conferences in which religious people, sometimes fundamentalists – for example, in South Africa at the Parliament of World Religions – spoke about the brain and evolution and what the consequences are. Many people don't want to know. I think that a lot of what's going on in brain sciences today involves telling people something they don't want to hear – that the brain is physical, that we evolved. All of those things are dangerous knowledge. They're knowledge that is not wanted, in some sense.

One conference I went to was "A Knowledge Worth Having in the Decade of the Brain." There were many in the audience who said that this is *not* knowledge

worth having, and their arguments sounded very much like the responses to the Copernican revolution or the Darwinian revolution. That is, we're in the process of pulling ourselves out of the center of the universe and the more we understand issues of consciousness, for example, the more we can say: Look, I am struggling to understand, and I think I have a story to tell. If, for example, 50 years or 100 years or however many years from now we have a relatively complete picture of what the brain is doing that contributes to what we call *consciousness*, that will have an effect far more drastic than the Copernican revolution. It will demystify something that many people don't want to demystify.

The question is: How do we communicate this in a way that does not limit the spirit, that does not limit the humor of the joke, that gives a spiritual piece to this story?

The analogy I would suggest is that of telling a person why a joke is funny. Most people don't want to know that. To tell the story ruins the experience. I think that we're not sensitive to that, and part of the reason I say this is I think that's part of the political issue, part of fundamentalist issue. One of the reasons that we're having this rise in fundamentalism is because of what science has done – what we have done in terms of trying to know these things. The question is: How do we communicate this in a way that does not limit the spirit, that does not limit the humor of the joke, that gives a spiritual piece to this story? We've not done so. There's nothing about what we've talked about and what most of my neuroscience colleagues talk about that has spirit in it.

TULVING: I just want to totally, utterly agree with Terry's statement that the major problem that faces people like us here today is the large number of people who think differently from us and do not want to know. Therefore, suppose that you can convert another one percent of Americans, let's say, to the view that perhaps evolution is not just a theory, it's a scientific fact and that our behavior is governed by the evolved brain in every single way and thought and idea and feeling and twitch. If we could get this going, wouldn't this be a better world at the end of the thousand years? There

is none of this argument going on about people not wanting to know, wanting to deny facts. That's a current problem but it also continues forever.



The whole idea of differences between people became eradicated, instead of looking at it as one of the greatest things the human species has: brain variability.

HOLLOWAY: Maybe it's time for an anecdote. I had the good fortune to go to Australia and spend some weeks there with Clive Harper who is a neuropathologist. We were working on, among other things, differences between males and females in terms of the corpus callosum and the effects of alcohol, which is a very serious problem in Australia. But years before, around 1985 or 1982, I hooked up with Clive Harper and met a fellow by the name of Jorge Klebamp. Klebamp and his friend at the time, Agnes Reidel, and Harper decided to take a very close look at Australian Aborigine brains. They collected a large number of them. They sectioned them; they did the histological work on them; they had a very large sample of German brains; and they made a comparison. What they found was that yes, indeed, the Australian Aboriginal brain is somewhat smaller overall than the German brain, but so is stature and those differences could really be explained very well by environmental things such as diet, and so forth.

But when they came back to area 17 of Brodmann, which I talked about a little bit yesterday, they found that the primary visual striate cortex in the Australian Aboriginal brains was roughly on the order of twice the volume of what they found in Germans. They tried very hard to find a dietary explanation for it: They were from the Outback or they didn't eat right or the mother milk wasn't good, and so forth. They had to really get rid of almost all of those hypotheses. Then they started looking at the scores on perceptual abilities and found that the Australian Aborigines were outscoring Caucasians – vastly more – because they were just much better at finding complex relationships in the environment. That material was published a long time ago.

Well, it took close to eight years of submitting these findings for publication. Nobody, of course, wanted to publish this kind of finding because, after all, that's

the sort of stuff that was demolished by Gould in *The Mismeasure of Man* [W.W. Norton, 1981] – wasn't it? The whole idea of differences between people became eradicated, instead of looking at it as one of the greatest things the human species has: brain variability. Well, the anecdote is this: The Australian Aborigines caught wind of this research and said, in essence, "Thank God we're not Caucasian!"



Whether we're going to have designer kids or not depends on whether there's going to be anything around to design.

KLEIN: It seems to me that if I were worried about the future, I would worry about whether there's going to be a human brain, primarily because there's a problem with climate change, which is humanly induced, and the possibility of viral diseases, which we have no antibiotics to deal with, or bacterial diseases. It seems to me that what you want to do is educate the collective human brain – society – to begin thinking about these questions, not a thousand years from now. There probably isn't ten years to do it. That might be the biggest issue of all. Whether we're going to have designer kids or not depends on whether there's going to be anything around to design. I think that's a really massive issue.

This bird flu that's out there mostly in Southeast Asia and which looks like it will eventually jump, if it hasn't already jumped, to people could have the same kind of effects. When was that flu epidemic – about 1919 – that killed 40 million people? Could be more than that. Nobody seems to be worried about the overuse of antibiotics. On a governmental or administrative level, nobody seems to be very much worried about what's going to happen when the back bay of Boston is under water or much of Lower Manhattan. It's going to happen and it's going to happen pretty quickly. That, to me, is what is imminent. The other stuff we can worry about after we solve that. It's really hard to get people collectively to deal with an issue like that.



I don't think we can get a rational collectivity until we have some understanding of exactly how social interactions are driven by the circuit logic in the brain.

TOOBY: To respond to what you said first, the assumption is: Can we get the collective to think rationally? We assume, as academics, that *we* think rationally and, therefore, our perceptions of the world's problems and the world's solutions – it's a problem of persuading those less rational than we are. I think there's some truth to that or I wouldn't be an academic. But there are social processes that occur when you put all these different psychological architectures together and certain things become markers of superiority of an in-group: *I perceive this moral problem; other people don't perceive that moral problem; therefore, they're inferior to me.* Therefore, certain types of attention go to certain kinds of problems much more than other kinds of problems. What I'm trying to say is that I don't think we can get a rational collectivity until we have some understanding of exactly how social interactions are driven by the circuit logic in the brain.

For example, witch hunts are fortunately remote in time so we can say, "Ah, that's irrational." But we don't really see the same things that pass through academic environments in the same kinds of ways, even though very similar underlying logics are driving those kinds of things. So, I see the connection to understanding the brain as very much relevant and connected to getting our collective brain to think rationally.

There's been this dialogue between universality and individual differences that has been going on for a long time. They're not in opposition, although the normal thing is to say that to look at individual differences is immoral because that raises the possibility of sex differences and race differences, and only demented people do that. So, there's a huge collective distortion in rational information processing on these questions.

On the other hand, I think that there is something extremely important that emerges out of the primary science about species typicality – that there is robust species typicality in the functional architecture because you can't get functional pieces to fit

together unless you have standardized parts. We have sexual recombination and if everybody had different functional pieces then the next generation wouldn't fit together. So, human species typicality is something objective and real, like the Toyota Camry standardized design, and looking at individual differences and how individual differences fit in the context of universality is a very interesting scientific question. Often, the very same phenomenon looks as if it's an individual difference when you look at it with one metric, and then you find an underlying principle, and you find principles variation, which means that there's a universal-principles relationship, which explains the variation, too.

Scientifically I very much sympathize with the feeling of oppression that people who objectively try to look at individual differences feel. On the other hand, I wouldn't want to go too far and say that universality is a platonic illusion and that it's not something real and hard and principled and important. If the functionality is going to turn out to be much more species-typical, then medically important individual differences will emerge as deviations from that.

Third, in thinking about the future and the brain, it's "God is in the details" so that it's a little bit hard to think systematically about the future.

A different way of expressing an important intellectual project is to say: What are the major unsolved questions about the brain? Everything about how the future emerges out of our understanding of the brain will come out of what the answers to those questions are. There's a sort of tacit premise – though I don't want to oversell this – that in some sense we're already on the right boat; we're already headed in the right direction; the major questions about the brain are sort of in principle understood. I don't think that's true at all. You pick on consciousness. I, myself, am much less worried about consciousness than other smarter people are, so I'm stuck in my materialist delusion.

... nobody knows (though there are many theories) what the connection is between material organization and knowledge.

Another very specific kind of major, fundamental, unsolved question is that you can walk through cognitive neuroscience and people don't really admit that nobody knows (though there are many theories) what the connection is between material organization and knowledge. Can we say: "Here is a set of cells; here are inputs to the cells. What's in the structure of this input? That's how information is carried. Here's the computation going on because of these cellular interactions. Here's the output." The most basic fundamental question about brains people don't have any idea about. That's a fundamental question that we don't understand and finding the answer to that would be unimaginably major. I think we wouldn't know what the implications of that would be. Finding the basic scientific answers to fundamental questions like DNA would have all these unforeseen consequences. There's nobody attacking, using technology, to really try to answer these fundamental questions and I find it surprising and a little bit disturbing.

VELAMOR: What we're coming up against in listing all these things is maybe a division in a binary sense as to what the nature of the issues is. One is to treat the brain like the black box and let's consider the inputs and outputs and see what the relationships are, as opposed to what I gather John to be saying, and perhaps somewhat resident in the comments by Ralph and Endel, too: No, let's understand the black box first and then everything else will fit.

DEACON: None of us, as far as I can perceive, would want to ignore what's in the black box. Crucially, opening the black box and doing the best we can is, of course, the important first move. That's going to happen. John's point is quite right. We don't have a general theory of brain function. We have a bunch of very cheap theories, mostly from the 19th century, and we're applying them with all of these new tools and I don't think we really still understand how to put it together. I don't think we can actually, unfortunately, make predictions on what we're going to find. When we find it, to know what to

do next – that will come up then. I don't think we can foresee that. That's a real problem we're in. Obviously, we have to continue the science.

VELAMOOR: Considering that we're focusing on a thousand-year horizon, they don't have to happen in an either/or, first/second sequence. They could happen simultaneously, which is, presumably, what is happening anyway.



You could argue that getting rid of violence is taking away something that is part of our evolutionary heritage ...

VARKI: I'm in favor of looking in the black box but also dealing with the situation as a black box, at the moment, because it's probably going to take a thousand years before we really know. We don't know how the lobster ganglion that controls whether the tentacle goes this way or that way, how it makes its output, and we're talking about things orders and orders of magnitude more complicated. So, I think it's going to be a long time before we get enough information about the black box in order to make rational decisions.

Meanwhile we are experimenting with the very evolutionary processes that brought us this black box, on a social level and in many different ways. You could argue that getting rid of violence is taking away something that is part of our evolutionary heritage, so we're experimenting there; we're experimenting with children; we're doing all these things. I think you have to proceed on both fronts, because one is a somewhat empiric approach to how things are and what you think might be the right answer, and hopefully it will be right when you find out the black box.

I want to briefly comment on the issue of differences. I think this is extremely important. In fact, the definition of life is that you have to have variety; otherwise there is nothing to select. I think this is a very important research agenda – I agree with Endel and Ralph – but I would say that when people say that they have trouble with this kind of research, that they keep getting flak, the reasons are obvious to me, right in what Ralph said. He started out by saying that comparing German brains – brains taken from a particular part of Europe – with brains from Australian

Aborigines – a reasonably defined group – and found differences. That's very interesting. I would want to know what that is. Then as he progressed to speak, he switched from *German* to *Caucasian*. I think that's what the problem is; that's what is causing this unnecessary backlash against this very important research. If you can get away from these old terms that have baggage hanging on them, which create unnecessary reactions from people, and stick with the scientific fact. You could say: I have these brains from Germany. They come from this particular group of people and I've identified that all these brains are from people who have three generations of ancestry locally here. I define my Aborigines not according to whether they happen to be in Australia and they're dark-skinned but according to what I know about their ancestry. Then I think people would be much more receptive.

All these terms are preventing a very important research agenda. Although I agree that you can keep changing names, I think the way to do it is not to throw away terms because people are used to them, but put them in scare quotes. So, when you talk about *race* in your lecture, you know you're using *race* in its old colloquial meaning and you know that there's no such thing, as a genetic term, but the people sitting in the audience think you're espousing it. It's very simple – just put it in scare quotes. Whenever you use these terms that are not scientific, but you still need to use them because of the historical significance, put them in quotes.

PINKER: This is, basically, calling for euphemisms, which I think ultimately will be ineffective. In fact, they won't even be effective on the short term. We already have changed from *black* to *African-American* and I don't think it's made any difference. I think, actually, that there is an impending crisis that all of the clashes between human genetics, behavioral genetics, evolutionary psychology, and so on, are going to reappear in a way that might make the whole Larry Summers thing look like a tea party by comparison. When the medical geneticists who are interested in differences in the genome that correlate with geographic ancestry – we can call it that instead of *race* but people will still know that that correlates pretty well with *race* – come up with characterizations based on clusters of genes instead of a single gene. It's true that skin color is a pretty minor part of the complex

but if you do a correlation matrix among all of the different human gene variations, there are going to be clusters, and the clusters are going to correlate with ancestry, and the clusters are also going to correlate more or less with traditional racial terms, at least on continent-wide scales.

Let's say that there are genes that are associated with variations in psychological functioning: intellect, personality, motivation, and so on. There are going to be statistical clusters that reflect our relative reproductive isolation on continent-wide scales until Columbus and they may find that some genes that are associated with personality and intellect are also associated with these clusters that were shaped by ancestry. There's no guarantee that that won't happen. It's quite possible that it will. Then there's going to be the bell curve wars, the Arthur Jensen wars all over again, and I think one of the challenges that people with a biological approach to mind behavior are going to come up against is how to deal with the ensuing outrage.

Just to give you an example, just three days ago there was a huge op-ed in *The New York Times* by a developmental biologist by the name of Armand Leroi, saying that contrary to the generalization that race doesn't exist – it's just a social construct; there's no such thing as race – there's going to be a statistical genetics that is going to reconstruct something probably pretty close to continent-wide races as a real biological entity. Again, I think they're very trivial compared to the universals, and I think scientifically there's not going to be a whole lot of interest compared to the universals because it's going to be such a minor part of the variation and it is so statistical. But people will find out about it when it happens and we have to be equipped to deal with the ensuing ruckus.

CALVIN: There are overgeneralizations that the public will engage in and there are beginners' errors that they will fall into and never get out of. One of the reasons we're never going to get a rational society is because most people will never get up to speed. They will stop at some point with a metaphor that was convenient. Robert Frost had this wonderful saying about metaphors. He said, "You don't know how far you can ride it and when it will break down." That's the position that even we, as scientists, tend to be in, but it's certainly the position of what the public's going

to be in, and it's simply a consequence that we don't live forever; we always have new children growing up instead. There will always be a substantial population that is not going to be able to get their heads around the issues we have to spend 20 or 30 years getting *our* heads around to understand it.



I have got to have some clear understanding of how brains vary ... to have some better understanding of what the evolutionary forces have been in the past ...

HOLLOWAY: I agree with John that the vast amount of variability is probably shared, as far as we can go with the phenotypic aspects of the brain. What troubles me about it is that it has a possibility of leading to a perception that the loss of this gene pool over here and the loss of this gene pool over there really isn't that terribly important to the human species, in a way, because, after all, we have all this tremendous shared genome that we can all count on. But as somebody who has studied evolution for 40-some years, I would not think of writing a paper or studying a phenomenon without having some understanding of the underlying variability to it. This is just part and parcel of what we do in anthropology. If a skull is found, I've got to go and study a whole mess of skulls and find out where this thing fits. Can I explain it with regard to the variability that I see in here, or is it outside that range?

I think the same applies to my understanding of how the brain evolved. I have got to have some clear understanding of how brains vary. It doesn't matter whether it's chimpanzee, whether it's gorilla or orangutan, whether it's *Australopithecus africanus*, or whether it's modern *Homo sapiens*, I've got to have that knowledge to have some better understanding of what the evolutionary forces have been in the past – and then to understand what the future of it might be. So, I'm intensely interested in Richard's point [Will there be a future to worry about the brain?], because what I see are political things happening and environmental things happening in which, for example, you might lose a good, significant proportion of the population of southern Sudan – the Darfur thing, as an example. These are very unrosy pictures that are taking place and I'm very concerned, really, to maintain as much variability as we possibly can. I'm thinking

that we have this tendency to get too academic about all these issues and don't really place it in the context of the political reality that is out there. I would like to hear a little more addressed to Richard's point.



I think this knowledge is the most dangerous knowledge we've had in our hands ... What's the significance for the ethical, moral, and political issues that are around this?

DEACON: The issues I see dividing here are not whether we should know what's in the box or what's out of it. It seems to me, clearly, that everyone wants to know both. The division seems, to me, to be about what's most important to know, as No. 1: how brains work, how they function; and what the consequences are of fiddling with them. No. 2 is: How do we deal with the ramifications – political, ethical, moral, communicative?

This knowledge is going to mean something. This knowledge is going to change things. Whether it's about individual differences, whether it's about population differences, this knowledge is not neutral. The bottom line is that this is knowledge about what it means to be *me*; therefore, this knowledge will not be neutral. If we don't pay attention to the fact that the knowledge is not neutral, that it is really hot, that when somebody brings up issues about Aborigines versus Germans, for example, this is not neutral information. We in the sciences can want to treat it as neutral information, but this is not neutral information. We need to be savvy about that and, in fact, as we do this research it will bring up all kinds of political hassles. I think religious problems will grow because of this. I don't think that we are going to see an end to this for a long time. I think this knowledge is the most dangerous knowledge we've had in our hands for all of these reasons. And so I think we need to think about that piece of it: What's the significance for the ethical, moral, and political issues that are around this?

VARKI: I think Terry has the two major issues absolutely correct: What do we need to know, how do we find out, and how do we deal with the consequences? But there's a piece in between. It's going to take a long, long, long time before we have this dangerous information, even though we may think otherwise. What are we going to do in the meanwhile? In the mean-

while we have to proceed on a somewhat empiric basis, based on our best guess, literally, of how we came to be what we are, how our brains work. We have to use all the information we have because it may be too late by the time we find out how things really work.

CALVIN: It seems to me that things like the genetic possibilities, the wired-brain kind of enthusiasms that science fiction writers come up with, and the early childhood softwiring possibilities are all things that we can talk about effectively for informing others about where our concerns lie.

I think that the political problems here are going to be very serious. No one would really have thought that public opinion would or could matter very much to the physicists investigating gravity. You just wouldn't think that the public's conception of it was going to bias the way the research went. Clearly, that's the sort of thing that *can* happen with the brain, because the things we're talking about implicates how children are brought up, and that arouses great emotions on the part of parents who think there's a right way. In many cases, they will not want to know. Things will happen in terms of the public getting its impression of the scientific enterprise coming from the people who make Gameboys™ or something like this. When we discover in another ten years what the effects are on the kids brought up on all that intensive training – the upsides and the downsides – the scientific enterprise will, in some sense, get painted by the public's reaction to those things. A lot of it is going to be out of our control.

We will probably discover a number of attempts like what we're seeing with the problems with teaching evolution and such now. There will be substantial enterprises, like trying to keep evolution out of the movies. Certainly, if you read *The New York Times* yesterday, it's already happening with the IMAX films.

OBSERVER: Could I ask the panel to think about one thing? Unlike going to space, which you can do with a thousand Ph.D.s and a few astronauts, this seems to be a different kind of enterprise. What fraction of the human population would you want involved in this enterprise? First, the genetic heritage of humanity is everybody, and the other thing is social. We're discussing what happens to the United States as opposed to other parts of the world, but actually that social backlash is going to come from everywhere at once.

TOOBY: Looking at all the cell surface proteins and all the possible interactions in a cell population of hundreds of billions, that's not all going to be mapped out for 150 years or 300 years. The increase in computation and simulation might actually get us somewhere some day. On the other hand, making very discrete, forward progress on concrete functional mapping is actually not all that hard, provided somebody actually does it. There's a lot of important neuroscience that I'm not including in this, but I'm talking about mapping widgets, and mapping widgets has concrete benefits very rapidly. It took us one graduate student and three years to find a way to turn off people's racial awareness. People think race is important and being able to turn that off is significant. Once we have circuit logic, we can look for the physical correlates of that, and I think some of these other things will start to get untied. I think real material progress could happen fairly rapidly.

CALVIN: What we're dealing with here is the long-term view of future brain evolution.

VELAMOOR: That is correct. Not for the next decade, not for the next 20 years, but over the long horizon.

OBSERVER: My work is in organizational behavior and education. I'm especially interested in pursuing the black box, but also what can be done immediately. I was intrigued with the line of question that Steven was taking us down about let's look at the reasons for secular progress that have happened over time and explore what is behind those and see if we might be able to accelerate those.

Second, Terry [Deacon] said that No. 8 [Will there be a future to worry about the brain?] is not a brain issue. I think it might be a brain issue if we think of it as a collective brain issue. One of the things that you have said is that human nature is not just in the brain but it's also out there. It seems that, as we connect more and more using the Internet, it's even more out there. I would be interested in comments from you folks on the idea of collective human nature or collective brain in this process and maybe touching on what Ajit [Varki] was talking about with the innovators and the imitators. It seems that part of our connectivity is quicker imitation.

Even knowing how the brain works, even knowing what we might call circuits of human nature ... we may still not be able to figure out how that works collectively.

DEACON: One issue that is a part of this but is very hard to put our fingers on at this time because of its complexity is what I think generally goes under the term *emergent properties*. Even knowing how the brain works, even knowing what we might call "circuits of human nature" or whatever, we may still not be able to figure out how that works collectively. We may still not have good models for how, when you put a bunch of these critters together that have these biases, what actually comes out is a collective process. That is a particularly difficult problem.

I think it is a problem of human nature because we are an ultrasocial species. Part of the problem of human nature is what you might call *collective human nature*. I think it's a very different phenomenon and we don't understand it well. It is clearly something that social science will help us with but I think not enough. We need to have some general principles also about how these collectives self-organize, and we have a long ways to go in that.

Part of my reason for talking about the offloading in evolution of processes into the world is something I think is critical about what we are. Our nature is a nature that has a lot of offloaded components to it, and, for that reason, we need to know that kind of emergent logic, as well as knowing what's inside the thing. This idea of inside and outside the black box, which I, myself, threw out, is a misnomer, in part, because I don't think the box has very nice insides.

VELAMOOR: Is there a likelihood that individual differences, in terms of decision-making or choices affecting the future, will be moderated by "the collective nature"? I would assume that if you look at history there is such a possibility, where, in fact, the collective can moderate and can, in fact, even out individual differences. Would someone care to comment on that?

DEACON: What I think is interesting about this is that often times collective processes amplify some differences and bury others. Often times it's very hard to

understand how that occurs. Now, curiously and not surprisingly, these same kinds of problems come up when we talk about how brains function collectively or how embryos develop collectively. We have some similar principles to look at that, which we can even draw out of this, but one of the things that I think is likely is that for the most part we're talking about general features that will eclipse, amplify, hide individual differences in ways in which our view that "my difference makes a difference" may be quite trivial. And the kinds of individual differences that we're talking about might be trivial, but perhaps some general algorithmic-like feature, when you put a group of people together, takes over and swamps out those differences.

VELAMOOR: It goes back to what Steven was raising as an issue: force and violence. I would imagine that the moderation of violence, whether it's on an individual level or at the collective level, has moderated individual differences and individual propensity here.



... how does cognition adapted to deal with rocks and plants get metaphorically extended to deal with molecules and quarks?

PINKER: I think there are a lot of issues about how individual psychology, when aggregated into a collection of people exchanging information and promises and threats and bargains, results in collective behavior, most of which we're completely ignorant of. Despite the fact that we have this social science tradition that appeals to culture and social change, and so on, a lot of it we really don't understand, such as the secular change in violence that I alluded to.

Another example of how individual talents and even individual differences can get subsumed into some collective, more or less mind-like entity is the scientific enterprise itself, where I think you can ask the question: How does a brain shaped for certain ways of building tools, negotiating social contracts, outsmarting plants and animals, come to understand the material basis of life, the origin of the universe? Part of it, I think, is purely psychological. That is, how does cognition adapted to deal with rocks and plants get metaphorically extended to deal with molecules and quarks?

Part of it is: How do human motives that otherwise get in the way of the rational pursuit of the truth get subsumed by a collective value of truth for its own sake? The scientific enterprise is as much about social mechanisms that prevent self-deception, and how ego and belief in the service of social identification may be submerged for this greater goal of figuring out the way the world works ... things like peer review, things like the ethos where even a graduate student can ask a challenging question of a Nobel Prize winner. If someone disagrees with you, you don't sue them, you don't challenge them to a duel, but you hash it out. You would lose points if you were to file a lawsuit against someone who challenges your idea or if you threaten, "Why don't we settle this outside?" So, that whole set of social norms that submerges a part of individual human nature, that tends to protect reputation, that tends to engage in self-deception, that tends to adopt beliefs as a form of social solidarity, I think, is well worth understanding as much as development of statistics and this so-called experimental method.

Another example is that most social changes really have no good explanation from within social sciences. Let's take as a simple example fads and trends in naming children, especially for female names. You can pretty much date the decade that someone was born in, depending on whether her name is Mildred or Betty or Linda or Susan or Jennifer or Ashley or Tiffany or Morgan or Meredith. All hypotheses that try to explain what causes these decade-to-decade changes fail. It's not that people are named after soap opera characters. It's not that biblical names become more popular at ages of revival of religion. It's some process that begins in individual psychology. A lot of people individually think that they are unique in naming their child Abigail, that it just sounds right. They don't know anyone else named Abigail. Then they go to the daycare center and all the other little girls are named Abigail.

What is it in the collective environment, obviously very subtle, implicit, unstated, but that can cause many uncoordinated minds to move in the same direction at the same time?

What is it in the collective environment, obviously very subtle, implicit, unstated, but that can cause many

uncoordinated minds to move in the same direction at the same time? It's a real mystery and I think an enormous amount of social change works like that. It's not a response to advertising. There's no company that profits if you name your child Morgan. It's not a question of any kind of role models. It's clear that some mechanism must be at work; it's a kind of explanation that clearly involves some self-organization, some sort of high-level patterning as the result of many low-level decisions that influence each other in weak ways.

Why did the NBA go from short, tight basketball shorts to long, baggy basketball shorts? Why did the first teenager decide to turn his baseball cap around backwards? These are trivial examples of something that, obviously, must happen at a more consequential scale. Things like, "Do I challenge someone to a duel if he chats up my girlfriend at a party?" – in different cultures, the response is going to be very different and these changes and differences might come about through this process of contagion or some sort of synchronicity-like process. If we understood it better, we might have a better handle on why societies change and whether there is any chink in this process in which we can insert a little bit of influence or whether that would be desirable at all.

VARKI: Changing the subject to interventions that improve the brain, I would like to point out something that is usually avoided in all these discussions and that is the very simple fact – it's been shown over and over again – that prolonged breastfeeding results in an improved IQ and a healthier child and a better outcome. There are hardly any exceptions to that. Meanwhile, society has appropriately decided that women are no longer to be – for want of a better word – "baby-making machines" and that women need to find an equal place in society. In the process of doing that, what has been done is to have good nutrition in childhood, resulting in early menarche in childhood: delay your first child as long as possible, minimize breastfeeding because it's a nuisance and gets in the way of your career. I have just described the prescription for ovarian and breast cancer, of which we have an epidemic going on right now.

Meanwhile, any male who brings this up will be immediately challenged as being a male chauvinist pig, so I want to bring it up not from that point of view but to point out that we need to realize that we're

re-engineering what our evolutionary background is and make appropriate adjustments.

There's a letter in this week's issue of *Science* that I co-authored. I had a graduate student in my lab have a baby. I had a post-doc have babies – twins, actually. And, of course, I watched what my wife went through when she tried to be an academic with a child, so we talked about this and somebody had just written an article in *Science* saying, "We need to adjust the tenure clock so that women can have..." It turns out, in fact, that that works negatively because if you give a woman an extra year, the men in the group think that there's some kind of special favor. We didn't use the term, but we should have – we should have said, "It's childcare, stupid."

In other words, what a young mother needs is to have immediate access to her baby while doing work and be able to breastfeed. This is a good prescription, but we don't do it for liability reasons and for cost reasons. We proposed a solution in this letter. I just want to point out that this is an example of social engineering that needs to be done in a positive manner, which would have a huge impact on the future of the brain because breastfeeding is a very specific biological fact. And along with that comes a lot of other things that I can't imagine aren't beneficial to the growing mind.

VELAMOOR: I would like to ask Endel about the conversation about individual differences and the collective brain, and we can expand that to individual consciousness and the collective consciousness or unconsciousness. Would you care to comment on that, Endel?



... the way society is organized is not synchronized with biological reality. It tries to deny what is absolutely true in nature in too many ways ...

TULVING: By *individual*, I did not really mean individual differences in the old psychometric sense of taking a bunch of people or population and giving them all kinds of tests, like Francis Galton, who started the tradition, as some of you know. I simply meant that there are probably kinds of variance in humanity that no amount of tinkering with will ever change, for reasons that Steve [Pinker] was alluding to. It's just

too complex for anyone to try to make sense of, and these conflict with our present social systems. This is a major problem I have with society as it is organized now, and unfortunately I cannot take any credit for this great insight because zillions of other people have said it before.

It is a fact that the way society is organized is not synchronized with biological reality. It tries to deny what is absolutely true in nature in too many ways for people who try to look at it objectively, perhaps. Take the two terms *pro-life* and *pro-choice*. Can you imagine that a thousand years from now you will have converted all of the individuals to one of these two positions? Of course not. Take religion: Some people are religious; some are not. Are you going to talk them out of it and others into it? No, because apparently, for reasons that I, as a psychologist, will only observe – I am in no position to really even speculate – this is a built-in system. Some people, let's say, “need” religion; others do not. These are individual differences. When we talk about “us human beings,” we have to remember that there are basic differences, fundamental differences.

The Foundation really doesn't want anyone to make predictions about the future. How can you talk about future without making predictions, because you know nothing else about it? And you have to remember one interesting psychological fact. Psychologists have studied it but it's well known to common sense, the wisdom of the hindsight, the 20/20 vision – it comes to the same thing about explaining and understanding behavior *after* something has happened. Through the history of the world or a nation or a group or an individual, it makes perfect sense. All the pundits know exactly why it happened. I'm so amused. Every day I look at the paper and see what has happened to the Dow Jones index and sometime it goes up 100 points and sometimes it goes down 8 points and sometimes it goes up 12 and comes down. They always have an explanation for it. The same way for the American dollar against yen and Euros – there's always an explanation. They know exactly what happened. And that creates an illusion that behavior is relatively easy to understand and to explain because we do it all the time.

I must say, not as a scientist but simply as a human being who's been around for a long time, I'm very skeptical about this ability.

VELAMOOR: I'm still waiting to hear you talk about the relationship, if any, between the idea of a collective brain and an individual brain.



There's no such entity as a collective brain.

TULVING: I don't think there is any collective brain. I think this is a “jack of spades” kind of entity. You can always define it; you can always point to it; but it does not exist. Individual brains behave totally differently in a different context. Pecking order changes; people become heroes; and others become followers. We know about dynamics of the masses. It's very easy to describe, but to say that this is a collective brain is like talking about collective memory, which is another one of these very popular literary terms. Media people love it. Scientifically it is nothing because you can't really do anything with it.

I don't know how to study collective brain independently of individual brains in different contexts: alone, in duos, in large collections. The dynamics change, of course. There's no such entity as a collective brain.

VELAMOOR: Is there an absence of evidence? Or evidence of absence?

TULVING: How can I prove that there is no collective brain? I cannot. The onus is on you to prove that there is one. When you do that, then we can always come up with alternative explanations and then we can argue about why your explanation is better than my explanation. You say, “My explanation is better because I believe in it, and I don't believe in yours,” and that's how it ends up in science a lot of the time.



... the fact that you don't have an operational scientific method to investigate something doesn't mean that it doesn't exist in a metaphorical sense ...

CALVIN: Obviously, “collective brain” is a metaphor and the fact that you don't have an operational scientific method to investigate something doesn't mean

that it doesn't exist in a metaphorical sense that may turn out to be scientifically approachable. It's just like saying that there's a knowledge of history that's available, if you look far enough for it, that will help inform your decisions. Clearly people respond differently when they're in committee settings, than they do when they're sitting down to write, than they do in a public forum. It's a different mindset.



Still, humans evolved in groups, unlike many other species, and so our brains are designed to interface with others in certain systematic fashions.

TOOBY: Taking the point about the metaphor, there's nothing unreal about people existing in groups and interacting in groups. They're real phenomena that can be studied like any other phenomena. If you look at individual brains, the fact is that the parts are in physical contact with each other, but the physical contact is an arbitrary feature. It dovetails with our intuitive physics of solid objects and, therefore, we think that solid, cohesive, bounded things are somehow real and other kinds of systematic stable relationships in the world are not.

The bigger difference between collectivities and individuals is in the stability of the relationship of the parts and the dynamics. Still, humans evolved in groups, unlike many other species, and so our brains are designed to interface with others in certain systematic fashions. Therefore, I think there is potentially a genuine social science that emerges out of our understanding of these evolved interfaces.

You were saying that in mass psychology the dynamics are well understood, but then you were saying that collective brains don't exist. I think there's the possibility of understanding mass psychology. Certain superficial features are obvious, and I think that eventually we will understand it.

Exactly the sort of collectivity and what kinds of systematic biases – I'm not sure I'm entirely fond of the word *bias* because it underplays the reality of the selectivity of what happens in human, social, network brains. But in any case, there's a real science there. As soon as you get rid of the blank-slate hypothesis, you can then make progress towards a real social science. Your intuitions about mass psychology can be turned

into genuine science, at some point.

TULVING: Now the discussion has turned in a direction I would classify as having to do with concepts. That's a different level of analysis and science altogether. We are now talking about what exists and what does not exist. In many other sciences, these things that exist and we study are taken for granted. When it comes to life science, and particularly psychological behavioral mind sciences (brain/mind sciences), this is a real problem because we use terms that were adopted from rather primitive societies, trying to press them into service to describe things that never, ever occurred to the hunter-gatherer.

This is a very important part of any science – the conceptual pieces – and it's totally, utterly neglected in all kinds of psychology: cognitive psychology or developmental psychology or neural psychology or your evolutionary psychology. What is what? Before you can start studying anything, you have to know what it is you want to study. Scientists have two kinds of ideas. Some say: How can I tell you what I want to study before I study it? Let me study it first, then I'll tell you what it is.

The other view is that you have to have some idea what you're studying. I'm studying memory. What is memory? I started studying it as a graduate student. I don't ask that question. That's for old fogies to worry about. I know exactly what I'm doing, and don't come and confuse me about these questions of what it is. I just do my job. I do the experimenting; I analyze the data; I write it up and then chew my fingers waiting for the acceptance or rejection letter. That's what I'm doing.

Then I reach the present age and I say, "We do not know. As a matter of fact we don't know what it is." It is a very important problem and if we knew it better, if we could get people – all those individually variable people in my little neck of the woods – to agree on what it is we're studying, we would be making faster progress. But we do not because everybody has his or her own idea what it is. Now, people who work with genes don't have that problem.

DEACON: There is one important thing that we have not touched on. When a bunch of folks get around to talk about brains and minds and evolution, all you hear about brains is thoughts and knowledge or tendencies or behaviors. A word that has never come up that I want to bring up is *art* or *literature*.

We have, over the course of the evolution of cultures, developed remarkable tools for educating the emotions, educating empathy. I think of literature as a part of that process, of helping us figure out what it's like to be in another mind, in another world, in another time, in another circumstance. I think those are incredibly important pieces of the story. I don't think that all ethical education comes from religion or from some sort of humanistic explanation of why we should do things. Most of it, in fact, comes from the stories we tell or hear or exchange, or the movies we watch, for that matter.

A very important part of the future of the mind or brain – however you want to look at it, and whether it is collective or individual doesn't matter in this story – is that we have to spend considerable effort at understanding how we do this. We have developed incredible tools for this, but we really just use them at random. Now, maybe that's the right way; it's the evolutionary way, to some extent. Those that stick around, stick around, but maybe not always for the right reasons.

It does seem to me that one of the things that we need to think about – even those of us who are not artists and literary folk – is the role of that. It's a very big part of our society, a very big part of our world, as big as religion in some ways. Yet even in the educational system, there is a pretense that it doesn't exist or that it plays a trivial, fun role – just to “entertain.” I actually don't think that arts and literature and music and plays are about entertainment. I think in the real world they're about educating the emotions and empathy. I think it's an important part of the future.

KLEIN: What I hear makes great sense to me. I think that if there were people sitting in the room whose backgrounds were in academic economics or political science, they would say that the issues that face humanity have nothing to do with the brain, really. It's interesting to learn a lot more about the brain, but you're being overly reductionist. We have to understand precisely how people operate in groups – that's the only thing that really matters. You want to solve a problem like global warming or the possibility of antibiotic resistance in lots of bacteria – that kind of stuff.

VELAMOOR: Would everyone agree that an understanding of how groups function or behave is a priority?



The neuroscience world ... has sold the country a bill of goods in saying, for example, that we're going to reform education by a better understanding of neurons.

PINKER: Yes. With a lot of social scientists, I would be skeptical as to how much information about, say, the neurophysiology of the brain is going to lead to insight into social problems. I think the right level of analysis is one of a higher level of function of entire circuits characterized in functional terms – basically the cognitive or psychological level rather than the neurophysiological level. The neuroscience world – as much as I'm part of it, and as much as I'm a booster of it – has sold the country a bill of goods in saying, for example, that we're going to reform education by a better understanding of neurons. There's been a lot of mischief that came out of that in the 1990s.

Where I would disagree with these social scientists and historians who would certainly say that is, by their own standards, on their own turf, there are enormous explanatory gaps such as some of the ones I alluded to before: Why have we gotten less violent? Why do we name our daughters Madison and Morgan? There are no answers coming from the social sciences. I don't think there will be answers coming, necessarily, from mechanisms of synaptic transmission either, but I think there will be an intermediate level of psychological functioning of cognition that, in combination with a better understanding of social network dynamics, might someday lead to answers to the questions that the social scientists themselves have posed for themselves but which they can't answer because they/we are still ignorant of so much of human psychology.

*Does fiction have a causal role in change of attitudes?
Does it educate the emotions?
We don't know the answer to that.*

To go back to an example that I mentioned and that Terry [Deacon] also brought up: Does fiction have a causal role in change of attitudes? Does it educate the emotions? We don't know the answer to that. I would

like to know. On the one hand, you have anecdotes such as: Apparently when Abraham Lincoln met Harriet Beecher Stowe, he said, “Oh, so you’re the little lady that started this big war,” because of the alleged influence of *Uncle Tom’s Cabin* on changing sensibility toward slavery.

On the other hand, we know that some of the Nazi leaders were great fans of literature and came from a culture that revered great literature. To what extent does fiction in TV and movies and video games and novels lead to a change in sensibility, and why? On the one hand, there obviously is a process of extreme empathy that goes on. That’s what makes fiction gripping. On the other hand, in order not to become deluded and not to blend what you learn about fiction with what you learn about reality, when it’s inappropriate, there’s got to be some mechanism in the brain that sequesters this hypothetical world from your knowledge of the real world. Now, both of those can’t be completely true because they are alternatives. If we understood something more about the interaction, maybe we would understand when something is just a story and is not taken seriously, as opposed to something that is capable of changing individual and then, perhaps, collective sensibilities. That’s one of many examples of how social change could get a lot of insight from studies of individual psychology.

VELAMOOR: A few years ago, television series on two great epics were produced and telecast at a certain time of the day in India. When these serials were on, the entire country came to a standstill and people were watching these programs. I don’t know what it did, insofar as any behavior modification, because I don’t see corruption levels or crime or anything else declining in India, but it certainly captured the attention and the imagination of these hundreds of millions of people for that one hour every day.

OBSERVER: There’s another story from India. When the first woman policeperson in India took over one of the largest and worst prisons in India, which was, apparently, a horrible place to be, and introduced Vipassana meditation to the inmates – not all of them; it was voluntary – it completely transformed that place. So, again, there is something very powerful there that is very difficult to understand, but there’s anecdotal evidence that says that interesting things are happening.

OBSERVER: I’m an educator in the Bellevue School District and I teach highly capable students who are in the fifth grade. Many function at post-high school level, and some go to the university after eighth grade. They’re sort of off the charts statistically.

The question I have, in relation to the development of the brain and the role of education, is: Is there a point at which individuals may crash and burn because of their development, whether it’s enhanced through education or however? For instance, I had a student who went to the university and graduated at the age of 18 *magna cum laude* in biochemistry. He committed suicide. I have been talking to his mother; every month we meet and talk about many of the other students who are in this program who are at the edge. They are the brightest minds and very highly developed.

And this is common: There are many suicide attempts among this group of kids. Something that she and I have talked about is this power of the human story. For instance, this boy had all of this scientific awareness, but he joined a religious cult right before he committed suicide. There was obviously something that he was looking for beyond the science and the systematic logic and the number crunching. I’m really concerned: Is there something else that we’re missing here related to education?



We’ve become so used to the notion that our human uniqueness means that we cannot be captured in a science ...

TOOBY: I want to follow up on what Richard and Steve said and then maybe address a little of that.

It’s certainly the case that if you have anthropologists and economists and many other social scientists in the room, they would absolutely say what you said: The brain is irrelevant. That’s been the default model for a hundred years. They believe it’s a famous fallacy – the compositional fallacy in Durkheim’s sociological method – that you cannot go from the individual to the group level. The group level is autonomous in some fundamental way that makes its interactions and its dynamics independent of the properties of individuals. That’s led to a very weak social science, so that there are all these anxieties and resentments

against the “real scientists” who have big machines with bright lights and lots of money and they can make predictions that come true.

At the physiological level, there’s not going to be all that much insight, although there might be some interesting technologies, like jetpacks, that will make our brains really super-efficient – one can’t rule out that kind of very important medical or augmentation possibility.

Science was started in the Renaissance and there was this Enlightenment notion that maybe we could have a science of humans. Before the rise of the standard social science model was the American Revolution, when Madison and the others said, “We want a government that maybe would work based on human nature.” There are several extremely significant claims about human nature in *The Federalist Papers* that were based on extensive reading of history, of what went wrong and how freedom was lost in these other opportunities, and they came up with the system of checks and balances. I have an engineer mentality, so I don’t think it’s necessarily a perfect system, but it’s been stable for a much longer period than any other democracy.

You can look at Hitler and Lenin: You couldn’t have known with a science – well-grounded, theoretically principled, comes from first principles, empirically validated set of models about computational structures in the human mind – that giving unbridled power to some small groups of people will lead to completely disastrous consequences. Yet that’s not something that’s even contemplated in the present nature of the social sciences – that you can say there are all these mechanisms in your mind that form coalitions, which have these computational variables that identify self-interests, which sort out people who are going to move in the same direction as you, that then develops myths or stories about the out-group and the righteousness of the in-group, and the importance of empowering the in-group.

We’ve become so used to the notion that our human uniqueness means that we cannot be captured in a science that we’ve given up the idea that there is a natural science of human nature that could exist and that would have real, important, functional dividends in forming a constitution in Iraq or a constitution in South Africa, and so on – that different structures will lead, over time, to different kinds of outputs like the

EU constitution, to take one realm of applicability.

I think that in 50 years or 30 years we could have a real, genuine human science. Economics is moving slowly in that direction, precisely to the extent that they have given up the “blank slate” notion that anything could be learned and that anything could happen. They have some very minimal, reductive claims about agency and self-interest, and so on. And they get a lot of traction that gives them a lot of empirical bite for that. To the extent that people are stepping away from “blank slate” notions to specific claims – and the more you make the claims computational rather than impulses or dispositions, what inputs go in, what representations get created, what motivational intensity magnitudes get generated – all those things can give you a really precise kind of model of human dynamics – not that it’s going to be like physics anytime soon, but it will be a fundamental transformation of the human condition to have a genuine natural science of humans.

Right now the people who are professionally entrusted with the social sciences don’t believe in its possibility. Not only do they not believe that it’s a possibility, they resent the very implication that something like that could exist, so there’s a huge resistance. That’s a problem but I think it’s a solvable problem. I think the world, over the next 40 or 50 years, will look very different, in the same way that every other fundamental scientific advance has had all these spinoffs.



... the recent tsunami phenomenon ... provides, in a sense, an absolute laboratory for ethnic responses to tragedy and disaster ...

HOLLOWAY: The young lady here was talking about the educational aspects and the sad case of suicide and what seems to be a dangerous, growing trend of suicide. I think it would be well to remember that the maturation of the nervous system seems to be viewed by everybody as complete by age 18 or 20. This thing is continuing on with myelination, cell death, and everything else right up into age 27 to 28.

I’m witnessing this with my own child who is now 23, who’s beginning to understand that I, too, have a brain. But it’s going to take another four years before he understands that I know he has a brain, too. That’s

just one aspect of it. There is the possibility that different populations differ somewhat to minor degrees in the speed at which those processes are completed. It might be interesting to think along those terms without getting too reductionist about it.

One of the other fragments of thought I had was the recent tsunami phenomenon, because this provides, in a sense, an absolute laboratory for ethnic responses to tragedy and disaster that seem to me, from what I read in the popular press, are really extremely different responses. There are two aspects to it: Now we are trying to get a worldwide tsunami system that can predict or give us warning. When you think about the fact that there have been tsunamis and earthquakes and all the rest of it and there has not been this ability already in place – I find it mind-boggling that it is now at 2005 and politicians are still arguing as to how to set this thing up.

Then there are what we read about the differences between the Tamils in Sri Lanka and their responses to the distribution of aid, and how the political processes could impede the easing of terrible conditions among millions and millions of people. You have the same thing in Sumatra. Then we read about the Thais and their ability to sacrifice to provide help for those in their country. I imagine that there are all sorts of different explanations for it, but it seems to me that we could look at this as a natural laboratory showing how the mind elucidates some aspects about human differences and human similarities.



What are the consequences insofar as our inherent natures and our capacities? ... Are we coming up against the limits of our flexibility relative to the pace?

VELAMOOR: It seems to me that what Paula described is a case of a child in fast-forward. The child may have been 18, but perhaps in a mental sense he has lived a lifetime. Maybe a proposition that we could entertain is that we, even though we have gone past age 18 in a civilizational sense, are also in a fast-forward mode.

What are the consequences insofar as our inherent natures and our capacities? Can we say that we are in a fast-forward mode, hastening the process to what the future holds? Are we coming up against the limits of our flexibility relative to the pace?

PINKER: It's exactly the kind of question that we should be asking and we could probably even be a little more specific: It may not be just how fast is the speedometer, but rather qualitatively what are the different challenges we as a species are designed to face at different points in our lives? It's sort of life-history biology. The most obvious thing from the point of view of evolutionary biologists is that when you reach biological adulthood in a social species, you've got to find a mate; you've got to establish status in the particular pecking order of your peer group; you've got to establish some claim to adult status. If you put children in an environment in which they're going to be miserable failures at all of those three life challenges at a stage when they are younger, more naïve, and in many ways ill-equipped for the social competition that is the most important thing that a human being does at that stage of life, then it can be a recipe for disaster.

It comes from thinking of kids just as little academic achievement machines and forgetting about the rest of human nature. It's not a subtle point. This is just one of the first things one would say about human life history, that that's the major challenge that emotionally we're equipped to face, the failure of which will have the most devastating consequences on our emotional well-being. That would obviously have to be elaborated to get more predictive power as to who succeeds and who fails when accelerated in this way. But I think that's an ingredient above and beyond the mere acceleration that a good science of human nature could help contribute to key questions like this.

VARKI: As I said in my talk, I think that until we know where we came from, we're not going to be able to know where we're going. Personally, I think that Alfred Wallace's paradox is still unsolved. The one possible explanation is, essentially, what you are saying. We used to think that the human brain was developing for three or four years. Now we're saying 25 years, 27 years, and we don't know when that long period of potential feedback and mental response occurred. I've read all the stories of feral children, and although they're all contaminated, you get the feeling that there's a lot of input needed.

As a *Gedankenexperiment* – this is one that I've posed to Terry [Deacon] and others in the past – let's go back in time and take a newborn baby, born from a perfectly healthy mother, and bring that baby here

today in an environment where its facial appearance and anything else will not be an issue. Actually, you may have to do it with 100,000 babies to look at the variations. I think everybody would agree that from 50,000 years ago we wouldn't notice any difference. That is, 100,000 babies from 50,000 years ago put into the right environment today would function no differently from any one of us.

[Some participants comment out of microphone range]



The second Gedankenexperiment is to take 100,000 newborn babies today and put them on a desert island and have them taken care of by robots ...

VARKI: Okay, there's a little bit of uncertainty there. Now let's go back a little further in time. I know that Terry would say that *Homo erectus* would be okay. It wouldn't be identical but it would be okay. Does anyone want to go further back in time than *Homo erectus*? The real question is: When did this feedback loop of prolonged helplessness, brain development, imitation, and innovation start and really take off? To me, this is a fundamental question. It is not easy to answer but I think it goes to the nub of what the problem we're facing is, so I ask you to think about it.

The second *Gedankenexperiment* is to take 100,000 newborn babies today and put them on a desert island and have them taken care of by robots that take care of their health perfectly but, unlike the case in the Nicaraguan sign language situation, there would be no prior exposure to human societies or interactions or even gestures. If you came back 50 years later, would they have a language?

CALVIN: Would they be alive?

VARKI: In terms of the experiment I'm giving you, the conditions of that island are such that they're going to be healthy and alive and functional.

TOOBY: It's a question about whether one can believe that premise that the co-adapted developmental process between mother and infant might be so highly interdigitated that it would be hard to imagine that a child brought up by a robot would not have lost a serious part of the normal nurturing environment.

VARKI: You're saying that there's a significant dependence on that external input even at that point.



... we have two genetic inheritances. One is ... the stable features of the environment that the genetic inheritance evolved to depend upon for reliable development.

TOOBY: If you want to call it *external*. The way I think about it is that we have two genetic inheritances. One is the genetic inheritance and the other is the stable features of the environment that the genetic inheritance evolved to depend upon for reliable development. So, if you monkey around with that, then you start not getting normal development.

VARKI: I'm leaving everything stable except cultural and linguistic input.

TOOBY: If you could, in a way that I can't imagine would be possible, remove cultural inputs but you still had maternal love and sociality and other kinds of things, if that's the thought experiment....

VELAMOOR: Would they have a language?

TOOBY: Yes, I think they would have a language.

VELAMOOR: The story in *The Lord of the Flies* is somewhat similar.



... there's also, I think, an expectation of a peer group of mixed age with knowledge and expertise filtering down from older kids to younger kids.

PINKER: There's a lot they wouldn't have. In addition to whatever expectation the brain might have of a mother, family, and so on, there's also, I think, an expectation of a peer group of mixed age with knowledge and expertise filtering down from older kids to younger kids. If that is disrupted, it would be like taking the fish out of water, putting the child in an environment to which it was probably not adapted.

The social ecology of the human being is one in which kids are in mixed-age peer groups that shade into adulthood and in which lateral cultures develop, but in which there's also a lot of vertical transmission

from older to younger. You have, presumably, some sort of learning mechanism including a desire for status proven by skill and expertise, which depends on acquisition from other people, who, in an ecologically natural environment, really will have more expertise.

Now, if you distort that environment so that a mechanism that might be equipped to getting knowledge from what ordinarily would be people with more expertise comes from people who have the same amount of expertise that you do, you might have all kinds of bizarre cults and irrational beliefs that get fixed – kind of like what you already see happening in various teenage cults, the Goths and the Columbine kids. Where you have severe isolation, you might have a disruption of that mechanism.

Like John, I don't think of it in terms of something that ordinarily needs to be shaped and you remove the shaping influence and you see what form the protoplasm might take by itself. I think of it more as a system equipped with certain devices for acquiring information from the environment with an expectation that the environment is structured in particular ways.

An experiment like that would be scientifically fascinating as a thought experiment, but the results would best be interpreted in terms of the key difference between that environment and the one that the organism expects.

VARKI: So, you would say that the social consequence would be such that it would be unpredictable. But I'm talking about the higher cognitive functions. If you did the same experiment with 100,000 piglets and there are enough resources on the island, we would probably find pigs doing what pigs do. If we did the same experiment with New World monkeys, I'm not so sure. If we did the same experiment with Old World monkeys, we would probably have greater problems. If we did the same experiment with chimpanzees, I think there would be even greater problems.

I have tried this thought experiment on many people, and it's interesting that the academics who think about this range from people who say that the children would have a language to people who say, "Well, I don't know. They may not have much of anything. They may not be what we call *human* at all." So, I think the jury is out on that.

PINKER: I think everyone would agree that they would

be significantly abnormal. The question is: Why? Is it because ordinarily they come in as blank slates and nothing is written on the slate, or is it because they come in with the expectation of a particular environment and when you change the environment there will be systematic pathologies, like taking an organism out of its typical environment?

That would imply, then, that we are caught in a feedback loop where ... our systems are designed to expect certain environments to come back to us.

VARKI: I would agree with that. That would imply, then, that we are caught in a feedback loop where we're very dependent, that is, our systems are designed to expect certain environments to come back to us.

PINKER: Yes.

VARKI: But those environments are not consisting of molecules or pH or anything like that. They're consisting of the input from the prior generations.

PINKER: I would argue that that's why we have language – because that's the ecosystem. We evolved in a social ecosystem and we depend on language, among other things, as a medium through which we acquire much of our survival-necessary skills and knowledge.

VARKI: So, if the other extreme end of the view is right – this would go to Terry's idea – in the evolution of humans we have thrown away dependence on genes and hardwired inputs more and more, but absolutely meanwhile the genes have been evolving to accommodate to this system so we're in this feedback loop. The other extent of the question is: How far can the feedback loop go before you start having problems?

... all organisms have genes that exploit certain regularities of their typical environment.

PINKER: I'm wondering if it would be best to frame it in terms of we depend less on our genes, but rather that all organisms have genes that exploit certain regularities of their typical environment. In our case, this

includes a social environment, as it probably does in other species as well. Humans may not be unique in this regard.

Is Terry's view an alternative to the view that we have an evolved nature with a lot of structure, or is it that view and is it what you would expect based on how all organisms work? Just in our case, our particular dependence on the environment, perhaps, is of a greater degree.

VARKI: It's on the social and cultural environment, as opposed to the physical environment. Of course, I'm sure that in many social animals this is going on, but I think we humans are an unusual case where we've made that commitment much, much further, to a point where it gives us an advantage and yet leaves us at a great disadvantage.

PINKER: I think the way to understand it might be to have more comparisons to other kinds of sociality. You take other social species – we're not the only ones – and you bring them up in this thought experiment. How much pathology would you see? I imagine it would be considerable.

VARKI: I haven't brought up the question. The next generation would be a total mess in this experiment.

PINKER: Yes. We know that close relatives, the orangutans, have far reduced degree of sociality and the answer might even be different for them than it is for us.



... under what circumstances would society tend to self-organize the same way that you would see in an unstirred pot of oatmeal?

CALVIN: One of alternatives – I think of it as pathology – under what circumstances would society tend to self-organize the same way that you would see in an unstirred pot of oatmeal? That is to say, you would get hexagonal columns, and the equivalent, I suppose, would be gated communities and everybody in enclaves. It's a question like what Terry was bringing up before, of self-organization properties where there are patterns that emerge and, of course, they're influenced by properties that are more traditional, but they're basically not evolution. They're self-organization, which you just discover along the way. All of a sudden teams

have formed up and you never have expected that.

DEACON: To take the thought experiment in a slightly different direction, imagine that a number of educational administrators have their way and decide that we can't afford the arts and they are going to cut it off: Literature is irrelevant, music in the schools is irrelevant, and so on. These are social engineering experiments that we don't necessarily know we're running. How much do we know that these are not absolutely critical parts of what's going on in that social ecology that we've come into the world with?

I think of ourselves as very close to social insects in a lot of regards, and social insects don't do so well when you change those kinds of things. In social insects, genes have – as Steve was pointing out – very much restructured around this process. But there is also a lot of loss of function as well. There are things they just cannot do.

There are things that we cannot do and the reason I pushed that side of it was to recognize that we're what I would call an ultrasocial species, one in which so much has been offloaded. A lot of social processes do things for us. For example, how many of you know how to repair a carburetor? Well, a few.

What I'm saying is that just spontaneously we've offloaded. I talk to students who think that we people know how to do all these things. The fact is that almost none of us knows how to do most of this stuff. We're totally dependent technologically, but I think we're totally dependent in other ways – emotionally, for example, and in terms of educating things like our capacities for empathy. Clearly there are genetic components for this. Clearly there's a biological base for all of this. It evolved in the context of those things. I think it's important to recognize that it's not an *either/or*. It really is a *both/and* problem. We need to understand that interaction relationship. It goes well beyond knowledge and technology. It goes into all aspects of human societies.

HOLLOWAY: Another example that comes to mind are the attempts by school administrators to take away recess in grammar school. There is a clear indication that boys and girls are simply not the same, and if you don't give boys at the ages of 12, 11, 10 the chance to get some of that energy outside, you really have extraordinary problems. I think that's just a little capsule of where we're at with that.

OBSERVER: If you're saying that brain development is now extending to age 20 and 25, and it's happening very much in the social context, then is the information content that specifies the brain so much more than the genes in really an entire society? How much information should I be thinking of as specifying connections?

Specifically, do these isolated children in this experiment have physical connections that are absent in their brains?

VARKI: I guess you're asking: What would be the physical structure of their brains? I don't know.

The notion that the developmental period lasts to age 30 has been around a long time. It comes from the observation of neurologists and neurosurgeons.

CALVIN: It depends on the techniques of how late things occur. There's a sense in which this softwiring process is just our long-term memory process that we use all the way through life.

The notion that the developmental period lasts to age 30 has been around a long time. It comes from the observation of neurologists and neurosurgeons. For example, the Army did a study of soldiers who got tossed out of Jeeps, back before Humvees were invented. The 18-year-old soldiers with the same kind of head injury as the 30-year-old soldiers recovered a

lot better. Thirty-year-olds don't have much plasticity to deal with that kind of thing. As our techniques get better, the whole notion will disappear; it will just be a process that's faster and slower.

VARKI: If you did the same analysis with pigs that have had no input, would you find as much difference as you would find in a human?

CALVIN: It would be on a different timescale, but yes, I would expect that humans are not unusual in this regard. What I'm talking about is something that I think you would see in any of the species that we regularly study.

PINKER: In your thought experiment, there would still be social stimulation; there would still be visual stimulation. It's not like Hubel and Wiesel bringing up a cat in a striped cylinder. There would be a lot of pattern visual input. There would be sounds. There would be correlated changes in the visual field, and so on. So, I bet that the brains wouldn't look different to anything that a neuroanatomist or a neurophysiologist could tell, but obviously they would be different in terms of the particular patterns, presumably synaptic strengths that store all of our knowledge, just in the same sense that brains of two people in two different cultures would have to be different.

VELAMOOR: With that, I think we can proceed to the next step. Thank you all for this discussion.

Section 4.3 | Transcripts

Emerging Knowledge of the Brain and Its Long-term Implications for Humanity

Closing Session

At the conclusion of the two-day workshop, the eight participants made final remarks regarding the future of the human brain and their evaluation of the workshop overall.

VELAMOOR: We have reached the end of our workshop on “The Evolution of the Human Brain.” Would any of the participants like to make any concluding remarks? Ajit?



Until we know where we came from and how we got here, it's going to be very difficult to know what to do in the future.

VARKKI: I would like to thank the Foundation for this wonderful opportunity. It's always great to meet people in different backgrounds and exchange views in a manner that's free of ego and purely intellectual.

I would like to conclude with the theme I brought up: Until we know where we came from and how we got here, it's going to be very difficult to know what to do in the future. I would say in the interim that that does not mean that we should not worry about the future. We very much should, but I think that, because of the rate of progress, we are going to be forced to use some very broad-based and somewhat empirical pieces of information to decide what to do until we know what the black box has in it. I don't think that, even when we know everything that's in the black box, we can stop worrying about the broader findings that we will make.



... but I think that most of the mechanisms that we understand about how brains changed in the past are not going to extrapolate into the future.

CALVIN: I think that's true, Ajit, but I think that most of the mechanisms that we understand about how brains changed in the past are not going to extrapolate into the future. If you make the story, as I do, that the abrupt climate changes of the past played a role in pumping up brain complexity, I don't think that another episode of it is going to do the same thing, because there are so many other conditions that have changed. I think that there are no further implications of the general growth in brain size and so forth.

I may be wrong in this, but I think that the problems we'll be dealing with in the future are going to be taking our knowledge of brain mechanisms and social mechanisms, and trying to figure out the long-term implications of this new, emerging knowledge. What are the potentials for good and for mischief in this, and how will they play out in time?



... it really comes down to ... not the brain but the wonderful, miraculous tricks that nature performs through the mediation of something called the brain.

TULVING: I now have a fairer idea as to what this exercise was all about. I'm very happy to have been here. It has been an interesting experience for me, too.

One thing, however, does bother me and that's something that I mentioned before, namely, that there's too much talk about the brain without the mind. There's no such thing in the universe. There's a brain behind the mind that exists in the physical universe, in reality, but it is totally, utterly irrelevant to anything

that is happening in the world unless something that happens in the brain is translated into what the body does – that’s a behavior – and the knowledge that the body has, and then consciousness that comes after it. So, do not please overlook that as a real challenge.

One way in which we could really make a difference, perhaps, in what is going to happen in the future is if all scientifically enlightened, well-meaning, intelligent people would understand that it really comes down to, in the final analysis, not the brain but the wonderful, miraculous tricks that nature performs through the mediation of something called the brain.



The way the research priorities have been laid out comes from this older social science theory that the past doesn't really matter because we're blank slates ...

TOOBY: I also thank the Foundation. If our species is driving along at high speed and nobody's at the wheel, then having the Foundation that encourages thinking about the broader issues is very much needed.

Ajit overestimated me, at least, by saying that we had interaction that was free of ego. If our species were serious about understanding itself, then there's been a serious under-funding – not just funding but it's a social process of exclusion. There have been wars familiar to all anthropologists in which biological people are basically on the losing end. The study of this huge number of different important issues in biological anthropology is being killed off as a field, or at least heavily stunted compared to the magnitude and importance of the scientific questions, which will then have real, material implications for our species.

Another specific application of this is hunter-gatherer studies. Studies of small-scale populations are almost gone. The next ten years is the last opportunity to have any real science of that. It is at least as important as going to the Moon. I'm a big admirer of going to the Moon, but getting all the information we can about primates and having a major paleoanthropology research effort would also be very important. The way the research priorities have been laid out comes from this older social science theory that the past doesn't really matter because we're blank slates and nothing about the past tells us anything about what we are now. From that point of view, biologi-

cal anthropology is a marginal discipline, and all sorts of different component sciences are vastly under invested-in.



... Chekhov: "Man will become better when you show him what he is like."

PINKER: I echo that and I've mentioned this to people at NSF and other funding agencies. All of the areas that are most critical to our species' autobiography are endangered, either by lack of funding or by imminent disappearance of the subject matter or both, but evolutionary psychology, hunter-gatherer studies, studies of great ape behavior in the wild, endangered languages – how much information are we going to lose about the scope and flexibility of the human language faculty when 90 percent of world's languages disappear within 100 years?

I don't know about paleoanthropology – it doesn't seem to be a very well-supported field and I don't know whether the actual material basis of the field is in danger of disappearing as crucial spots become inaccessible because of war and other difficulties, but it seems that that's another area where we're doing much less than we should if we really want to understand where we came from.

The reason all of this is important is because of a quote that I have at the beginning of *The Blank Slate* from Chekhov: "Man will become better when you show him what he is like." I suspect that that is a sentiment that all of us would agree with and that the Foundation is committed to.



There's something about whatever happened 50,000 years ago, whether it's a new brain or at least a brain that has a different genetic underpinning ...

KLEIN: I certainly like the idea of more money for paleoanthropology, if that could be arranged. It's not a very well-supported field. It's interesting that there's such a disproportion between the attention it gets in the press and the amount of funding it receives. Hardly a month goes by when there isn't an article

in *The New York Times* or on CNN about what they perceive to be an important find, but in fact, the total number of people doing it would certainly fit in this building without any problem. The total amount of money available for paleoanthropological research is maybe a million or two million dollars a year. It's not extraordinary.

When Steve was saying before that we don't understand why first names assigned to little girls shift through time – a shift in fad or fashion; there is the same lack of understanding as to why hemlines go up and down or cars sometimes have fins and sometimes don't – but I can tell you that that sort of thing didn't occur until 50,000 years ago. If you look at the artifacts from before 50,000 years ago, they are the same for tens of thousands of years and over vast distances. We only get the sense that somebody is interested in novelty, whether it's functional or stylistic, after 50,000 years ago, and then you get these very rapid changes, at least in some places, in what they produce.

There's something about whatever happened 50,000 years ago, whether it was a new brain or at least a brain that had a different genetic underpinning than it had before, or whether it was just some kind of change in social organization. Whatever it was, it produced something that we're familiar with. It's almost inconceivable to us, I think, in terms of what we know about recorded history, that you could have material culture persisting for 10,000, 20,000, 30,000 years, and it wouldn't make a difference whether you were looking at the artifacts from, say, Crimea, France, or Cape Town. For 100,000 years they're the same. The only way you can tell the difference is that the raw materials would be a little different because the rock types that were available to people were different.

So, whatever it is that underlies this fad and fashion change in naming, that's a modern human thing in the last 50,000 years. That would imply to me that the brain before 50,000 years ago was not modern, for whatever reason.



... there have been these inordinate changes in material culture and, indeed, psychological culture ... that do not parallel in any sense neurological changes.

HOLLOWAY: I'm delighted to have been here and I've had a very fine time listening to my colleagues and getting insights where they stand on various issues. I have to say that I certainly agree with Richard here regarding funding.

It's a very interesting problem as to why paleoanthropology is so popular. I see it in terms of ecological dynamics. That is to say, anthropology departments are putting out PhDs like crazy, but unfortunately there are only a few fossil finds to go around, so the most is made out of it and that hits the press.

With regard to the stasis that one finds with the tool types over so many thousands and hundreds of thousands of years, I don't agree with Richard here. The reason I don't is because tool types really don't necessarily correlate one to one with their use. It seems to me that the possibility is open that while we see the same tool types again and again through many, many long periods of time, the way they're being used and the way they're being interacted with might very well be somewhat different.

What brought me into physical anthropology in the first place – and the evolution of the brain, in particular – was trying to understand the dynamics behind the rise and fall of the Third Reich. That was a very important part of my individual bringing up, not because I came from a Jewish background – I certainly didn't – but because I was in a Jewish neighborhood and when 1945 came and 1946, the behavior of peer groups toward each other changed as the evidence for what really happened became available. It really struck me how it was possible for arbitrary symbol systems to put together regimes and that arbitrary symbol systems could do what they did. That fascinated me.

So, when I got into paleoanthropology and started looking at the evolution of the brain, I wanted to know as much as I could about the development of the brain through time, of course. But what I come out with now, having studied it and trying to understand, in particular, the reorganizational aspects that

have taken place starting at least 3.5 million years ago, I would take human nature much further back than most people would. Of course, it has evolved over the last 3.5 million years, but I would say by about 1 to 1.5 million years, I'm very sure that you've got human nature and it hasn't really changed enormously.

The other thing I get a little antsy about is when we think of all the progress that has taken place over the last 50,000 years and need to get some "monster gene" that has come in there to make it possible to do that. I just wonder what my great-great-great-grandfather would think if he were suddenly plopped into this room or plopped onto that highway out there or plopped into the middle of an airplane. It seems to me that without any change whatsoever in the hardwiring of the brain, there have been these inordinate changes in material culture and, indeed, psychological culture, if I could put it that way, that do not parallel in any sense neurological changes. I would dearly like to have Thomas Edison sitting here and telling us what in the world he thinks about our electronic gadgets at this point. So, I'm a little skeptical of that interpretation.

I'm very, very grateful to be here. One of the hallmarks of humanity that has been around a very, very long period of time – maybe 3.5 million years – and one of the hallmarks of us is curiosity and wanting to know. I think that's kept us going for a long time.



Homo erectus, with its simple Swiss Army knife, made it for a million and a half years ... they were an evolutionarily stable strategy. We are not.

DEACON: It looks like I may have the last word!

I'm going to be a little pessimistic, because I think scientists oftentimes tend to be a little optimistic. Let me start it with an optimistic piece and then do my pessimistic rant.

The optimistic piece is something I've remembered every time I come into a conversation like this. On one of these many trips I've taken across the country, running through airports, seeing people piled up and arguing with each other, I saw a young woman just sitting – one of the many people just sitting there – engrossed in a book and sobbing. It had an incredible impact on me that this person, living somebody else's life who never lived probably, was totally transfixed.

Her entire consciousness was in the mind, in the soul, in the experience of this potentially fictional character. It's just an incredible thing that we don't really realize about being a human species. There's no other species that would do that. This is so totally unusual and so incredible. That's the positive.

The negative: We start with Ralph's comment about the Nazis. We often blame this on some psychopath or a few psychopaths. But normal people can do horrible things. It's part of every one of us, and we have to be totally conscious of that part.

The second piece of it is that I think if a civilization at 2 million years were to come down to Earth and assess the hominids, *Homo erectus* would be the winner. *Homo erectus*, with its simple Swiss Army knife, made it for a million and a half years; didn't destroy its ecology; didn't have to change, in my perspective; didn't have to be creative because they were an evolutionarily stable strategy. We are not.

This is not an evolutionarily stable strategy. I suspect that it doesn't have a long time to go. I think that the very stuff we're doing is so threatening to the spiritual health of so many people – partly because they don't understand it; partly because they think we're telling them that they're robots and "there's nobody home" that I don't think that the fundamentalism is going to go away. I think what we're going to see is those few places where it hasn't spread – Canada, Europe – are going to become more fundamentalist, as we do as well. Those of us thinking these thoughts – because we haven't figured out how to get the aesthetic out of it; how to bring the spiritualism into this conversation; how to communicate that this stuff is uplifting, not subtractive – we haven't done that and we have not figured out how to do it. No matter how well the popular press seems to be playing up this stuff, I think they also play up the "Wow, gee whiz!" weirdness of it.

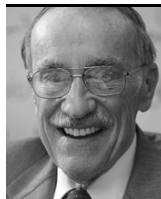
We have to recognize that our denial of consciousness ... pretending that it's not there or pretending that we'll explain it away – is a spiritually threatening message.

I think these conversations could, indeed, be a dying breed and I thank the Foundation for trying to keep it going, but we have to think that thought. We have

to think the thoughts from the negative. We have to recognize that our denial of consciousness, to some extent, in a lot of this work – pretending that it's not there or pretending that we'll explain it away – is a spiritually threatening message. And I think that the vast, vast majority of people in the world are not ready for that message and, in fact, will stop us from telling the story.

So, what do I see in this organization that's a positive to me? A time capsule. I hope that some of this stuff survives the Dark Age.

VELAMOOR: Walter, would you like to close the workshop?



*... there's too much emotion,
too much feeling, too much pride in
all these things, which prevents these
matters from being well studied.*

KISTLER: We've talked about the human brain and many other things more or less connected with it. Maybe I may give my view of what's important in this world.

There is, of course, a big environmental movement to save the environment, and that is certainly very appropriate and very good. I fully agree with their goal. But still, the most important thing in this world is the human being. There is lots of difficulty with studying human beings so that we could understand

what's going on and maybe predict, a bit, the future.

Studying man himself – his mind, thinking, sensitivities, drives – is all very much taboo. It touches the people in their feeling, in their ambition, in their pride – mostly in their pride. Analyzing people today, telling them what they are or what groups they are in or really making a science of humans, is a very touchy matter. I hope some day that will change. That's my personal view and hope, that this will slowly change, that people will start feeling above these matters of belonging to a group: *That group is bad*, or *that group is good*, or *that should be preferable*. They feel insulted at being classified or being in a group. I would say that there's too much emotion, too much feeling, too much pride in all these things, which prevents these matters from being well studied.

We are very poor in understanding the human mind: what drives it and what is the basis of it. So, I hope that will be studied a bit more from two viewpoints. The brain, very roughly analyzed, has basically two parts – the cortex, which is mostly a reservoir of knowledge, and the inner brain, the limbic system, where the emotions, the drives, the motivation are. Analyzing this and expanding this a bit better would be a worthwhile long-range study. I hope that will slowly evolve along these lines.

I am glad you all came and shared your research and your thinking with us. Travel safely to your homes. I hope we will meet again.

Section 4.4 | Transcripts

Closing Session



Appendix 1

Workshop Agenda

March 19, 2005

Foundation For the Future building in Bellevue, WA

- Welcome
— WALTER KISTLER, President
- Introduction to the Foundation For the Future;
Introduction to the Center for Human Evolution
— BOB CITRON, Executive Director
- Introduction to the workshop “The Evolution of
the Human Brain”
— SESH VELAMMOOR, Deputy Director, Programs
- Self-introductions by workshop participants
- Viewing of Video *Cosmic Origins: From the Big
Bang to Humanity*
- Presentation of papers followed by Q&A

Paper 1 William H. Calvin

Paper 2 Terrence Deacon

Paper 3 Ralph L. Holloway

Paper 4 Richard G. Klein

Paper 5 Steven Pinker

Paper 6 John Tooby

Paper 7 Endel Tulving

Paper 8 Ajit Varki

March 20, 2005

Foundation For the Future building

- Summary of Day 1 activities
— SESH VELAMMOOR
- Discussion of Critical Questions
- Closing remarks and adjournment
— WALTER KISTLER
— SESH VELAMMOOR



Appendix 2

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William H. Calvin



WILLIAM H. CALVIN, Ph.D., a theoretical neurobiologist, is Affiliate Professor Emeritus of psychiatry and behavioral sciences at the University of Washington School of Medicine in Seattle. He is also affiliated with

Emory University's great apes project, the Great Ape Trust of Iowa, and on the Board of Advisors of the Foundation For the Future.

His 1998 cover story for *The Atlantic Monthly*, "The Great Climate Flip-flop," grew out of a long-standing interest in abrupt climate change and how it influenced the evolution of a chimpanzee-like brain into a more human one. He addressed the same topic in his 2002 book, *A Brain for All Seasons: Human Evolution and Abrupt Climate Change*, which won the Phi Beta Kappa Book Award for Science.

Calvin has written a dozen books for general readers. *A Brief History of the Mind: From Apes to Intellect and Beyond* (2004) addresses what led up to the "Mind's Big Bang" about 50,000 years ago, a creative explosion compared to the very conservative trends in toolmaking over the previous 2.5 million years. That span featured two million-year-long periods without much progress – despite the growth in brain size.

Calvin's neurobiology research interests primarily concern the neocortical circuits used for detailed planning and for improving the quality of the plan as you "get set," presumably utilizing a milliseconds-to-minutes version of the same Darwinian process (copying competitions biased by natural selection) seen in the immune response and species evolution on longer timescales. His research monograph, *The Cerebral Code: Thinking a Thought in the Mosaics of the Mind* (1996), concerns Darwinian processes in neural circuitry that can operate on the timescale of thought and action to resolve ambiguity and shape up novel courses of action. He also collaborated with the linguist Derek Bickerton to write *Lingua ex Machina: Reconciling Darwin and Chomsky with the Human Brain* (2000) about the evolution of syntax.

Following studies in physics at Northwestern University, Calvin branched out into neurophysiology via studies at MIT, Harvard Medical School, and the University of Washington (Ph.D., physiology and biophysics, 1966).

Terrence Deacon



TERRENCE DEACON, Ph.D., is a Professor of biological anthropology and neuroscience at UC Berkeley. His research combines human evolutionary biology and neuroscience, with the aim of investigating the evolution of human cognition. His work extends from

laboratory-based cellular-molecular neurobiology to the study of semiotic processes underlying animal and human communication, especially language. He is the author of *The Symbolic Species: The Co-evolution of Language and the Brain* (1997).

Dr. Deacon's neurobiological research is focused on determining the nature of the human divergence from typical primate brain anatomy, the cellular-molecular mechanisms producing this difference, and the correlations between these anatomical differences and special human cognitive abilities, particularly language. In pursuit of these questions he has used a variety of laboratory approaches including the tracing of axonal connections, quantitative analysis of regions of different species brains, and cross-species fetal neural transplantation. Future research plans will focus on isolating elements of the developmental genetic mechanisms that distinguish human brains from other ape brains, and attempting to study the cognitive consequences of human brain differences using *in vivo* brain imaging.

His theoretical interests include the study of evolution-like processes at many levels, including their role in embryonic development, neural signal processing, language change, and social processes, and focusing especially on how these different processes interact and depend on each other. In addition, he has a long-standing interest in developing a scientific semiotics that could contribute to both linguistic theory and cognitive neuroscience. This is fueled by a career-long interest in the ideas of the late 19th century American philosopher Charles Sanders Peirce.

Deacon is completing a new book, *Homunculus*, which explores the relationship between evolutionary and semiotic processes. His Ph.D., in biological anthropology, is from Harvard University. He taught at Harvard for eight years before relocating to Boston University's Department of Anthropology in 1992, and from there to UC Berkeley.

Ralph L. Holloway



RALPH L. HOLLOWAY began teaching in the Department of Anthropology at Columbia University in 1964, after receiving his Ph.D. in anthropology from the University of California, Berkeley, under the late Professor T.D. McCown. His dissertation was titled “Some Quantitative Relations of the Primate Brain.”

Dr. Holloway’s main interest is the evolution of brain and behavior, particularly in hominids. To understand that evolution from roughly four to five million years ago requires a careful consideration of the fossil evidence for human evolution, and the most direct part of that evidence, at least for the brain, are brain endocasts, i.e., paleoneurology. While endocasts do provide basic information regarding brain size, it is Holloway’s belief that in addition to brain size increase, either allometric or not, there have been important episodes of reorganization, meaning shifts in the quantitative relationships between parts of the brain. An example is the relative reduction of primary visual cortex (area 17 of Brodmann) and a relative increase in posterior association cortex, something that appeared during Australopithecine times three to four million years ago. Holloway is also keenly interested in neural variation between and within populations, and has studied sexual dimorphism in primate brains, particularly involving the corpus callosum. His earliest neurological work was with dendritic branching in environmentally stimulated rats.

In addition to writing roughly a hundred peer-reviewed articles, Holloway edited the 1974 volume *Primate Aggression, Territoriality, and Xenophobia: A Comparative Perspective*, published by Academic Press. His book with co-authors Broadfield and Yuan, *Brain Endocasts: Paleoneurological Evidence*, is the 3rd volume in the Schwartz/Tattersall *Human Fossil Record* series, published in June 2004 by John Wiley & Sons. It won the 2005 Association of American Publishers Award in Sociology and Anthropology. Holloway has done extensive paleoneurological work with hominids from South Africa, Kenya, and Ethiopia, as well as Indonesia and Europe, and has built a comparative hominoid endocast collection of roughly 200 apes, including *Pan paniscus*, the pygmy chimpanzee.

Richard G. Klein

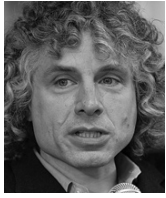


RICHARD G. KLEIN, Ph.D., joined the faculty at Stanford University in 1993 and is a Professor in the Program in Human Biology. Dr. Klein researches the archeological and fossil evidence for the evolution of human behavior. He has done fieldwork in Spain and especially in South Africa, where he has, since 1969, excavated ancient sites and analyzed the excavated materials. He recently finished directing the first of three excavation seasons at the 200,000-year-old archeological site of Duinefoutein 2, near Cape Town. He has focused on the behavioral changes that, about 50,000 years ago, allowed anatomically modern Africans to spread to Eurasia, where they swamped or replaced the Neanderthals and other non-modern Eurasians.

Klein has published articles on various aspects of human evolution and two book-length syntheses: *The Human Career: Human Biological and Cultural Origins* (University of Chicago Press, Second Edition, 1999), aimed at professional paleoanthropologists and their students, and (with Blake Edgar) *The Dawn of Human Culture* (John Wiley, 2002), written for non-specialists.

After earning his undergraduate degree from the University of Michigan, Klein earned his M.A. and Ph.D. degrees from the University of Chicago. He has taught at the University of Wisconsin-Milwaukee, Northwestern University, the University of Washington, the University of Chicago (for 20 years), and now at Stanford University.

Steven Pinker



STEVEN PINKER, a native of Montreal, received his B.A. from McGill University in 1976 and his Ph.D. in psychology from Harvard in 1979. After serving on the faculties of Harvard and Stanford universities for a year each, he moved to MIT in 1982, where he spent 21 years before returning to Harvard in 2003 as the Johnstone Family Professor of Psychology.

Professor Pinker's research has focused on visual cognition and the psychology of language. The research has been reported in two technical books and many journal articles, and won the Troland Award from the National Academy of Sciences, the Henry Dale Prize from the Royal Institution of Great Britain, and the Early Career Award and McCandless Prize from the American Psychological Association. Pinker has also received awards for graduate and undergraduate teaching, two prizes for general achievement, three honorary doctorates, and eight awards for his critically acclaimed popular science books, *The Language Instinct: How the Mind Creates Language* (William Morrow, 1994), *How the Mind Works* (W.W. Norton, 1997), and *The Blank Slate: The Modern Denial of Human Nature* (Viking, 2002). The latter two were finalists for the Pulitzer Prize in Nonfiction. Dr. Pinker also won the Walter P. Kistler Book Award in 2005 for *The Blank Slate*.

Pinker is an elected Fellow of several scholarly societies, including the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the Neuroscience Research Program. He is an Associate Editor of *Cognition* and serves on many professional panels, such as the Usage Panel of the American Heritage Dictionary, the Scientific Advisory Panel of the *Evolution* series on NOVA, and the Endangered Language Fund. Dr. Pinker also writes in the popular press, including *The New York Times*, *Time*, *The New Yorker*, and *Technology Review*.

John Tooby



JOHN TOOBY, Ph.D., is best known for his work in co-founding the new field of evolutionary psychology. This multidisciplinary new approach weaves together evolutionary biology, cognitive science, human evolution, hunter-gatherer studies, neuroscience, and psychology into a unified new framework for discovering the functional organization of the human mind and brain. By using models of the adaptive problems our hunter-gatherer ancestors faced during their evolution, researchers can empirically map the detailed functional designs of the reasoning algorithms, emotion programs, and motivational systems that evolved as part of our universal human nature.

Dr. Tooby developed his interest in rebuilding psychology along evolutionary lines while an undergraduate at Harvard in the early 1970s. He continued at Harvard, where he received his Ph.D. in biological anthropology, and married his long-time collaborator, Leda Cosmides. He did postdoctoral work with Roger Shepard, a cognitive psychologist at Stanford, and then became a Fellow at the Center for Advanced Study in the Behavioral Sciences, where he helped to form the Special Project on Evolutionary Psychology. In 1990 he joined the Department of Anthropology at the University of California, Santa Barbara, where he is now Professor in anthropology. Tooby co-directs the UCSB Center for Evolutionary Psychology with Cosmides. In 1992, they published *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, an edited volume designed to be a state-of-the-art survey of the new field.

Dr. Tooby has published in the fields of cognitive psychology, evolutionary biology, evolutionary psychology, cultural and biological anthropology, neuroscience, evolutionary genetics, philosophy, and economics. He has won various awards and honors for his work on the foundations of evolutionary psychology and evolutionary biology. In 1991, Tooby won a Presidential Young Investigator Award from the National Science Foundation. In 1999, he received a John Simon Guggenheim Foundation Fellowship, and was President of the Human Behavior & Evolution Society from 1999–2001.

Endel Tulving



ENDEL TULVING, Ph.D., holds the Tanenbaum Chair in Cognitive Neuroscience at the Rotman Research Institute of Baycrest Centre, University of Toronto, as well as the Clark Way Harrison Distinguished Visiting Professorship of Psychology and Cognitive Neuroscience, Washington University in St. Louis, Missouri.

He was born in Estonia in 1927 and came to Canada in 1949. He completed undergraduate work at the University of Toronto, and received his Ph.D. in experimental psychology from Harvard. He taught at the University of Toronto continuously from 1956 to 1992, with the exception of a few years at Yale University in the early 1970s. In 1992 he retired as a University Professor Emeritus and accepted his present position at the Rotman Research Institute.

Dr. Tulving has studied human memory all his academic life. Among the concepts he has introduced to the field and discoveries he has made are: subjective organization (1962), the distinction between availability and accessibility of stored information (1966), encoding specificity principle (1973), cue-dependent forgetting (1974), stochastic independence between priming and episodic memory measures (1982), retrieval mode (1983), the distinction between noetic and autonoetic consciousness (1985), the recognition/know (R/K) paradigm (1985), the distinction between perceptual and conceptual priming (1990), the hemispheric encoding/retrieval asymmetry (HERA) model of the involvement of frontal lobes in memory processes (1994), the novelty/encoding hypothesis (1996), episodic retrieval mode (1983, 2000), and chronesthesia (2002).

Tulving has been elected to seven national or international academies of science, including the Royal Society of London and the National Academy of Sciences (USA), and has received honorary degrees from five countries. Among his other honors are the Howard Crosby Warren Medal of the Society of Experimental Psychologists, Distinguished Scientific Contribution Award of the American Psychological Association, Killam Prize in Health Sciences of the Canada Council, and Gold Medal Award for Life Achievement in Psychological Science of the American Psychological Foundation.

Ajit Varki



AJIT VARKI, M.D., is Professor of Medicine and Cellular & Molecular Medicine; Co-director of the Glycobiology Research and Training Center; and Associate Dean for Physician Scientist Training at the University of California, San Diego. He studied physiology, medicine, biology, and biochemistry at the Christian Medical College (Vellore, India), University of Nebraska, and Washington University (St. Louis). He also has formal training and board certification in internal medicine, hematology, and oncology.

Dr. Varki's research interests are currently focused on a family of sugars called the sialic acids, and their roles in biology, evolution, and disease. He is particularly intrigued by finding multiple differences in sialic acid biology between humans and our closest evolutionary cousins, the great apes. These differences are a signature of events that occurred during the last few million years of human evolution, and may be relevant to understanding several aspects of the current human condition, both in health and disease.

Dr. Varki was Executive Editor of the textbook *Essentials of Glycobiology* (Cold Spring Harbor Laboratory Press, 1998) and serves on the editorial boards of several journals, including *The Journal of Clinical Investigation*, *PloS Medicine*, and *Glycobiology*. He also serves as Coordinator for the multidisciplinary UCSD Project for Explaining the Origin of Humans and is an Affiliate Faculty Member of the Living Links Center of Emory University. He is a recipient of a MERIT award from the NIH and an American Cancer Society Faculty Research Award, and he serves on the Scientific Advisory Boards of PubMed Central (NLM/NIH), the Human Gene Nomenclature Committee, and the Huntsman Cancer Institute (University of Utah). Significant past appointments include: Co-head, UCSD Division of Hematology-Oncology (1987–89); President of the Society for Glycobiology (1996); Editor-in-Chief of the *Journal of Clinical Investigation* (1992–97); Interim Director of the UCSD Cancer Center (1996–1997); President of the American Society for Clinical Investigation (1998–1999); Scientific Advisor, Complex Carbohydrate Research Center (University of Georgia), and Scientific Advisor, the Yerkes Primate Center (Emory University).