Why is teaching, understanding, and accepting evolution (science) so *@#!hard?

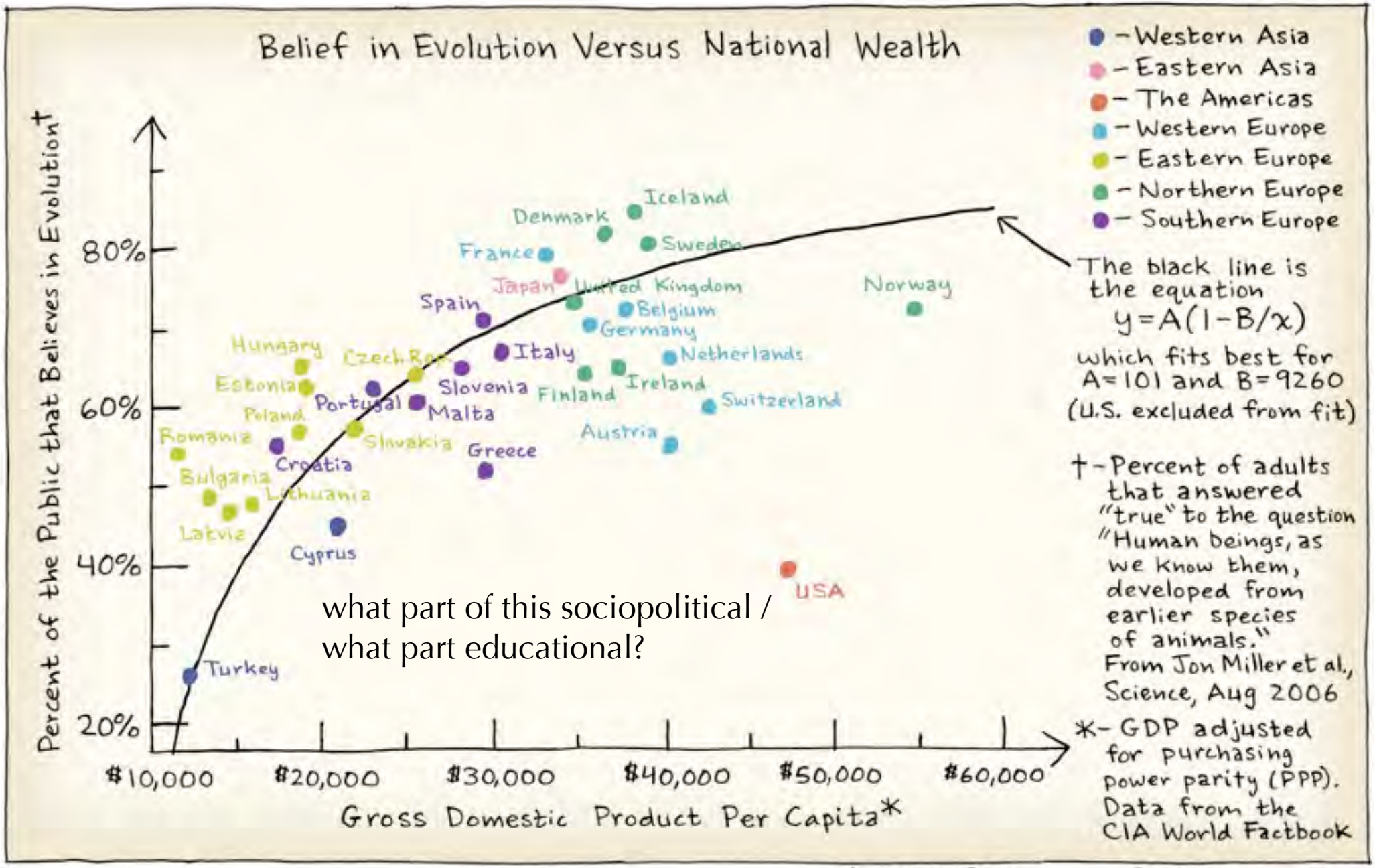
Mike Klymkowsky
Molecular, Cellular & Developmental Biology & CU Teach
Center for STEM Learning, UC Boulder
http://klymkowskylab.colorado.edu

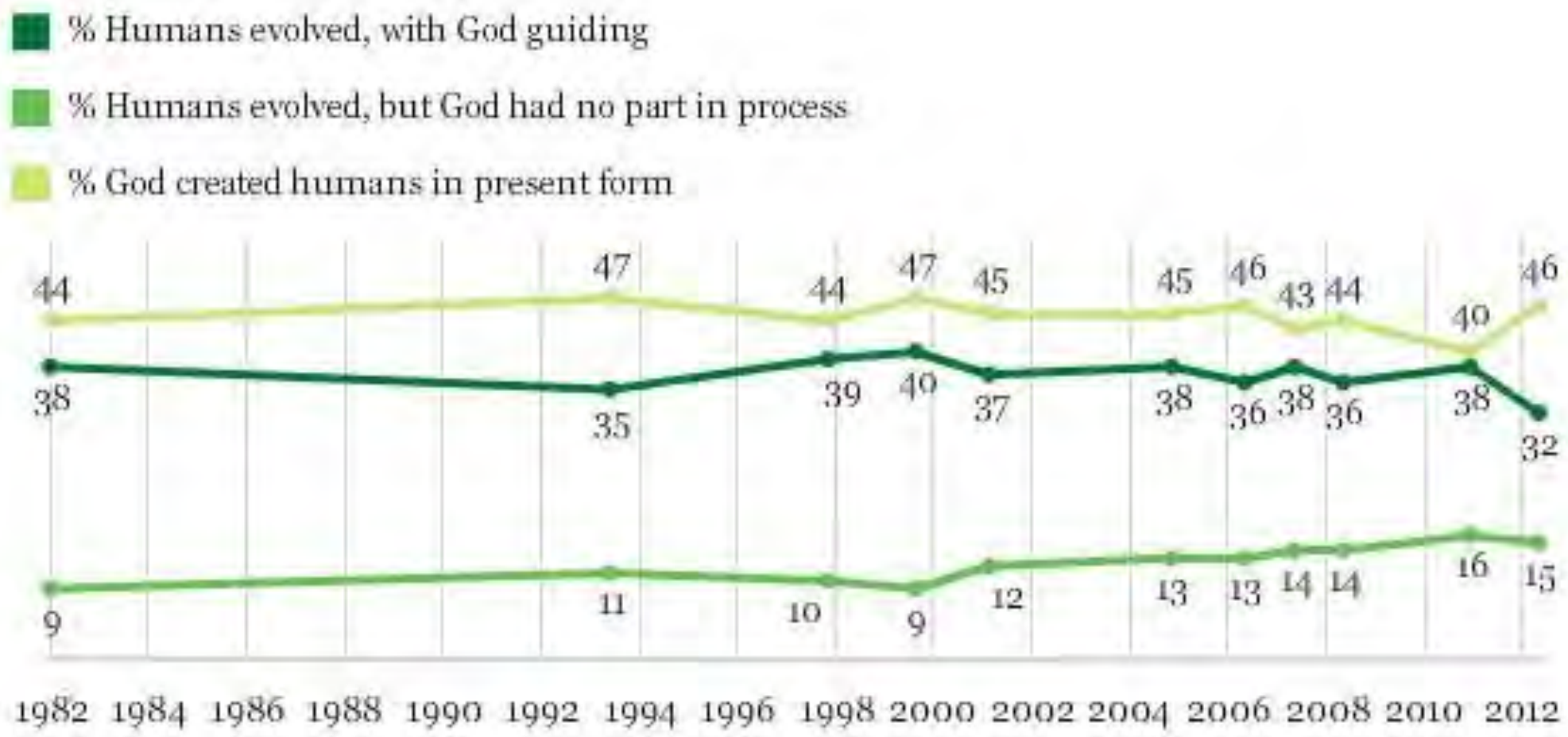
Christian Right Lobbies To Overturn Second Law Of Thermodynamics

the ONION

House Science Committee Member: Evolution, Big Bang (and embryology) **'Lies Straight From The Pit Of Hell'**

NOT the ONION




% Humans evolved, with God guiding
% Humans evolved, but God had no part in process
% God created humans in present form
44 47 44 47 45 45 46 43 44 40 46
38 35 39 40 37 38 36 38 36 38 32
9 11 10 9 12 13 13 14 14 16 15
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012

GALLUP

What provokes anti-scientific responses?

include climatology, genetic engineering, anti-vaccination, homeopathy ….

National Science Foundation: Science Hard

the ONION

High-School Science Teacher Takes Fun And Excitement Out Of Science

Enlarge Image

POLITICO OF THE YEAR

Chairman Smith Versus the Scientists

U.S. Representative Lamar Smith (R–TX) likes to recall how a "D" in a freshman physics class at Yale University taught by a former presidential science adviser, D. Allan Bromley, caused him to switch his major to American studies —and started him on the road to a career in politics. Now, the tables have turned: This year, Smith gave a failing grade to the National Science Foundation (NSF) as part of a controversial attempt to reshape U.S. science policy that has scientists talking.

As the new chair of the House of Representatives science committee, Smith has drafted legislation that would alter how NSF manages peer review. He says the proposed changes would make the system more transparent and ensure that tax dollars are being spent wisely. But science leaders view the bill as a threat to a system that has fueled 60 years of innovation—and that other nations are trying to copy.

In a bid to preempt the draft legislation, this month NSF announced plans to sharpen its descriptions of funded grants to emphasize their relevance to important societal goals. Will it be enough?

feature http://www.asbmb.org/asbmbtoday/asbmbtoday_article_print.aspx?id=13071

Teaching disconcerting scientific ideas

BY MIKE KLYMKOWSKY

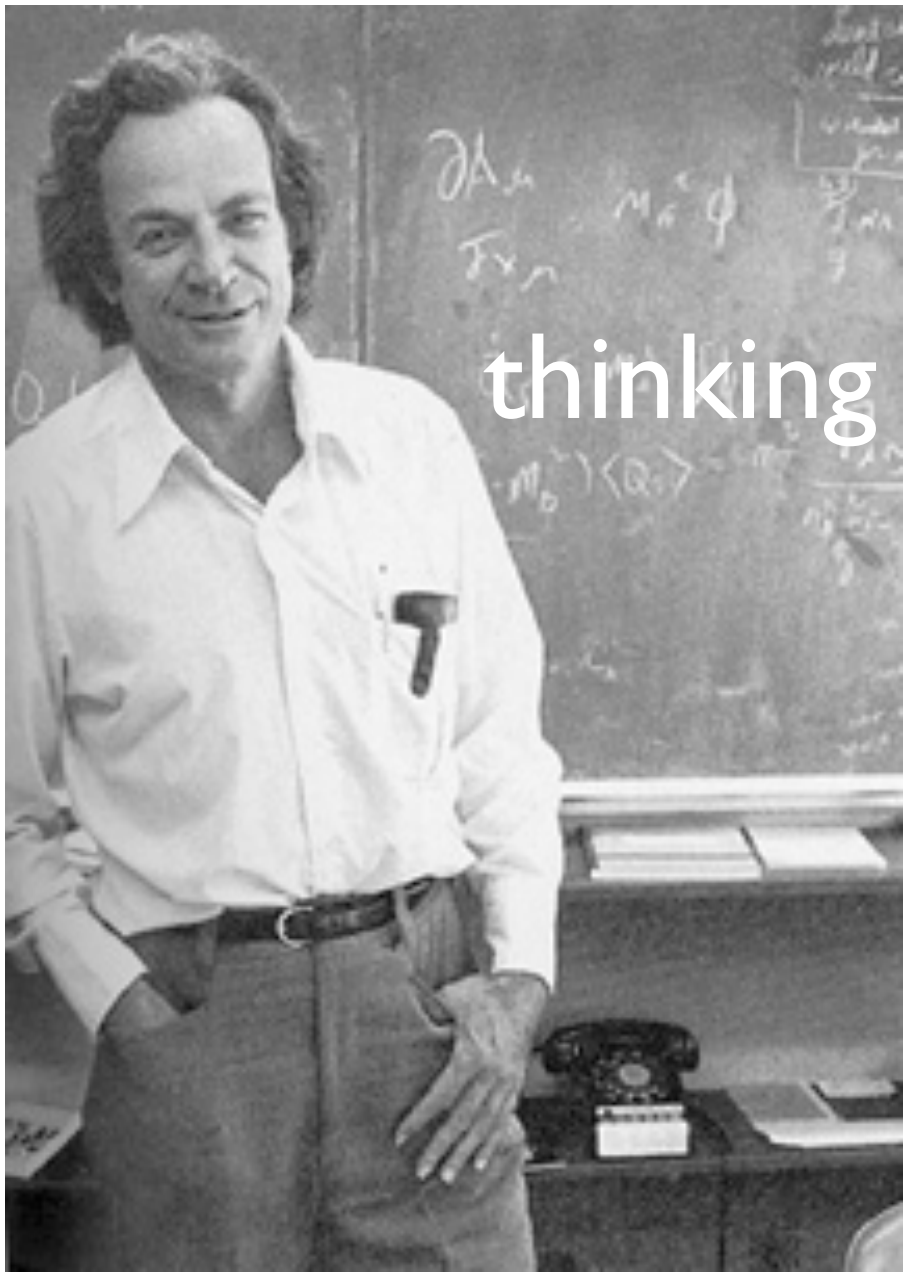
Explaining the scientific process will help the public understand why scientists trust their own conclusions.

Many scientific ideas are deeply counter-intuitive, difficult to accept, and with disconcerting implications.

Strange scientific ideas

- Matter is composed of atoms, which are mostly empty space.
- The universe emerged out of nothing (about 13,700,000,000 years ago).
- There are billions of galaxies, each containing billions of stars.
- Time and space are not distinct.
- All organisms are built from similar building blocks called cells.
- All cells are derived from pre-existing cells in a continual lineage that extends back about 3,500,000,000 years.
- The heavier atoms in our bodies were formed within stars or exploding stars.
- Matter and energy are different versions of the same thing.
- The universe is running down yet expanding at a faster and faster rate.
- Random noise can produce complex structures.
- At the molecular level, everything is reversible.
- A collection of cells can, by itself, produce a self-conscious entity that thinks it is more than a collection of cells.

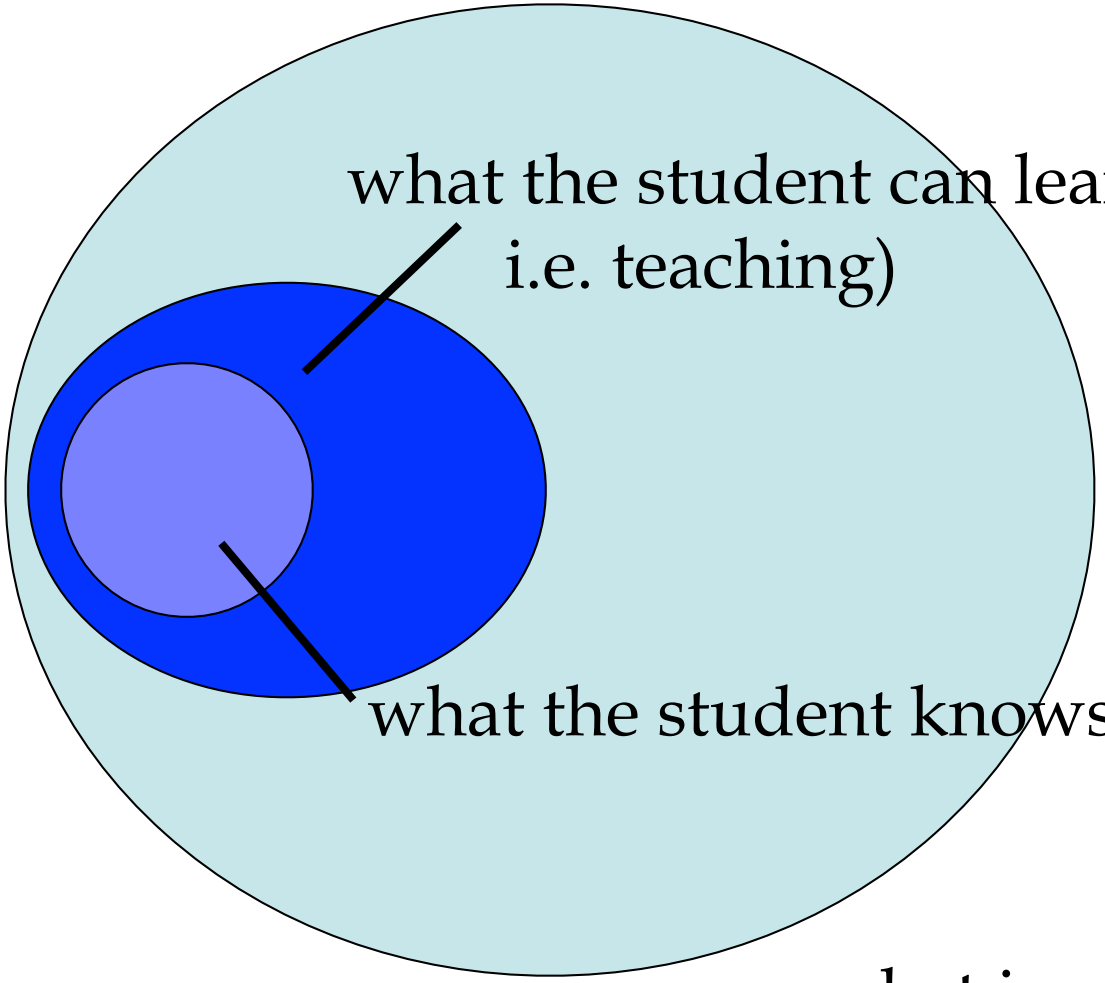
What does teaching/learning science involve?



thinking about magnets

http://www.youtube.com/watch?v=MO0r930Sn_8

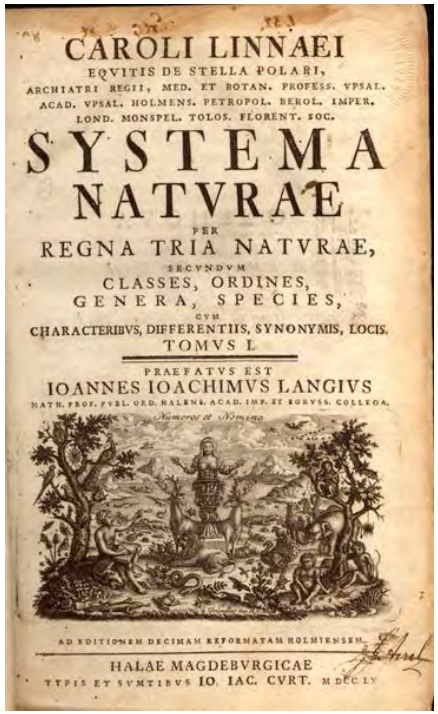
The zone of proximal development (Vygotsky + common sense)

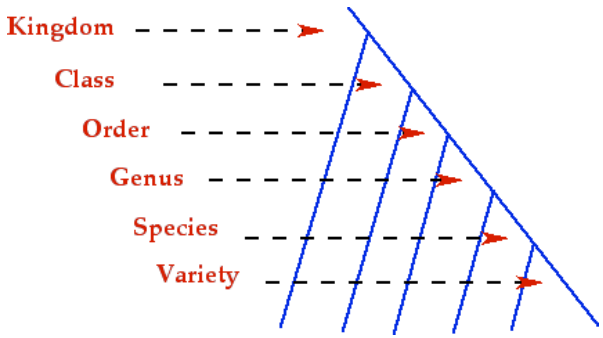


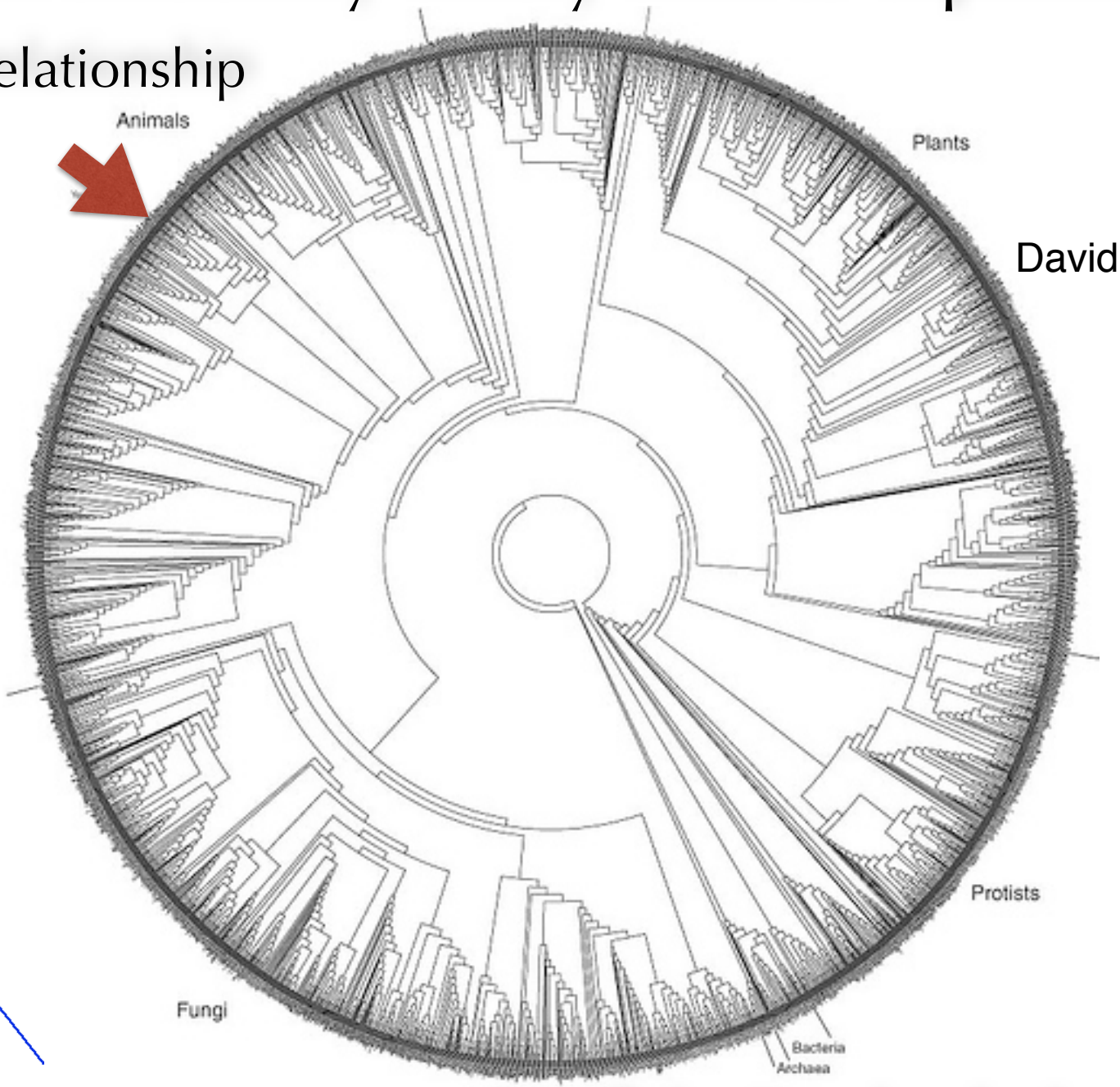
A disclaimer: I cannot teach you evolutionary biology, its various mechanisms, and the observations that lead to these conclusions in an hour!

Q: What does evolutionary theory seek to explain?

The appearance of relationship between organisms


CAROLI LINNAEI
EQVITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. ET BOTAN. PROFESS. VPSAL.
ACAD. VPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.
SYSTEMA
NATVRAE
PER
REGNA TRIA NATVRAE,
SECVNDVM
CLASSES, ORDINES,
GENERA, SPECIES,
CVM
CHARACTERIBVS, DIFFERENTIIS, SYNONYMIS, LOCIS.
TOMVS I.
PRAEFATVS EST
IOANNES IOACHIMVS LANGIVS
AD EDITIONEM DECIMAM REFORMATAM HOLMIENSEM.
HALAE MAGDEBVRGICAE
TYPIS ET SVMTIBVS IO. IAC. CVRT.





David Hillis

to cellular & molecular level

Q: What does evolutionary theory seek to explain?

strange adaptations and weird behaviors:

http://www.youtube.com/watch?v=NZR_jo_tCy0

Q: What does evolutionary theory seek to explain?

strange adaptations and weird behaviors:

http://youtu.be/lGSUU3E9ZoM

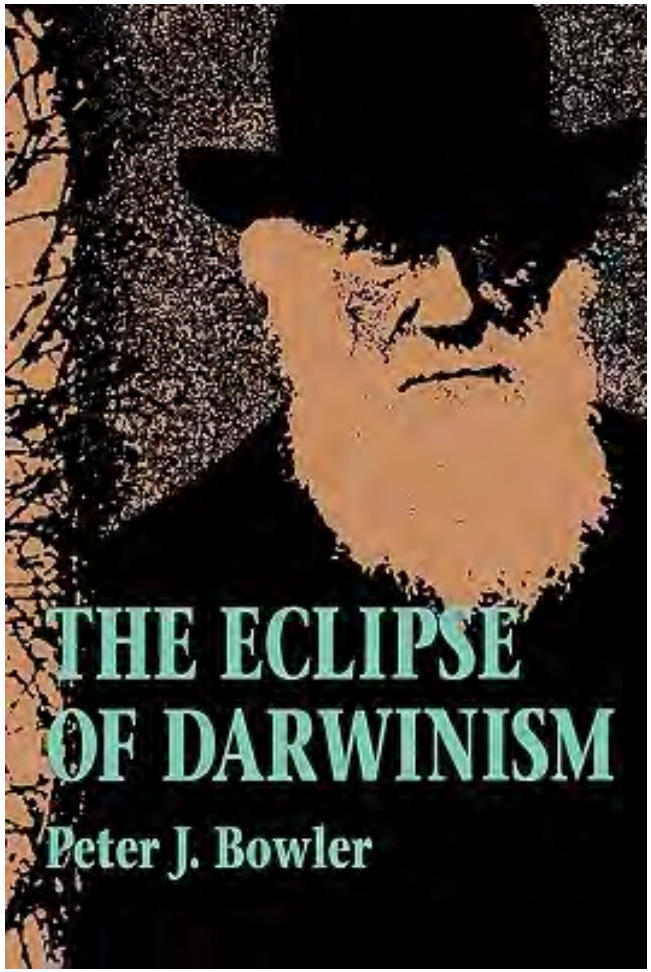
"What a book a devil's chaplain might write on the clumsy, wasteful, blundering, low, and horribly cruel work of nature!" Charles Darwin [letter to his friend Joseph Hooker (1856)]

Q: Keys to understanding biological systems

non-essentialist nature of organisms

Q: Keys to understanding biological systems

How do organisms “work” at the physicochemical (molecular) level?



Modern biology= molecular & evolutionary mechanisms + history

Noise (random mutation, bottlenecks, drift, genome dynamics)
+
selection (natural, sexual & social)
can
lead to
novel adaptations, structures, behaviors, and new “species”

How might a mutation be creative?

Article

Understanding Randomness and its Impact on Student Learning: Lessons Learned from Building the Biology Concept Inventory (BCI)

Kathy Garvin-Doxas* and Michael W. Klymkowsky†

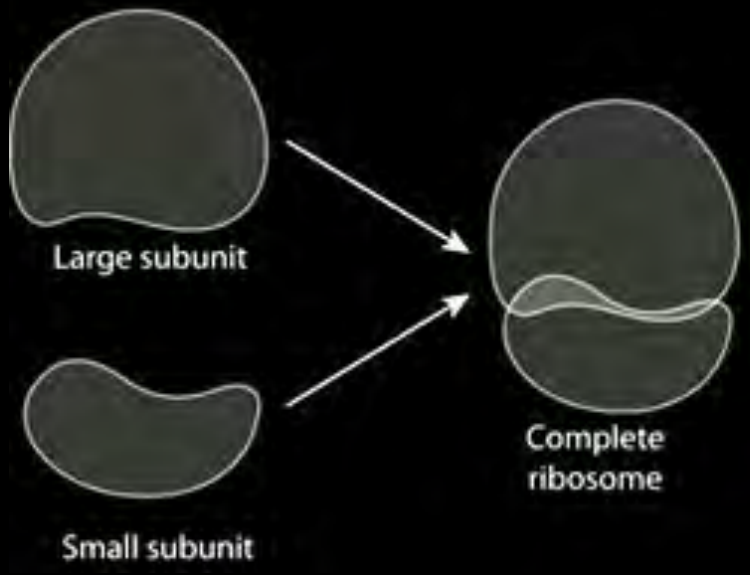
*Center for Integrated Plasma Studies and †Molecular, Cellular, and Developmental Biology Department, University of Colorado, Boulder, CO 80309

Submitted August 23, 2007; Revised January 14, 2008; Accepted February 7, 2008
Monitoring Editor: Bruce Alberts

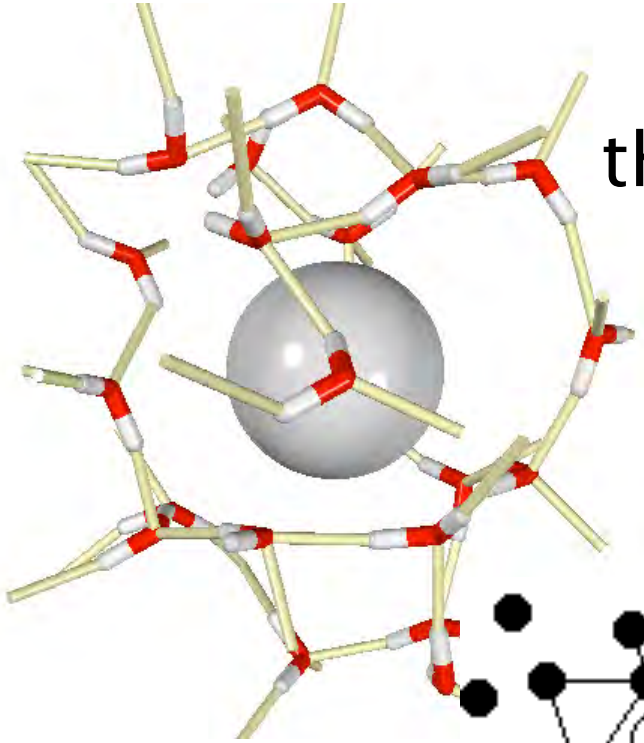
CBE—Life Sciences Education
Vol. 7, 227–233, Summer 2008

Yet randomness is rarely illustrated

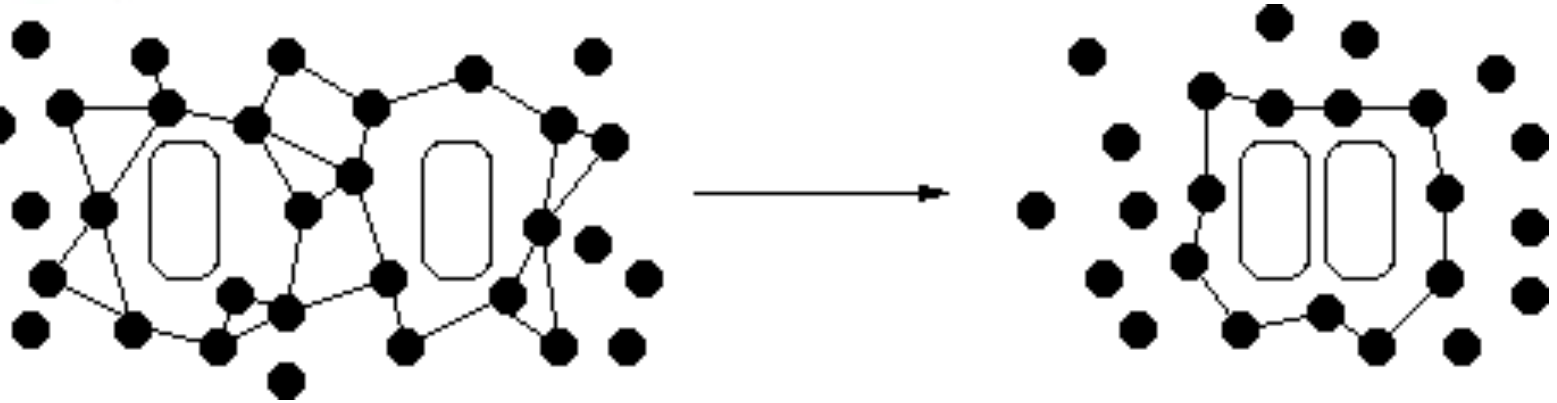
translation video



What do oil and water separate?



this is an entropy driven process!



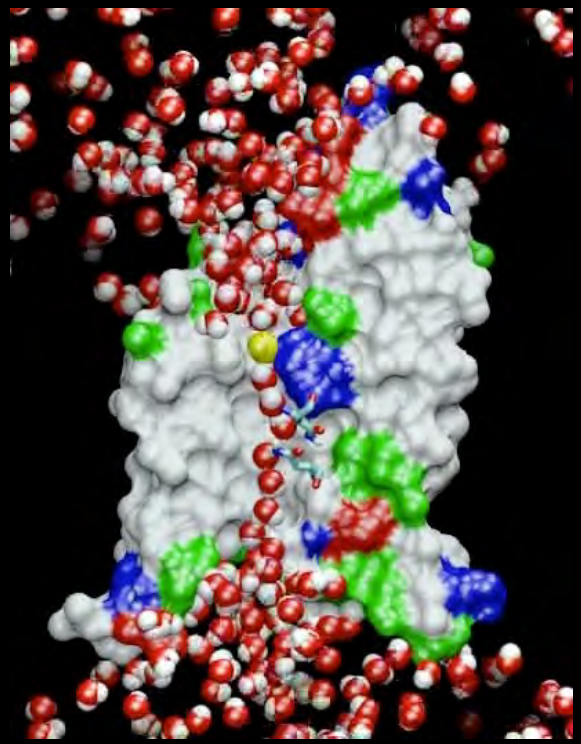
Random processes seem impossible but work.

THEORETICAL AND COMPUTATIONAL
BIOPHYSICS GROUP

NIH Center for Macromolecular Modeling and Bioinformatics
www.ks.uiuc.edu

presents

Water Channels in Cell Membranes



http://youtu.be/GSi5-y6NHjY

how do mutations (changes in genomic DNA) create novel functions?

Consider the universe of possible mutations

Based on their effects on a particular function, mutations can be classified into 6 (and only 6 types)

no effect

amorphic and **hypomorphic**

hypermorphic and **antimorphic**

neomorphic

RESEARCH ARTICLE

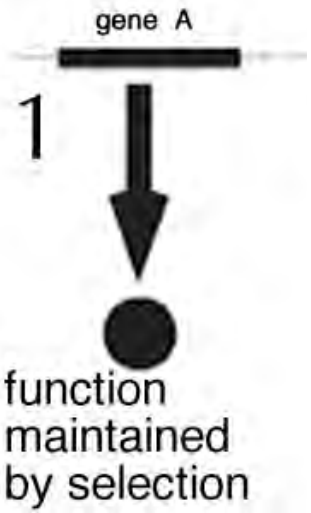
Expand

Turning randomness into meaning at the molecular level using Muller's morphs

Kathleen Henson[1,*], Melanie M. Cooper[2] and Michael W. Klymkowsky[3,‡]

Mutations can create conflicts

adapted from Bergthorsson et al (2007, PNAS 104:17004-09)



Science. 2014 Jan 23. [Epub ahead of print]

Origin and Spread of de Novo Genes in Drosophila melanogaster Populations.

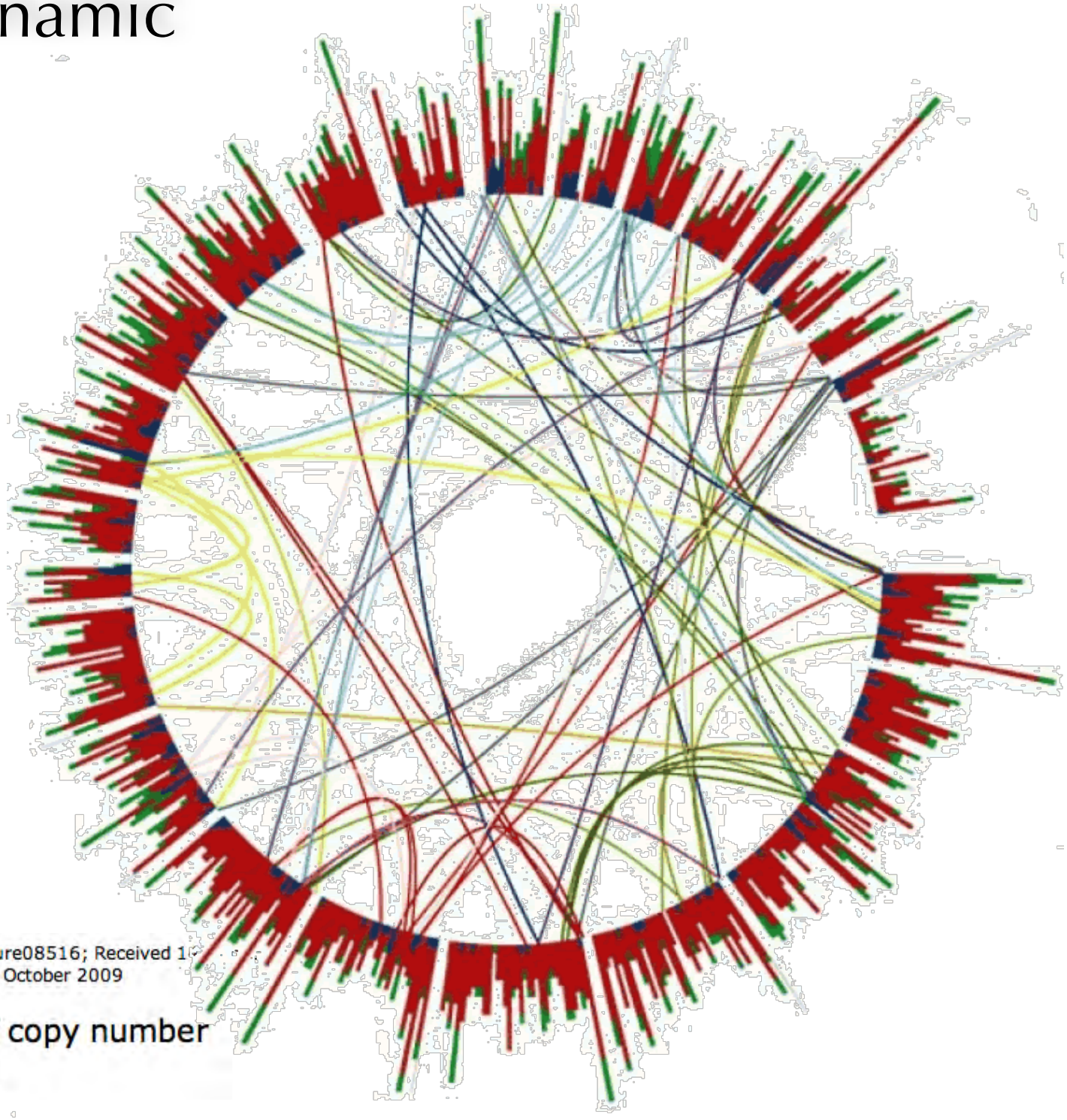
Zhao L, Saelao P, Jones CD, Begun DJ.

Abstract

Comparative genomic analyses have revealed that genes may arise from ancestrally non-genic sequence. However, the origin and spread of these de novo genes within populations remain obscure. We identified 142 segregating and 106 fixed testis-expressed de novo genes in a population sample of Drosophila melanogaster. These genes appear to derive primarily from ancestral intergenic, unexpressed open reading frames (ORFs), with natural selection playing a significant role in their spread. These results reveal a heretofore-unappreciated dynamism of gene content.

PMID: 24457212 [PubMed - as supplied by publisher]

Genomes are dynamic



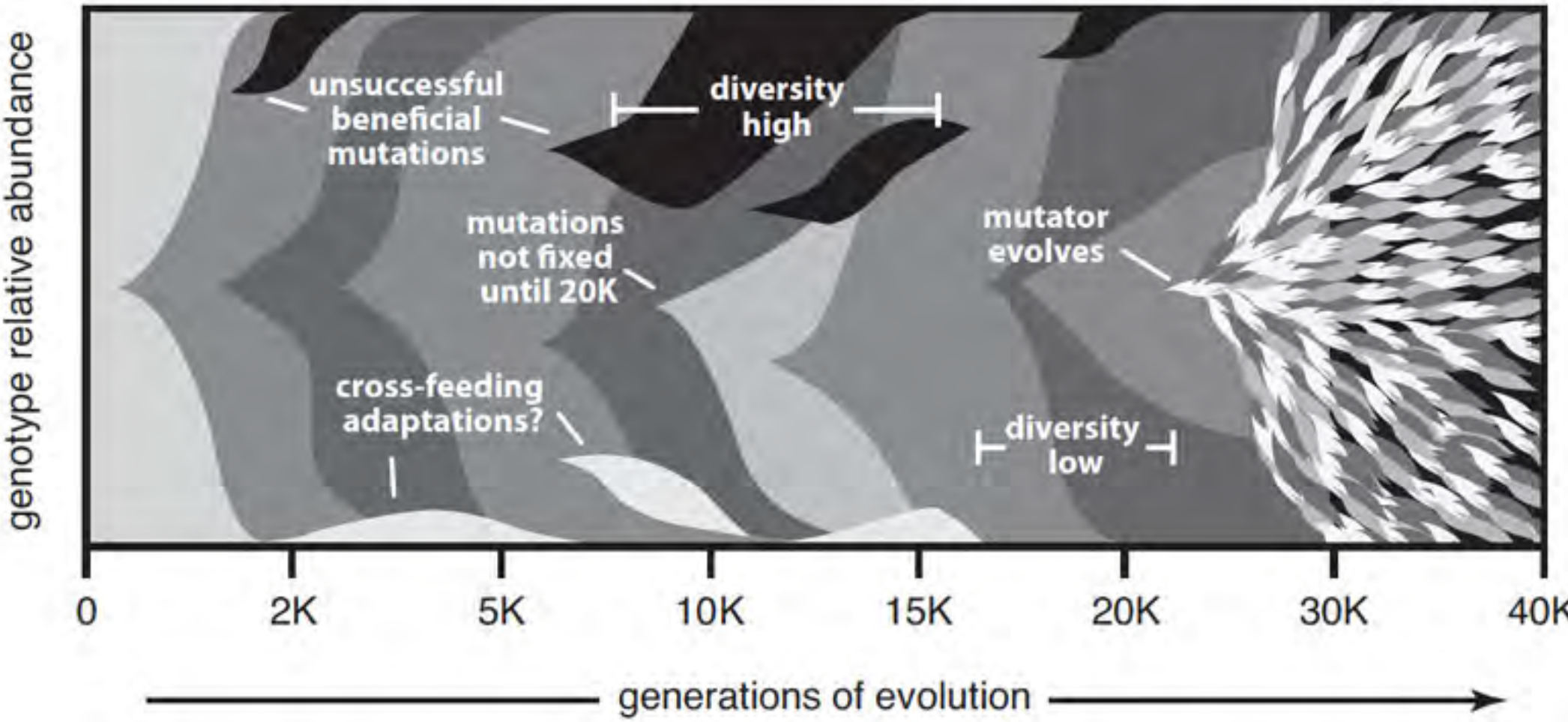
Nature **464**, 704-712 (1 April 2010) | doi:10.1038/nature08516; Received 1
2009; Accepted 21 September 2009; Published online 7 October 2009

Origins and functional impact of copy number variation in the human genome

how does happenstance (genetic drift and such) influence evolution?

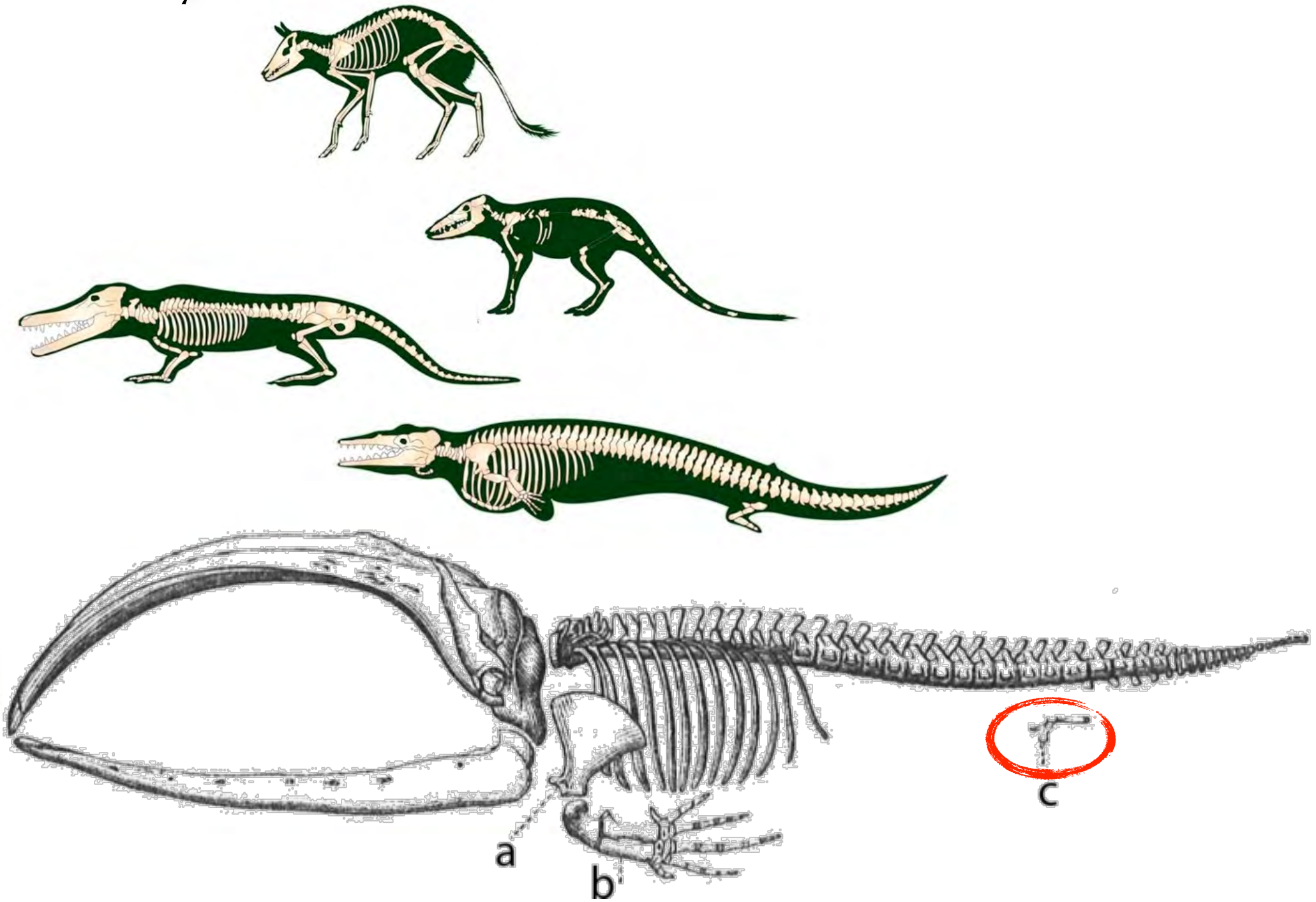
The Lenski experiment and citrate metabolism in *E.coli*

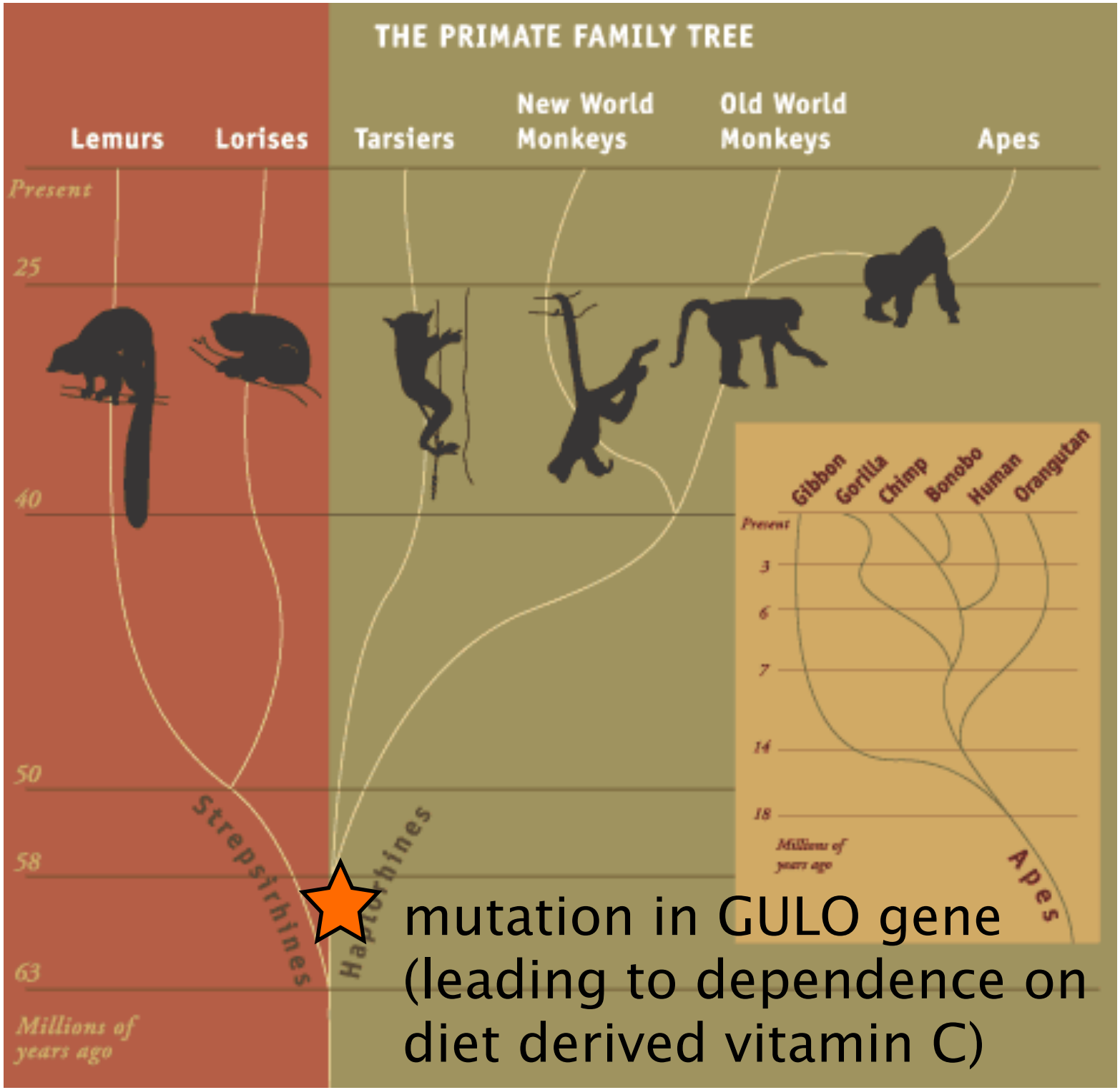
http://youtu.be/geAtbETEDko



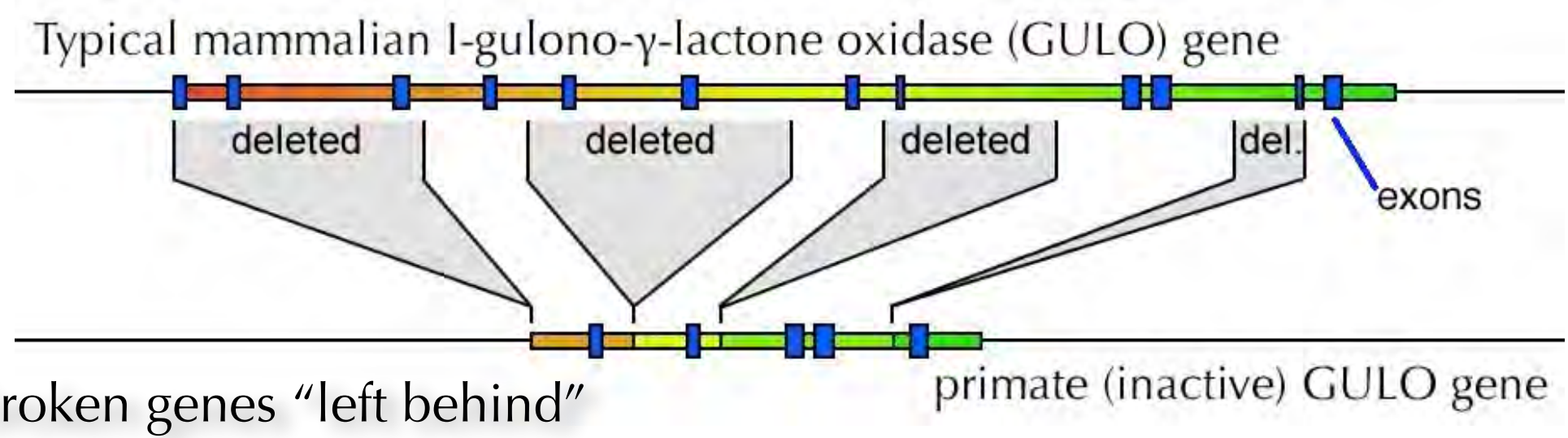
http://myxo.css.msu.edu/ecoli/genomicsdat.html

History leaves its mark…





mutation in GULO gene (leading to dependence on diet derived vitamin C)



broken genes “left behind”

Available online at www.sciencedirect.com
SCIENCE DIRECT®
Genomics 83 (2004) 482–492
GENOMICS
www.elsevier.com/locate/ygeno

Functional rescue of vitamin C synthesis deficiency in human cells using adenoviral-based expression of murine L-gulono-γ-lactone oxidase☆

Michael N. Ha,[a] Frank L. Graham,[a,b] Chantalle K. D'Souza,[a] William J. Muller,[a,b] Suleiman A. Igdoura,[a,b] and Herb E. Schellhorn[a,*]

[a] *Department of Biology, McMaster University, Hamilton, ON, Canada L8S 4K1*
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Received 16 July 2003; accepted 20 August 2003

how do evolutionary mechanisms conspire to create novel traits, structures, behaviors, species?

A pessimistic estimate of the time required for an eye to evolve

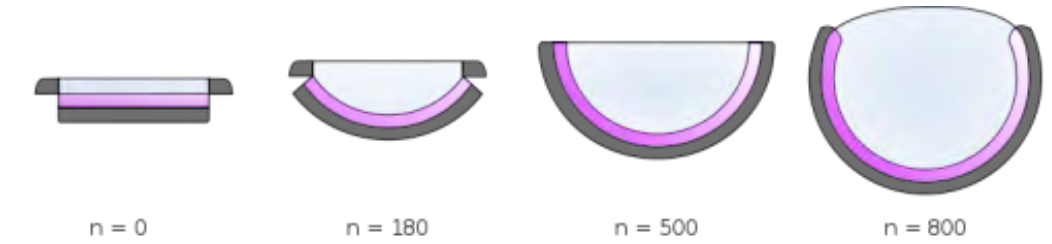
DAN-E. NILSSON[1] AND SUSANNE PELGER[2]

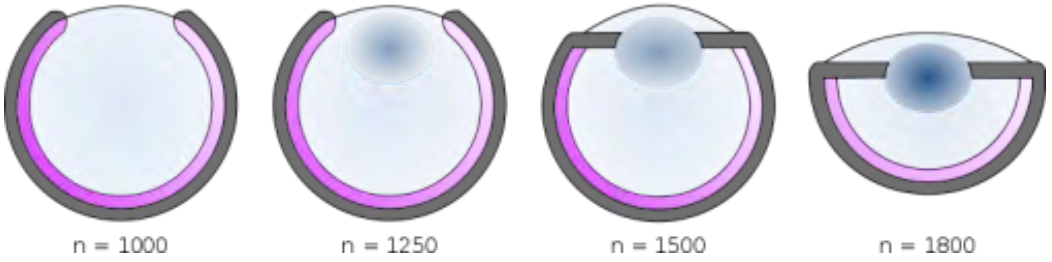
[1] *Department of Zoology, Lund University, Helgonavägen 3, S-223 62 Lund, Sweden*
[2] *Department of Genetics, Lund University, Sölvegatan 29, S-223 62 Lund, Sweden*

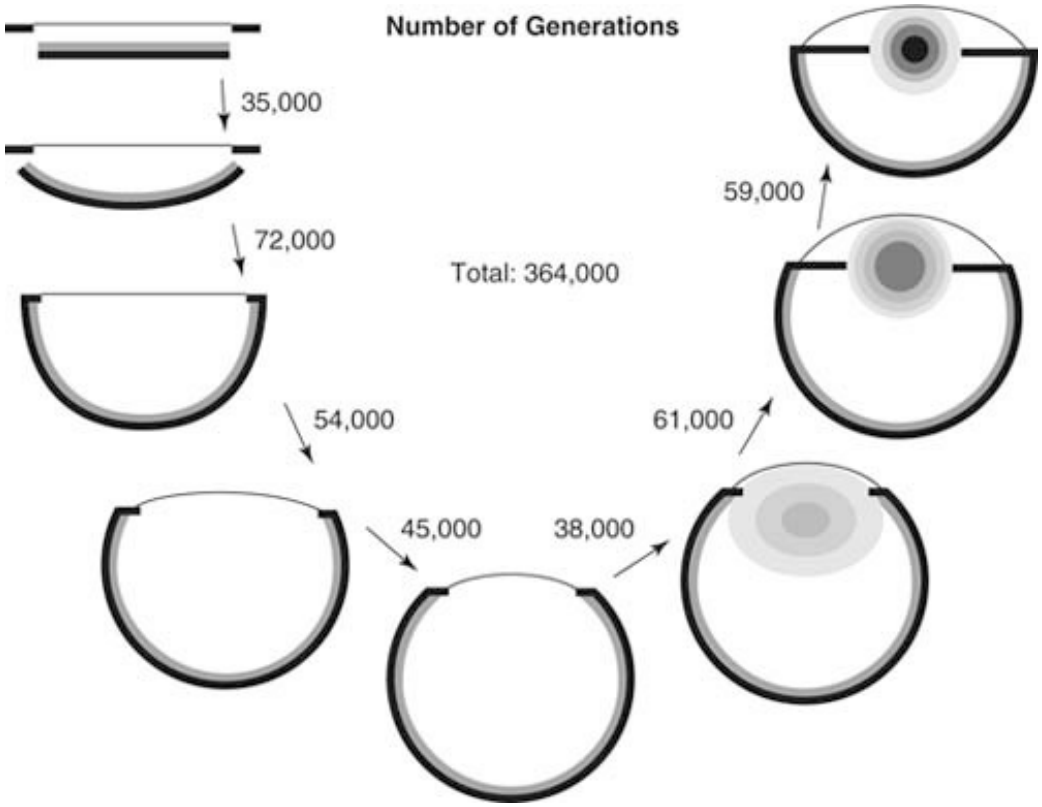
SUMMARY

Theoretical considerations of eye design allow us to find routes along which the optical structures of eyes may have evolved. If selection constantly favours an increase in the amount of detectable spatial information, a light-sensitive patch will gradually turn into a focused lens eye through continuous small improvements of design. An upper limit for the number of generations required for the complete transformation can be calculated with a minimum of assumptions. Even with a consistently pessimistic approach the time required becomes amazingly short: only a few hundred thousand years.

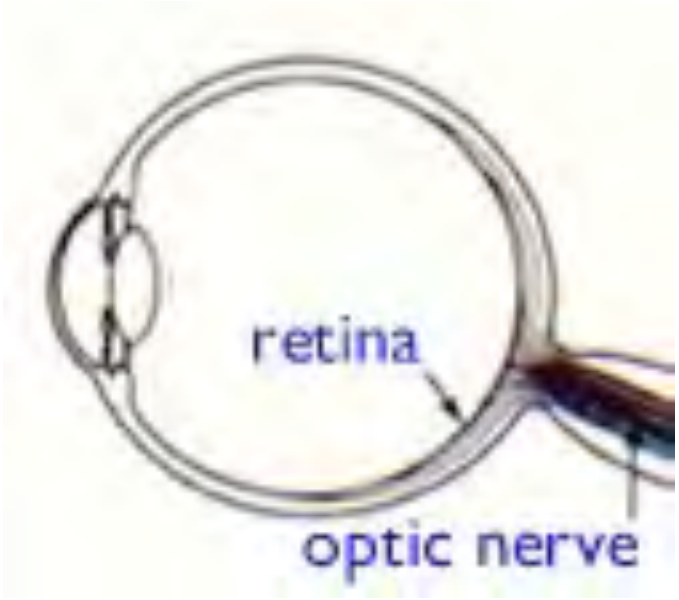
PROCEEDINGS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES


n = 0
n = 180
n = 500
n = 800

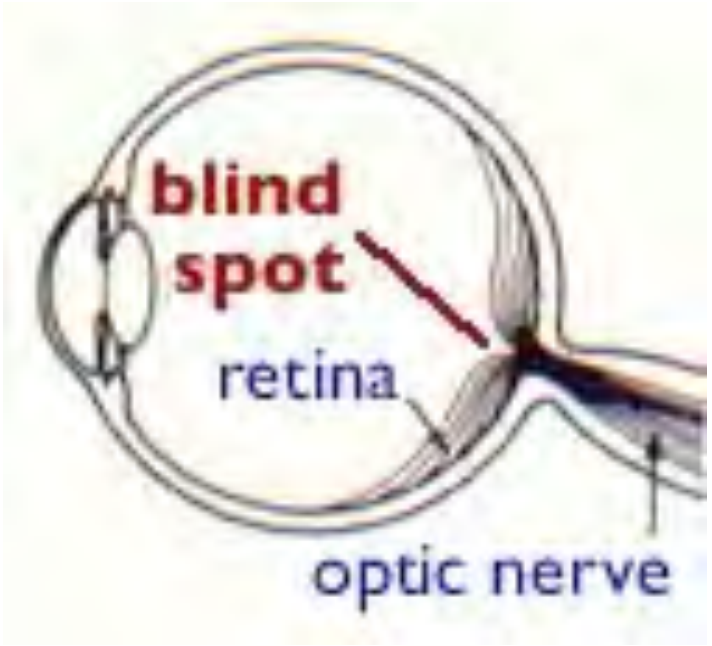

n = 1000
n = 1250
n = 1500
n = 1800


Number of Generations
35,000
72,000
54,000
45,000
38,000
61,000
59,000
Total: 364,000

Multiple (independent) pathways to complex eyes.

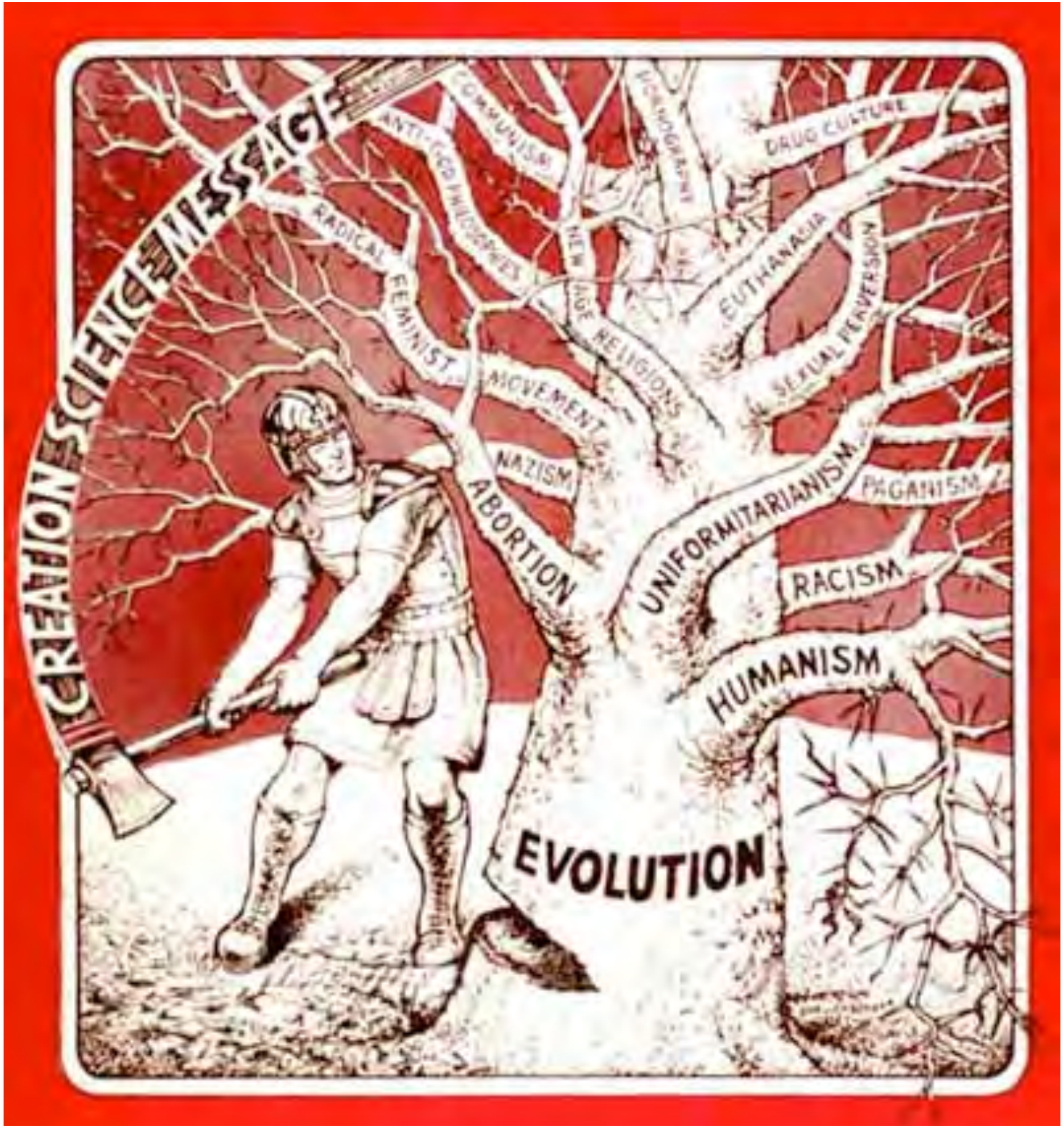


octopus



human

A second issue: evolutionary amorality

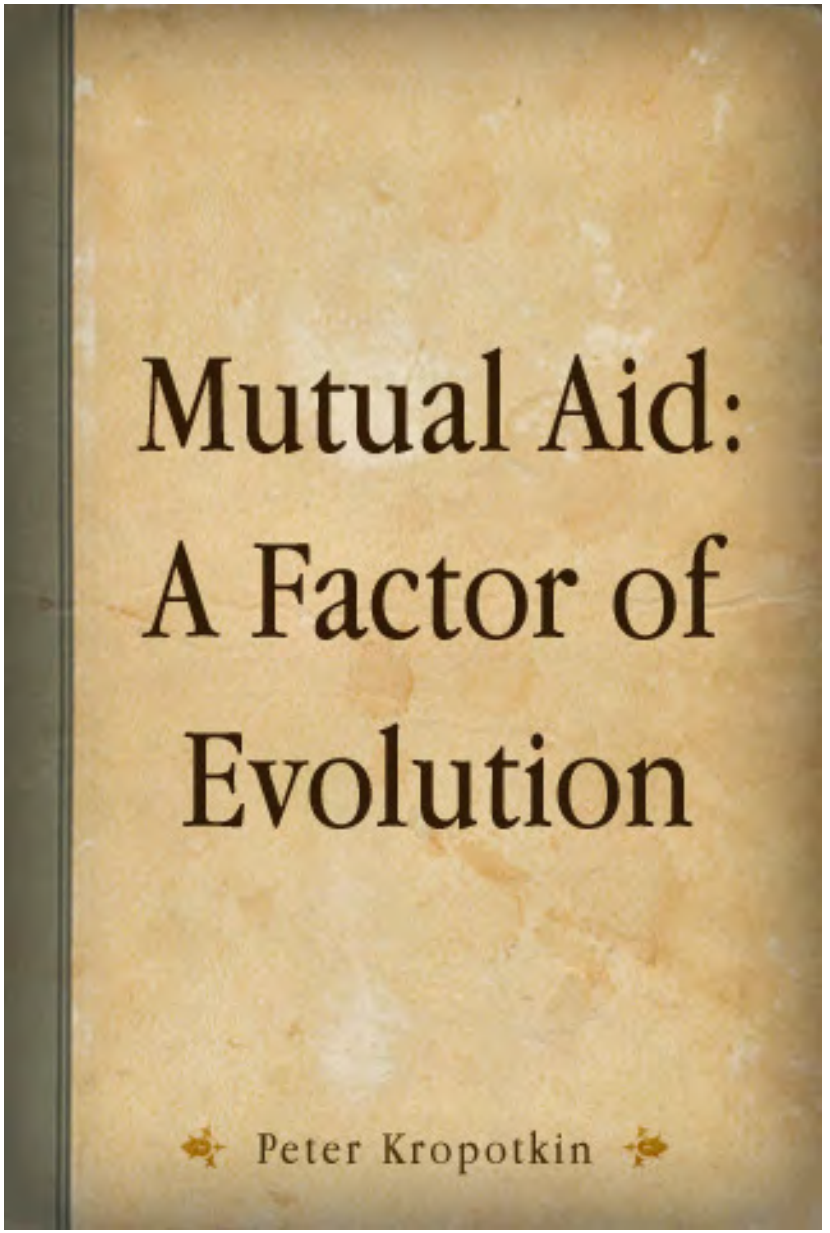

CREATION SCIENCE MESSAGE
RADICAL FEMINIST MOVEMENT
ANTI-GOD PHILOSOPHIES
COMMUNISM
NEW AGE RELIGIONS
PSYCHOLOGIES
DRUG CULTURE
EUTHANASIA
SEXUAL PERVERSION
NAZISM
ABORTION
UNIFORMITARIANISM
PAGANISM
RACISM
HUMANISM
EVOLUTION

Explicitly address "evolutionary amorality"

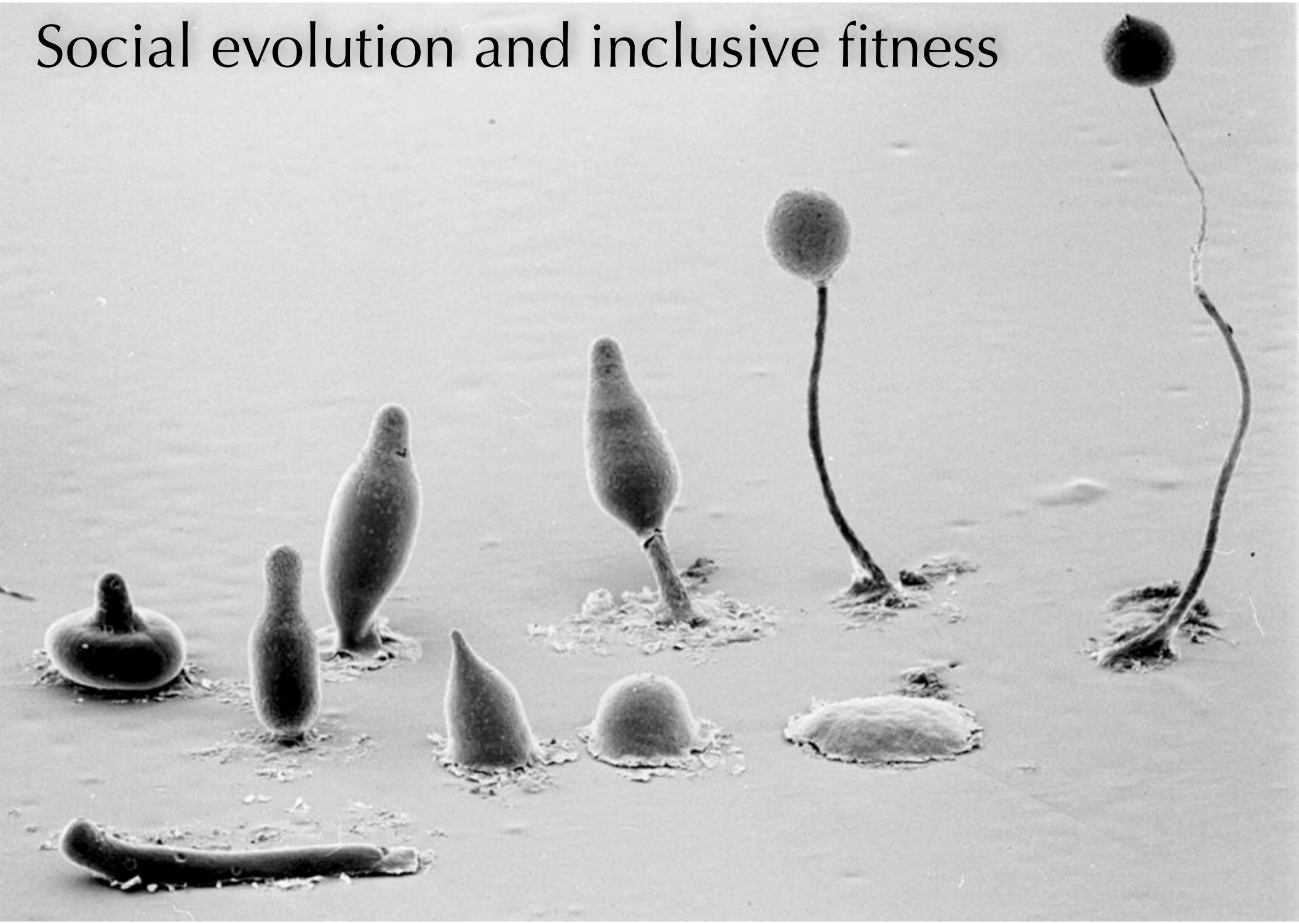
present evolutionary mechanisms leading to of altruism, love, kindness & community.

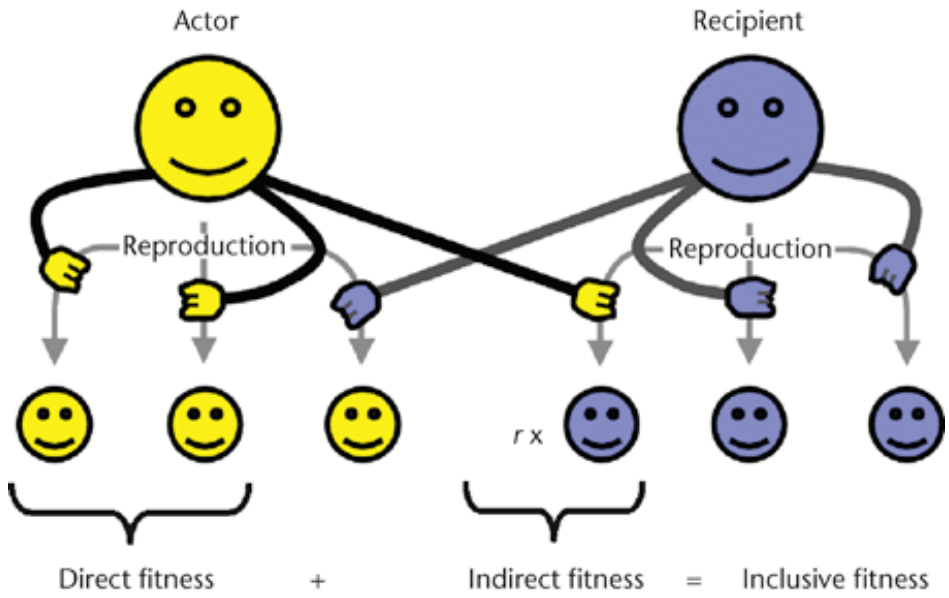
PETER KROPOTKIN

Geographer, Biologist, Anarchist
December 09, 1842 to February 08, 1921



Social evolution and inclusive fitness





inclusive fitness and social processes

multicellularity and differentiation
sexual reproduction
parental care
social organization
eusocial species (bees and (naked) mole rats)

VOLUME 80, NO. 1 THE QUARTERLY REVIEW OF BIOLOGY MARCH 2005

THE EVOLUTION OF PARENTAL CARE

MART R. GROSS
Department of Zoology, University of Toronto
Toronto, Ontario M5S 3G5 Canada
E-MAIL: MGROSS@ZOO.UTORONTO.CA

Parent-Offspring Conflict

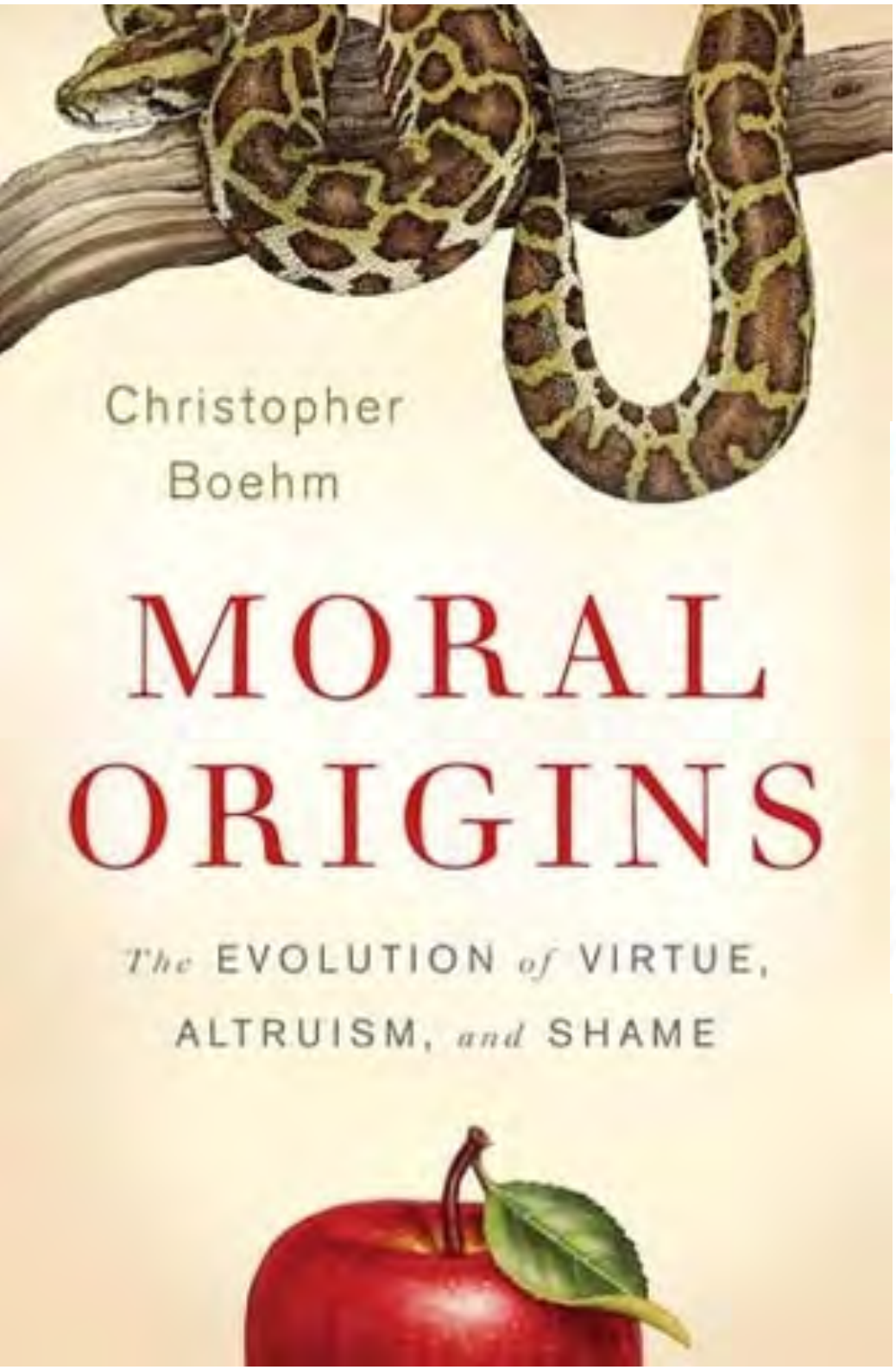
ROBERT L. TRIVERS

Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts 02138

AMER. ZOOL., 14:249-264 (1974).

maternal care in a stink bug

marsupial frog (gastrotheca)



Social Cognition

REVIEW

Evolution in the Social Brain

R. I. M. Dunbar* and Susanne Shultz

The evolution of unusually large brains in some groups of animals, notably primates, has long been a puzzle. Although early explanations tended to emphasize the brain's role in sensory or technical competence (foraging skills, innovations, and way-finding), the balance of evidence now clearly favors the suggestion that it was the computational demands of living in large, complex societies that selected for large brains. However, recent analyses suggest that it may have been the particular demands of the more intense forms of pairbonding that was the critical factor that triggered this evolutionary development. This may explain why primate sociality seems to be so different from that found in most other birds and mammals: Primate sociality is based on bonded relationships of a kind that are found only in pairbonds in other taxa.

Mirror neurons and the social nature of language: The neural exploitation hypothesis

Vittorio Gallese
University of Parma, Parma, Italy

SOCIAL NEUROSCIENCE, 2007, 00 (00), 1–17

Psychology Press
Taylor & Francis Group

This paper discusses the relevance of the discovery of mirror neurons in monkeys and of the mirror neuron system in humans to a neuroscientific account of primates' social cognition and its evolution. It is proposed that mirror neurons and the functional mechanism they underpin, embodied simulation, can ground within a unitary neurophysiological explanatory framework important aspects of human social cognition. In particular, the main focus is on language, here conceived according to a neurophenomenological perspective, grounding meaning on the social experience of action. A neurophysiological hypothesis—the "neural exploitation hypothesis"—is introduced to explain how key aspects of human social cognition are underpinned by brain mechanisms originally evolved for sensorimotor integration. It is proposed that these mechanisms were later on adapted as new neurofunctional architecture for thought and language, while retaining their original functions as well. By neural exploitation, social cognition and language can be linked to the experiential domain of action.

Psychologists: Physical and Social Pain Hurts the Same Way

People have long described experiences of social rejection or loss with words indicating physical pain, and only recently have scientists discovered evidence that social pain may actually be processed by the brain region that monitors physical pain.

BY CHRISTINE HSU | FEBRUARY 22, 2012

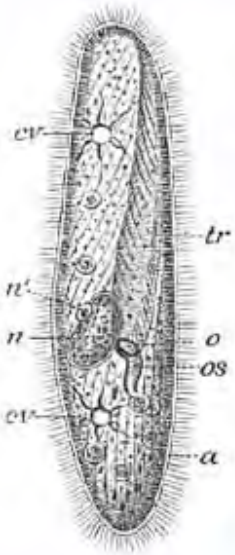
Text Size

People have long described experiences of social rejection or loss with words indicating physical pain, and only recently have scientists discovered evidence that social pain may actually be processed by the brain region that monitors physical pain.

Biofundamentals™ (MCDB 1150) is an attempt to build a more conceptually coherent and rigorous introductory course in modern biology (testimonial)

We use an interactive teaching style and web tools to "get Socratic". You will need to read and engage with the text and embedded assignments **before** class.

To insure that you do, highlighter functions are incorporated throughout. [**watch** this video on how to use the text].



As you read you can leave questions and comments and respond to the comments left by other students. Class time is spent considering the most difficult ideas.

Our goal is to help students master and apply difficult ideas, not to sort students..

We use novel testing strategies that include "I know it now!" tests designed to allow students to demonstrate their understanding of key ideas.

Biofundamentals™ is part of a larger course and curricular redesign effort that includes Chemistry, life, the universe & everything (for which we have data for improved student learning!)

link to: *rethinking the cell & molecular biology curriculum*

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MUSEUM OF NATURAL HISTORY
UNIVERSITY OF COLORADO

Upcoming Lecture:

What Darwin Didn't Know
The New Science of Evo-Devo and the Origins of Animal Diversity

Daniel Medeiros, Ph.D.
Department of Ecology and Evolutionary Biology
University of Colorado - Boulder

Thursday, February 20, 2014 - 7:00 pm
University of Colorado Museum of Natural History
Paleontology Hall