Design By Evolution

Education and Outreach on the
Creative Potential for Random Mutation
and Natural Selection

The Problem

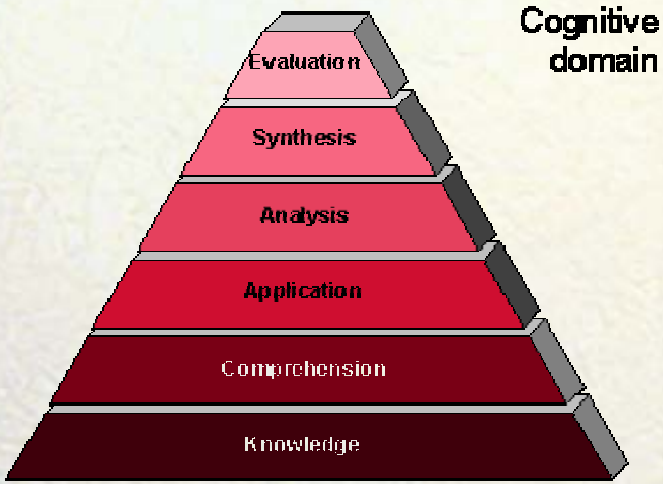
- Public resistance to evolution…
  - …and to science in general (e.g. GMO foods)
- Science literacy
  - Surveys and Polls
  - International Assessment Tests: PISA, TIMMS, NAEP

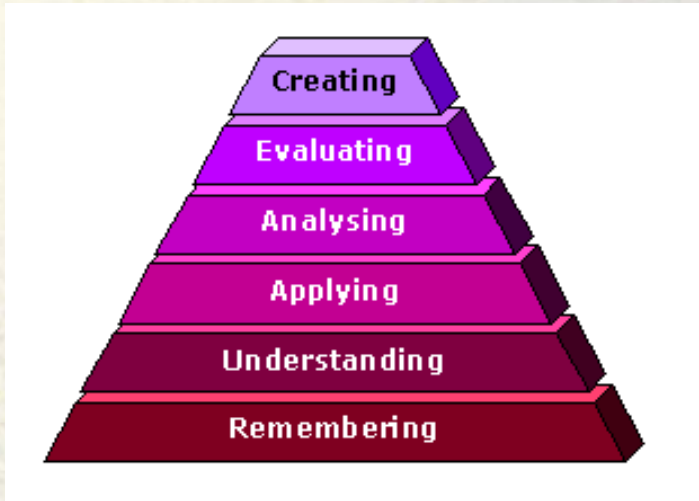
Programme for International Student Assessment (PISA)

- It compares 15 year olds for science and math literacy among 57 countries
- The US consistently ranks average or below, particularly at higher levels of learning..,
- …whereas Canada consistently ranks near the top

Country	Overall Science	Identifiying Scientific Issues	Explaining Phenomena Scientifically	Using Scientific Evidence	Mathematics
Canada	3/57 Above Average	5/57 Above Average	4/57 Above Average	4/57 Above Average	7/57 Above Average
United States	29/57 Below Average	25/57 Average	31/57 Below Average	30/57 Below Average	35/57 Below Average

Levels of Learning





Bloom 1956 Anderson & Krathwohl 2001

- US 15 year olds were statistically worse at understanding and applying scientific concepts than at remembering them
- Does our educational system not put enough emphasis on higher level learning? ▪

What's Science?

- An attempt to explain how the universe works
- These explanations (hypotheses) must be testable empirically

Scientific Method

- **Phenomenon:** something in nature that we wish to explain
- **Hypotheses:** educated guesses of cause and effect
- **Theory:** the conceptual framework within which our hypotheses are framed
- **Predictions:** logical deductions of our hypotheses
- **Tests:** empirical falsification or verification of our predictions

Genetic similarity data can be used to test hypotheses of past relationships

- Parentage: Who sired whom?
  - Theory: Mendel's Law of Segregation
  - Prediction: offspring get half their alleles from Mom and the other half from Dad
- Pedigrees: Whole families
  - Theory: Mendel's Law of Segregation
  - Prediction: the more closely related two individuals are, the more alleles they will share (e.g. full sibs share 50% of their alleles, half sibs 25%, first cousins 12.5%, etc.)

Genetic similarity data can be used to test hypotheses of past relationships

- Phylogeny: The tree of life
  - Relationships among populations
  - Relationships among species
    - Theory: reproductively isolated populations or species will diverge genetically, and the longer two such populations or species have been reproductively isolated, the greater this divergence will be.
    - Prediction: the more closely related two populations or species are, the more similar their DNA sequences will be

Darwin's Natural Selection

- Individuals vary in appearance, or phenotype.
- Some of this variation is passed on from parent to offspring, or is due to genotype.
- Populations produce more offspring than the environment can support; thus, there is a struggle for existence.
- Some individuals, due to their phenotypes, have higher rates of survival &/or reproduction than other individuals.
- Those favored phenotypes, if heritable, will increase in frequency in the next generation.

Random Mutation and Natural Selection

- Natural selection acts on existing genetic variation, and reduces it.
- Where does new genetic variation come from?
- Mutation

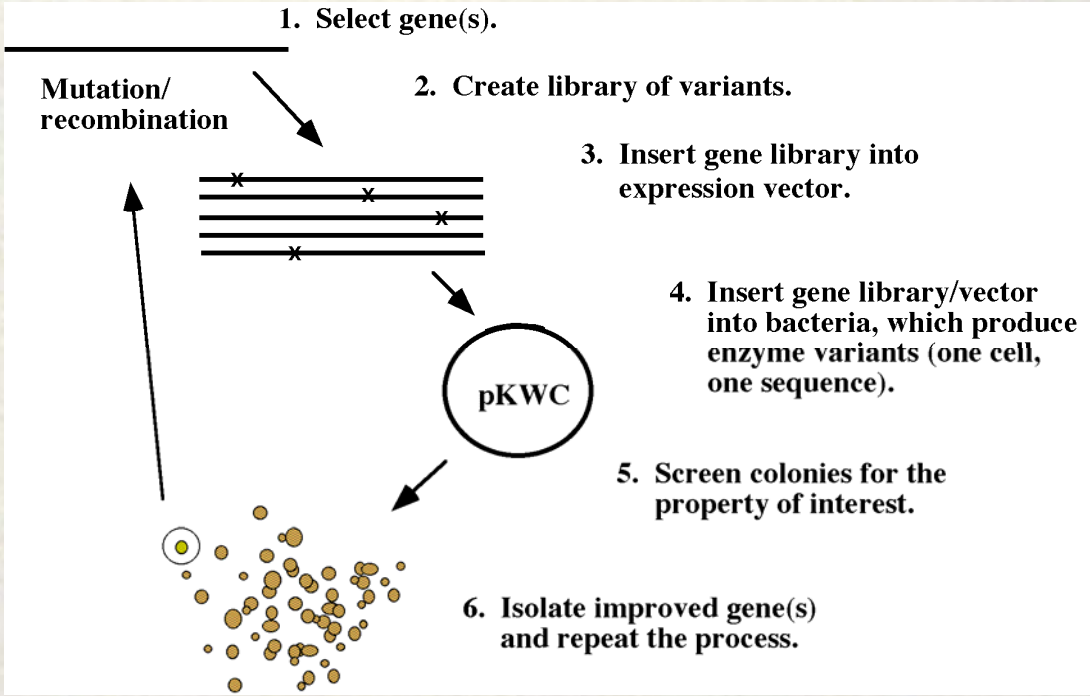
Practical Applications of Random Mutation and Nonrandom Selection

- Directed Enzyme Evolution
  - New Scientist Article: The universal constructer set:
- Evolutionary Algorithms in Engineering
  - New Scientist Article: Evolutionary algorithms now surpass human designers

Directed Enzyme Evolution

(link)

Through a process of inserting a gene of interest into a bacterium, mutant screens, and selection for improved function of that gene product, scientists are able to improve on nature in molecular design



Evolutionary Algorithms

(link)

- Define a vector whose elements represent “genes,” and whose values determine the “phenotype,” and a function that translates “genotype” into “phenotype”
- Define a function that measures performance, “fitness,” and which “genotypes” sire the next generation
- Reproduction with mutation and recombination
- Evaluate offspring fitness
- Lather, rinse, repeat

EAs have been used to design all sorts of things

- Aircraft Wings (link)
- Aircraft Traffic Flow (link)
- Circuits (link)
  - Sometime these yield unexpected results. In one case, the engineers wanted the EA to evolve an oscillating circuit, but instead it evolved a radio that picked up an oscillating radio signal already present in the environment (link)!
- Even improvisation in jazz (GenJam)!

What About Intelligent Design?
ID's *modus operandi*

- Try to prove that some evolutionary phenomenon is theoretically impossible, e.g. the evolution of irreducible complexity..,
- …and have ID win by default
- Thus far, ID is untestable

What's wrong with this picture?

- Can't prove a negative. Proving theoretical impossibility is logically impossible, and can be falsified by…
  - Models of possibility
  - Empirical examples of possibility
- The null hypothesis in science is, "We don't know." It isn't ID, or any other untestable hypothesis.

ID's *MO* is inspired by the following quote from Darwin's *Origin* (Ch 6)

"If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down…"

"…**But I can find out no such case**…"

Consider Irreducible Complexity (IC): (Michael Behe, Darwin's Black Box, p 39)

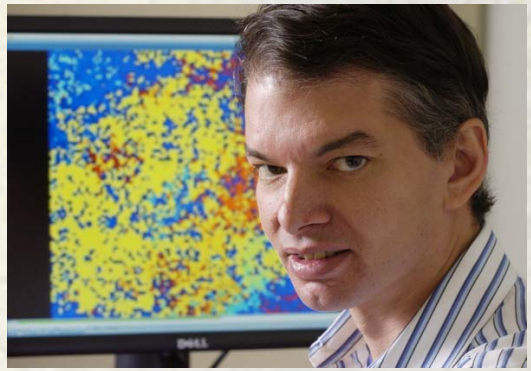
- "By irreducibly complex I mean a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning."
- "An irreducibly complex system cannot be produced directly (that is, by continuously improving the initial function, which continues to work by the same mechanism) by slight, successive modifications of a precursor system, because any precursor to an irreducibly complex system that is missing a part is by definition nonfunctional."
- "An irreducibly complex biological system, if there is such a thing, would be a powerful challenge to Darwinian evolution."

Some historical antecedents of IC…

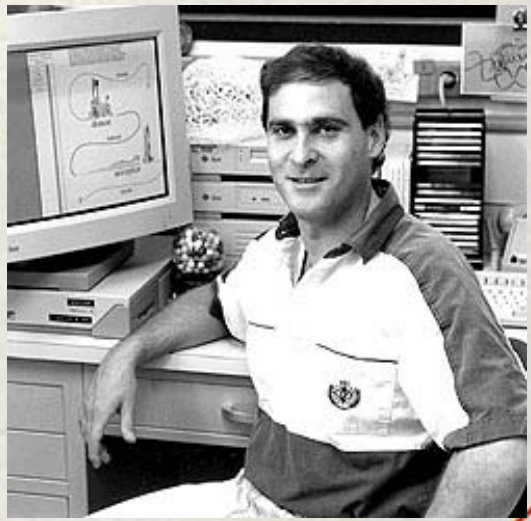
- "The whole is more than the sum of its parts" (Aristotle, *Metaphysics*)
- Design implies a designer (William Paley, *Natural Theology*)
- Interaction in statistics
  - Consider $Y = aX_1 + bX_2$ versus $Y = aX_1 + bX_2 + c(X_1X_2)$
  - X_1 and X_2 are two parts that determine the whole, Y, and a, b and c determine the magnitudes of the effects of X_1, X_2, and their non-additive interaction, respectively.
  - In the first equation, the whole is determined by the sum of its parts ($c = 0$); whereas, in the second equation, the whole is more than (other than) the sum of its parts ($c \neq 0$).

In fact, it ***is*** mathematically possible for random mutation and natural selection to give rise to "irreducible complexity"

- Chris Adami (link, link)
- Adami, C 2006. **Reducible Complexity**. Science, 312:61-63. (link)
- Adami, C, Ofria, C & Collier, TC 2000. **Evolution of Biological Complexity**. PNAS, 97:4463-4468. (link)

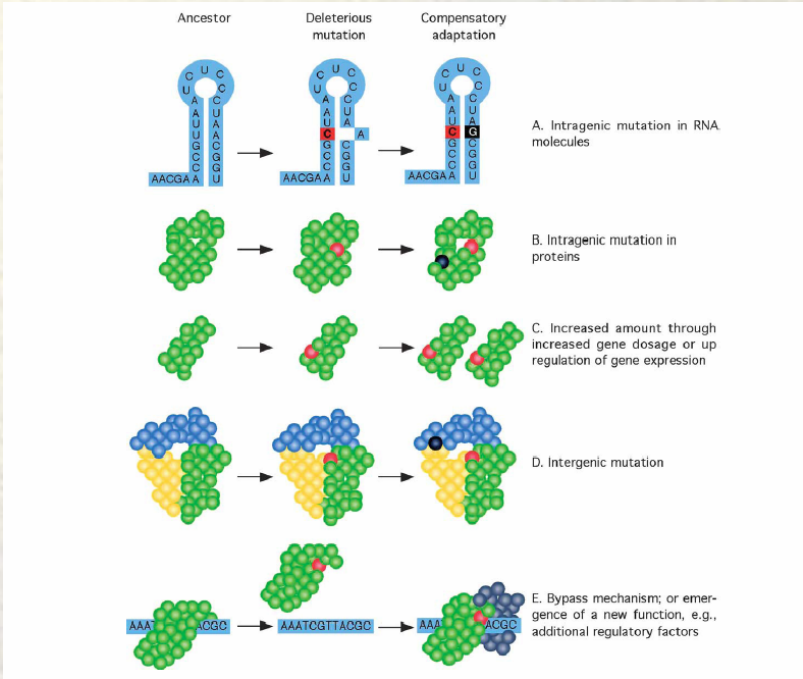


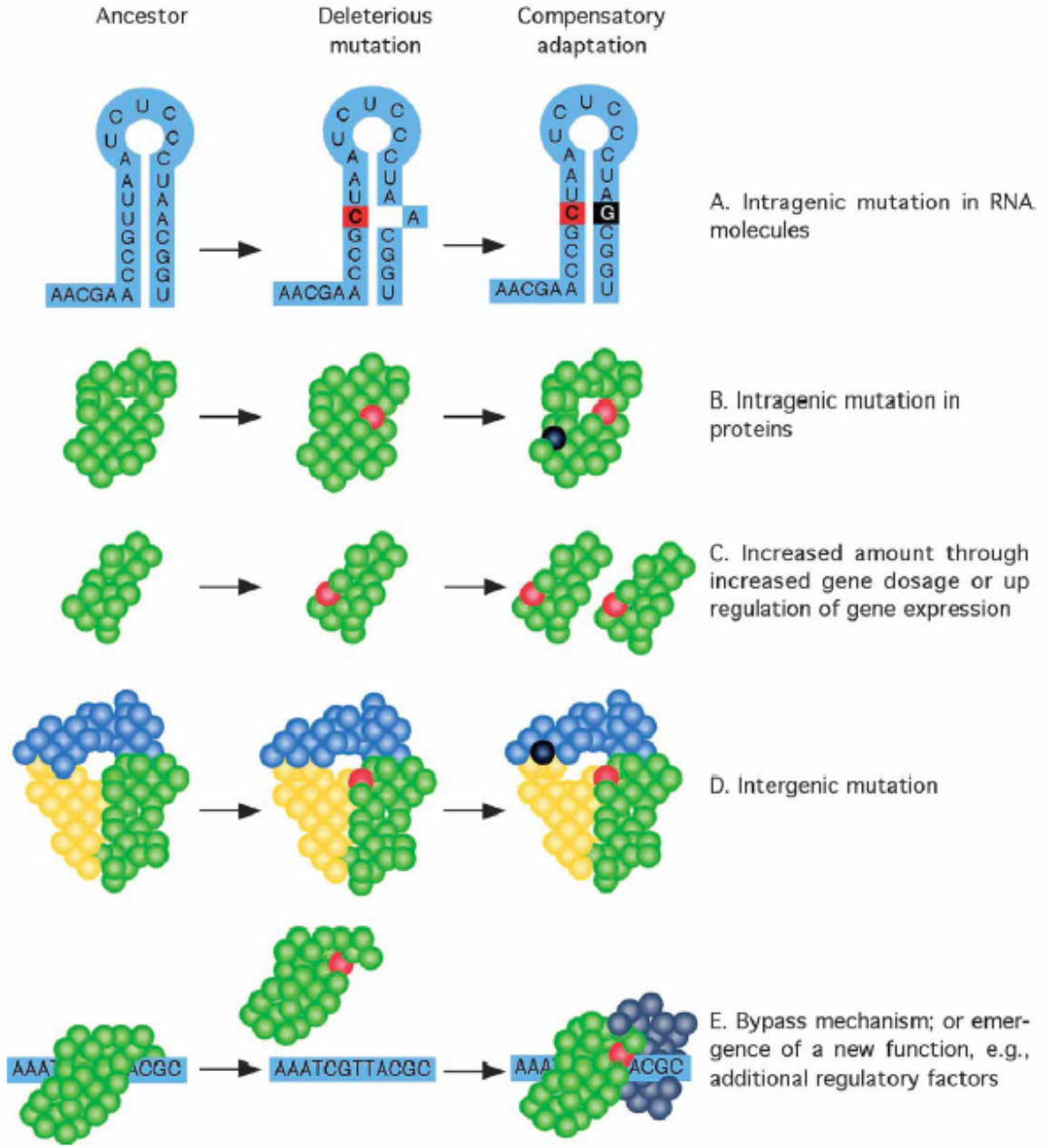
- Tom Schneider (link, link)
- Schneider, TD 2000. **Evolution of Biological Information**. Nucleic Acids Research, 28:2794-2799. (link)



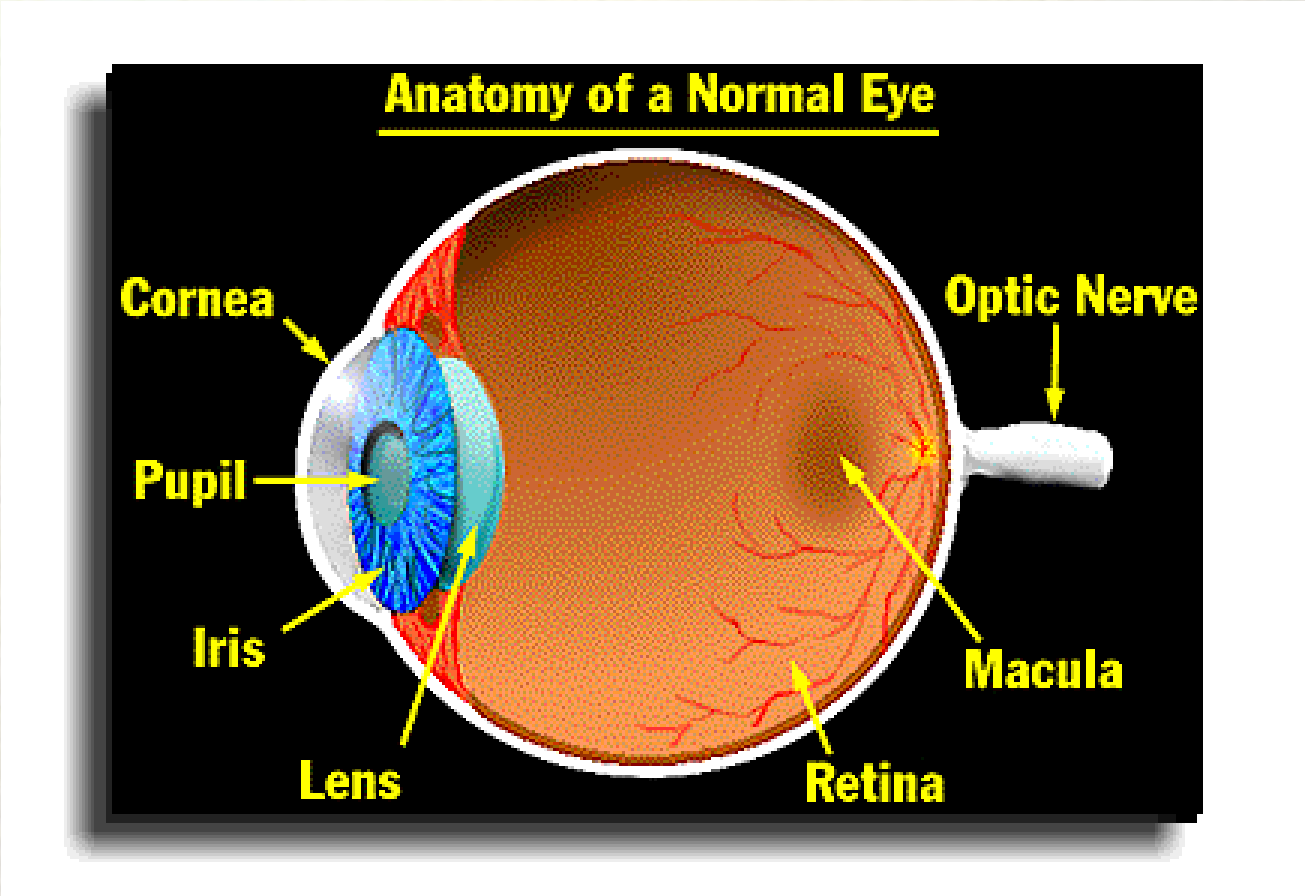
Examples: Microevolution of Irreducible Complexity

- S Maisnier-Patina & DI Andersson 2004. **Adaptation to the deleterious effects of antimicrobial drug resistance mutations by compensatory evolution.** Research in Microbiology, 155:360-9 (link)




Ancestor
Deleterious mutation
Compensatory adaptation
AACGAA
AACGAA
AACGAA
A. Intragenic mutation in RNA molecules
B. Intragenic mutation in proteins
C. Increased amount through increased gene dosage or up regulation of gene expression
D. Intergenic mutation
AAA
ACGC
AAATCGTTACGC
AAA
ACGC
E. Bypass mechanism; or emergence of a new function, e.g., additional regulatory factors

Examples on a macro scale: the eye

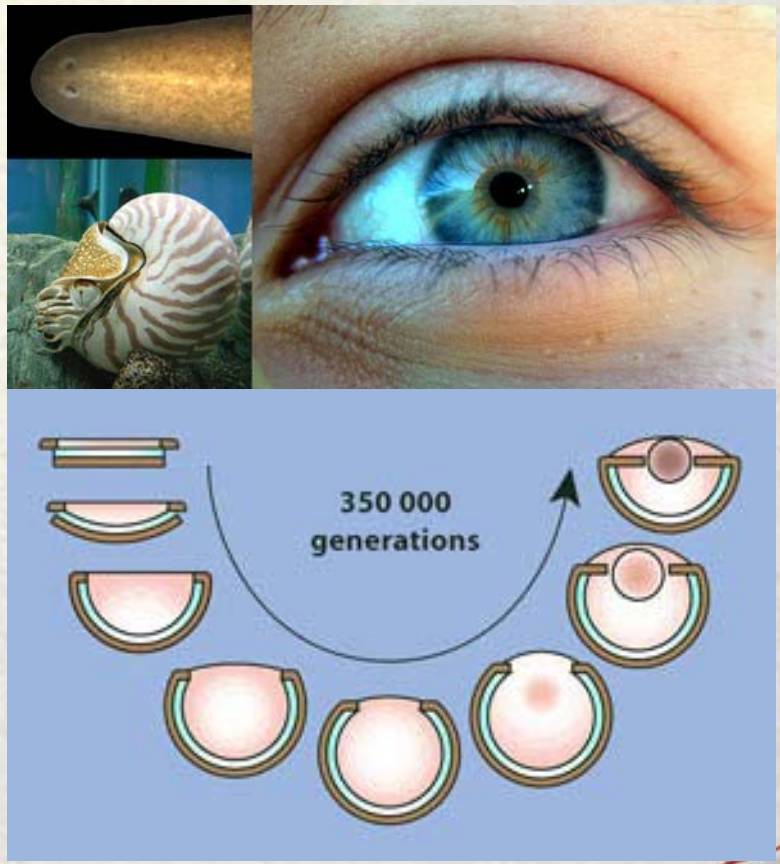


William Paley and the Eye

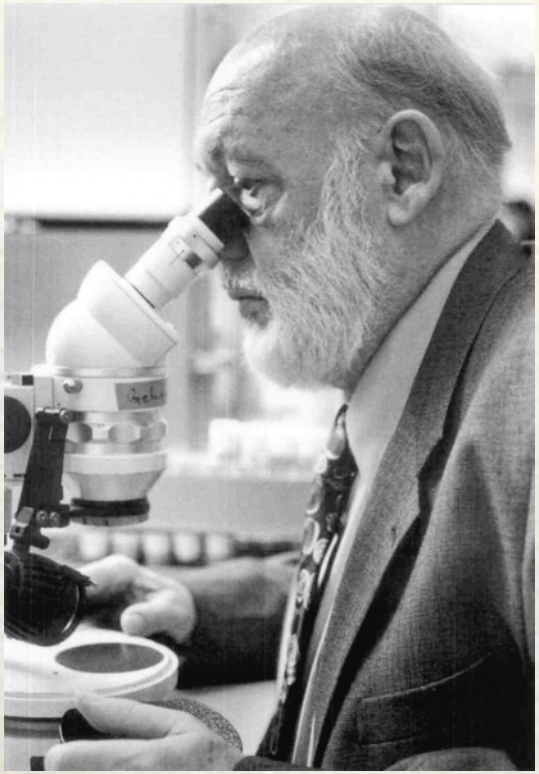
- ***Natural Theology***, 1839 (link)
- Design in nature implies a Designer
- Compares the eye with the telescope

The eye is reducibly complex

- Dan-Eric Nilsson (link)
- Video for building an eye (link, follow QuickTime or RealPlayer links)
- Nilsson and Pelger 1994: A pessimistic estimate of the time required for an eye to evolve. Proc R Soc Lond B 256: 53-58
- Photo Credits (link, link)



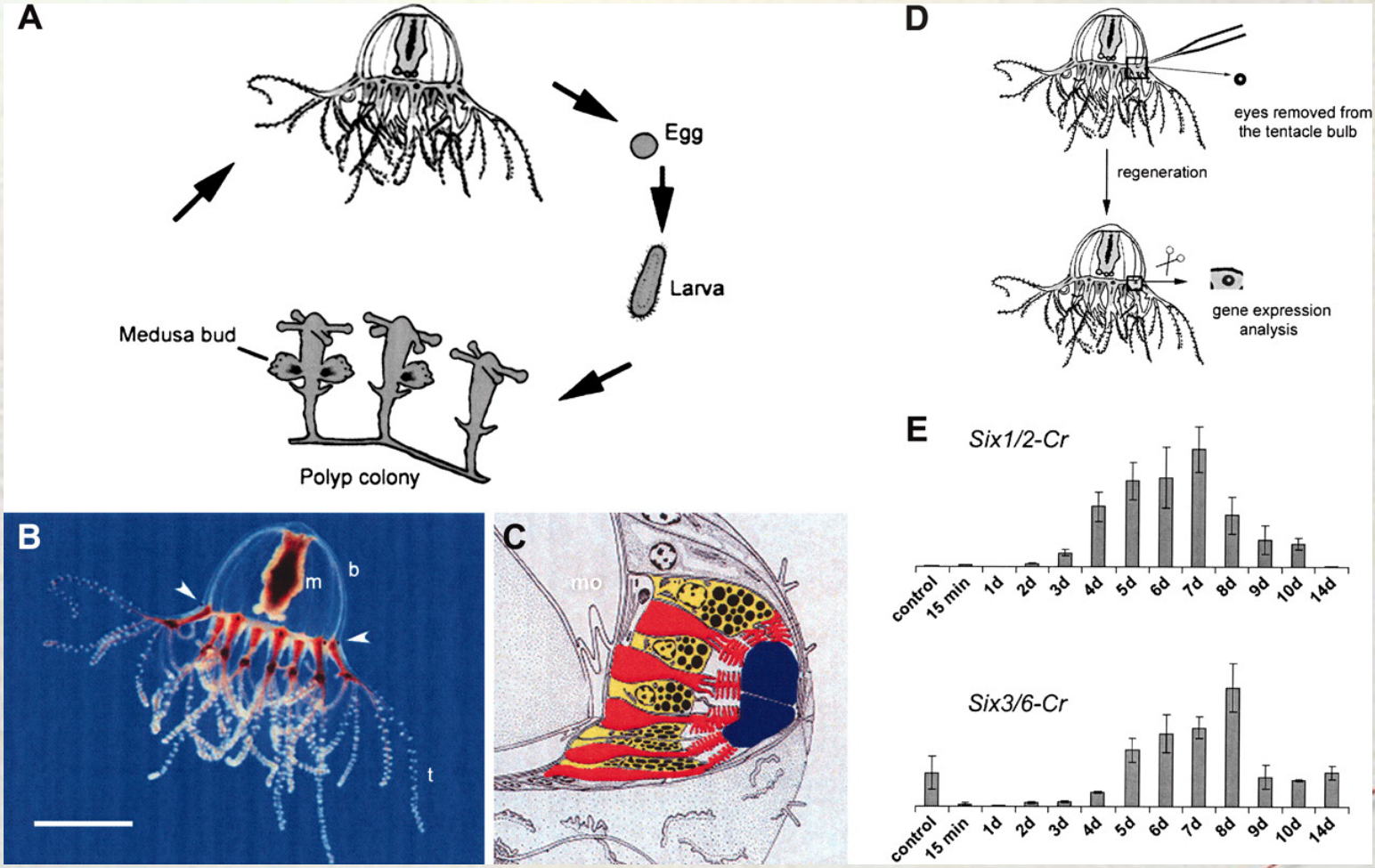
More on Eye Evolution



- Walter Gehring (link)
- Gehring WJ. 2005. **New perspectives on eye development and the evolution of eyes and photoreceptors.** J Hered. 96:171-84. (link)
  - Camera Eyes without CNSs
  - Eye spots without neurons
  - Eye organelles in dinoflagellates
  - Russian Doll Model

Camera eyes with no CNS

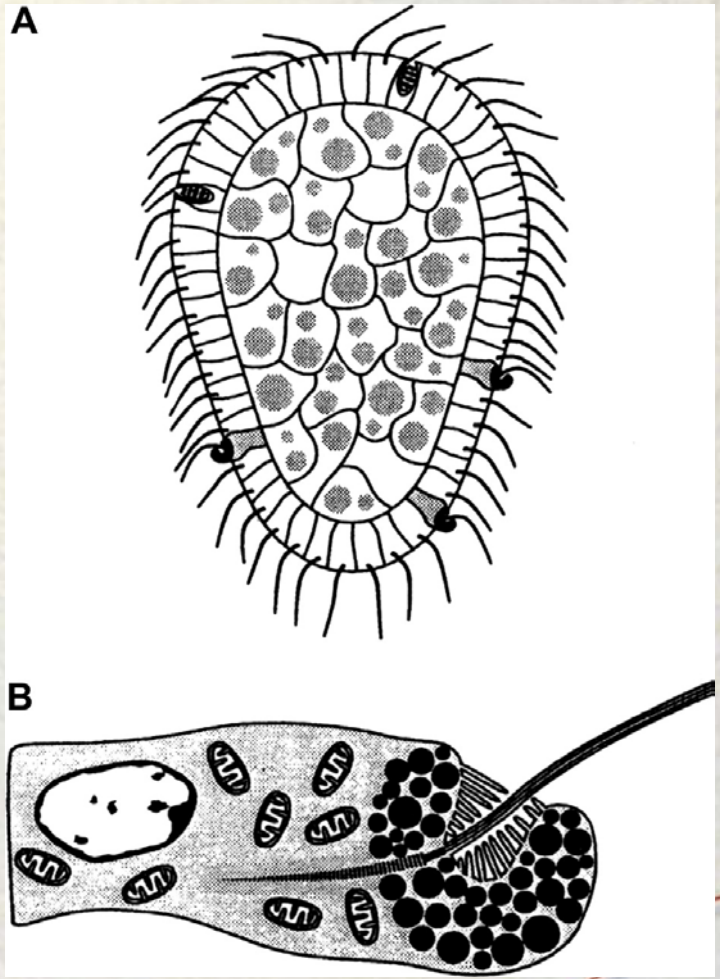
([link])



Eyes spots with no neurons

(link)

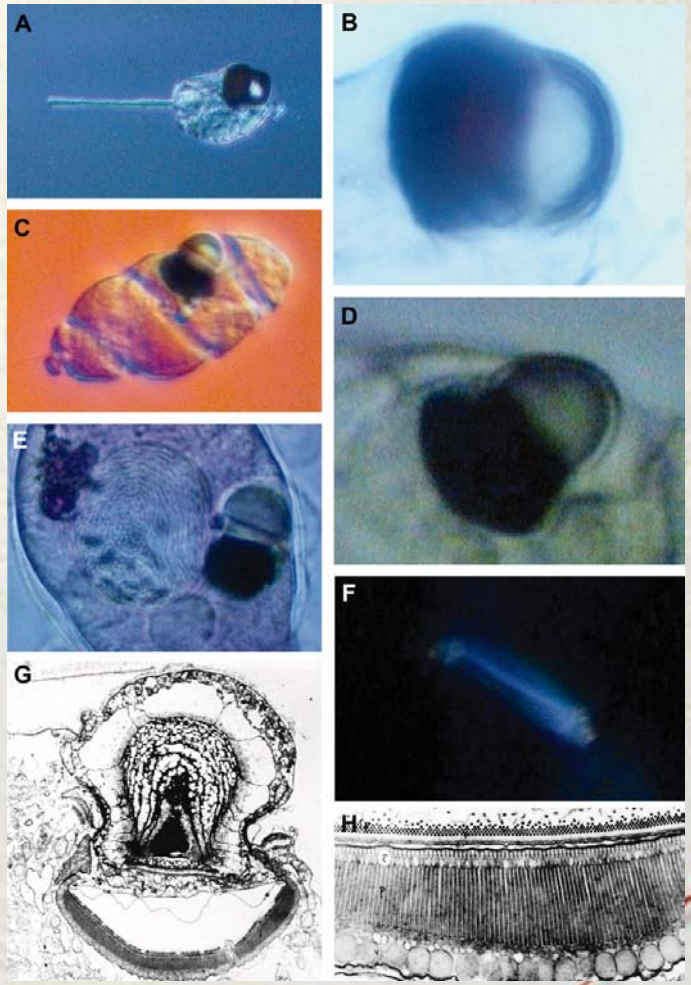
- Planula larvae have eye spots with no nerve cells



Dinoflagellate Eyes

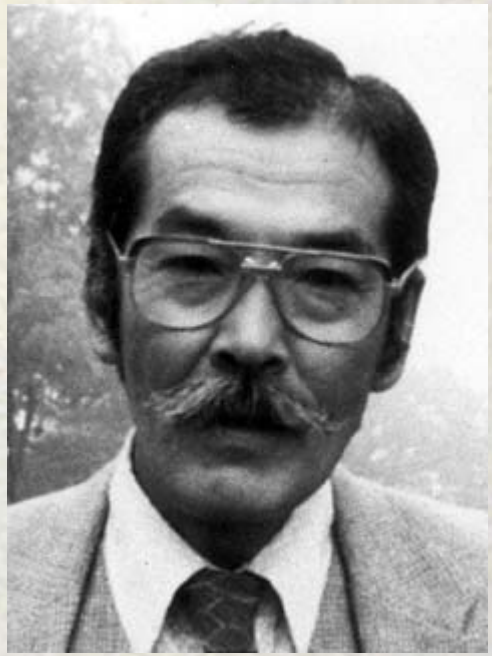
(link)

- Camera eye organelles in dinoflagellates
- Russian Doll Hypothesis: Cnidarian eyes arose from several episodes of endosymbiosis



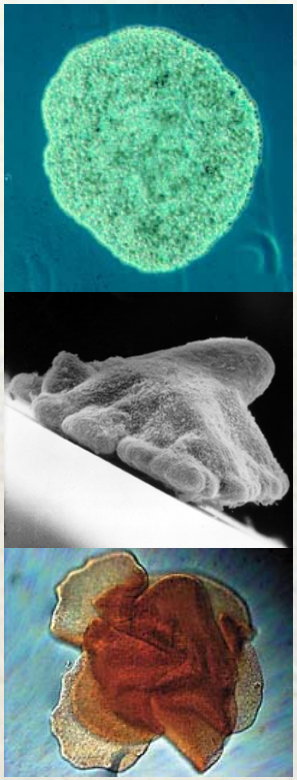
Example 2: Gene Networks

- Susumu Ohno
- The Cambrian pananimalia genome
  - "…I propose that all those diverse animals of the early Cambrian period, some 550 million years ago, were endowed with nearly identical genomes, with differential usage of the same set of genes accounting for the extreme diversities of body forms." PNAS 1996 93:8475-8. (link)
- Episodes of macroevolution often were preceded by episodes of gene duplication
  - Ohno, S 1970. Evolution by Gene Duplication. (Springer, New York).

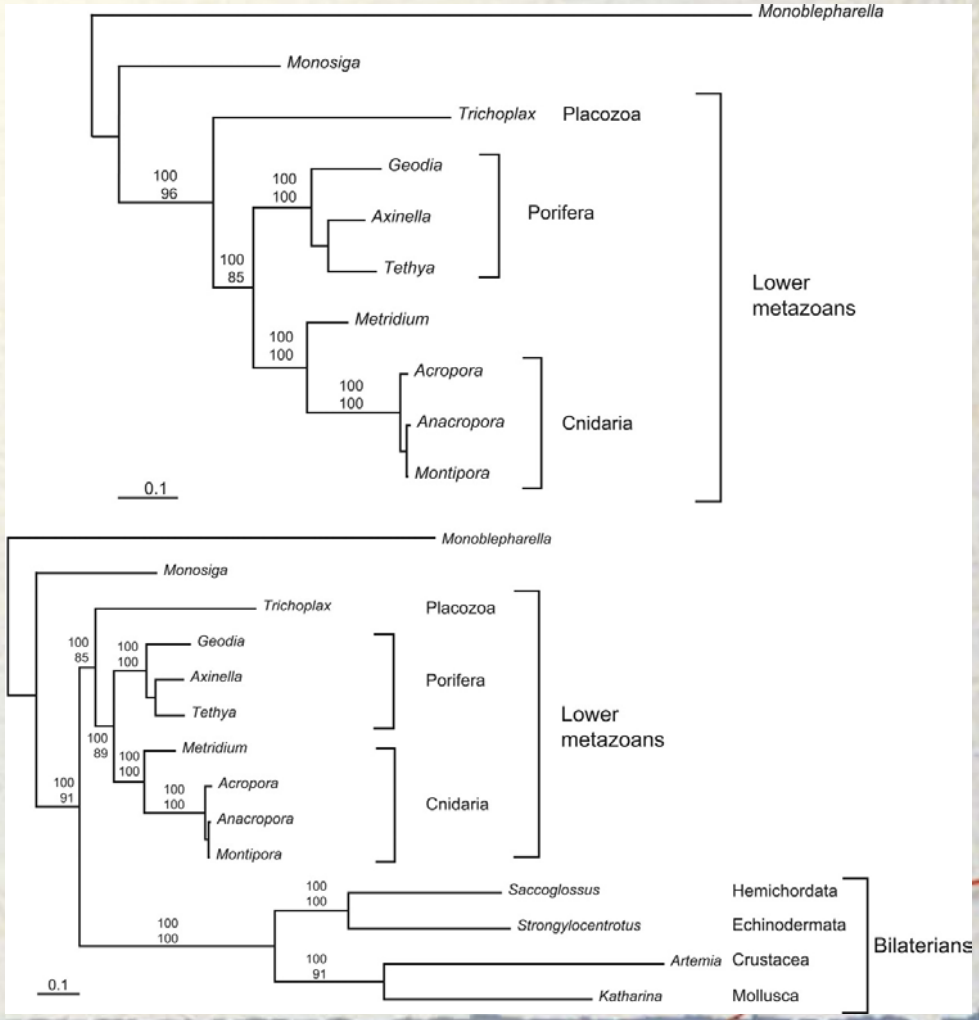


Trichoplax, the most basal metazoan

(Photos: link, link, link; Mt DNA Phylogeny: link)

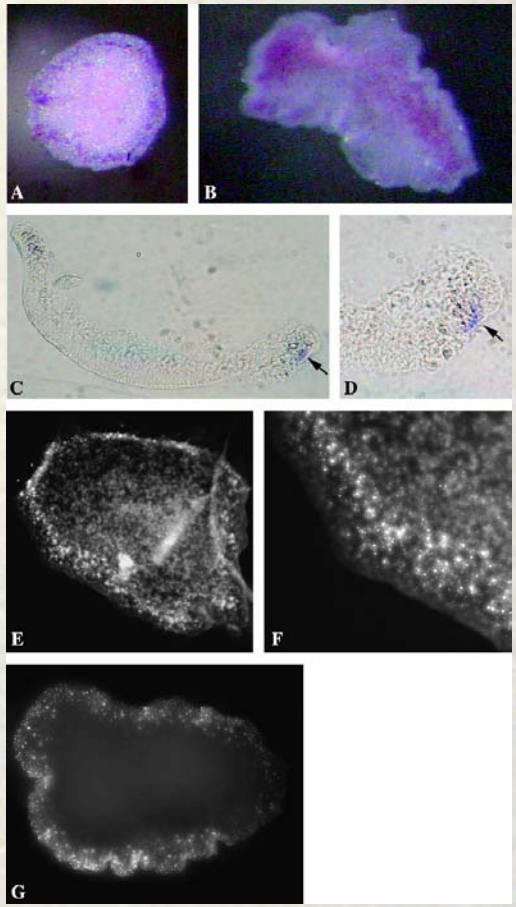


SL Dellaporta, et al 2006.
PNAS 103:8751-56 (link)



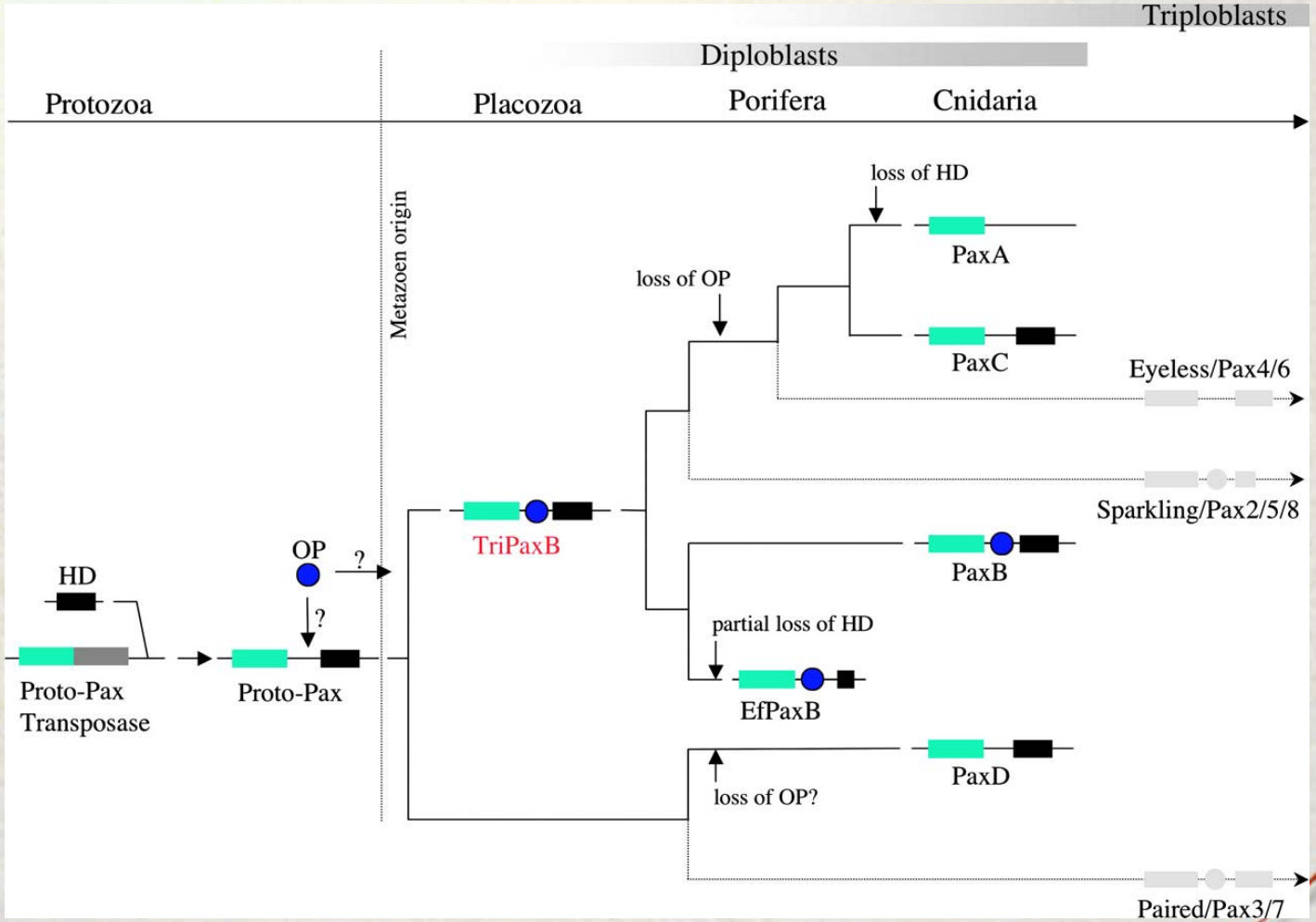
Trichoplax PaxB Gene

- T Hadrys, R DeSalle, S Sagasser, N Fischer, & B Schierwater 2005. **The Trichoplax PaxB Gene: A Putative Proto-PaxA/B/C Gene Predating the Origin of Nerve and Sensory Cells.** MBE 22:1569-78 (link, link)



Pax Evolution

(link)



Pax Evolution

- Pax genes, which are associated with the development of neural and sensory systems are phylogenetically older than those systems, and are older than the Cambrian Explosion.
- They had other functions back then.
- Thus their role in neural and sensory development is reducibly complex.

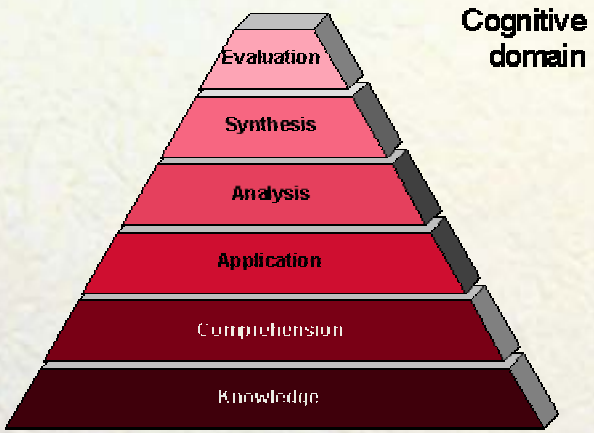
The Problem

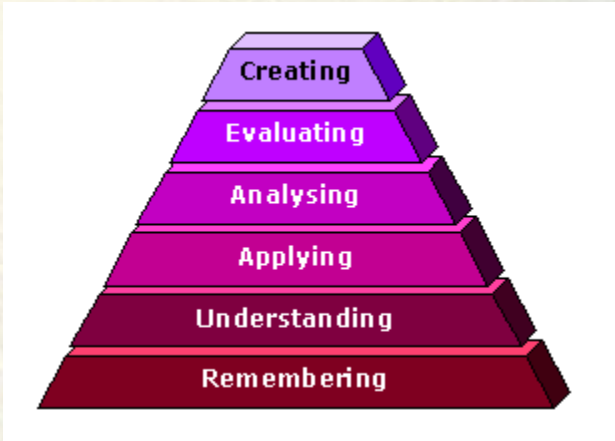
- Public resistance to evolution…
  - …and to science in general (e.g. GMO foods)
- Science literacy
  - Surveys and Polls
  - International Assessment Tests: PISA, TIMMS, NAEP

What do we do about the problem?

- Nurture creativity
- Supplement the reward structure
  - Reward teaching
- Avoid authoritarianism
  - Us/them mentality run amok
  - One size doesn't fit all
- Put the "life" back into biology
  - As teachers connect with our passion for why we're here

SCAPA Bluegrass: School for the Creative and Performing Arts





Bloom 1956

Anderson & Krathwohl 2001

- SCAPA admits students on the basis of artistic talent, nurtures that talent, and consistently averages some of the highest standardized test scores in the state
- Does selecting and nurturing creativity, one of the highest levels of learning, indirectly enhance lower levels of learning?
- Does artistic creativity carry over to other disciplines such as math and science?
- Should we be teaching creativity in math and science?

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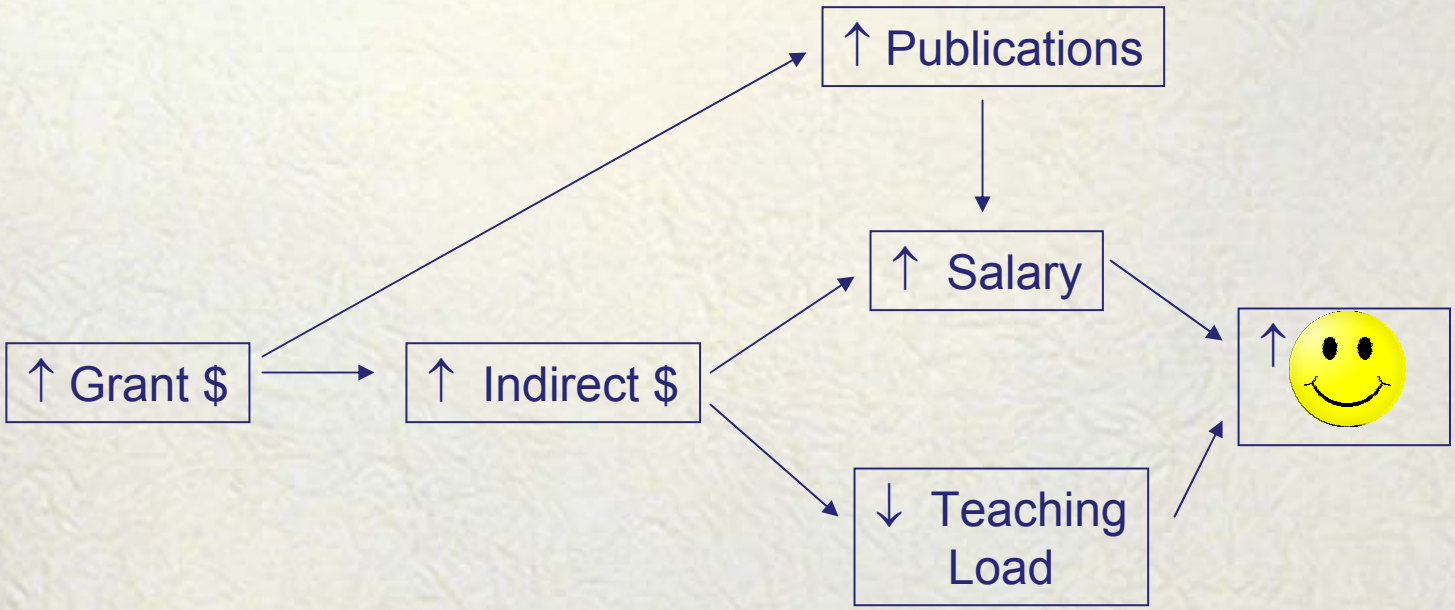
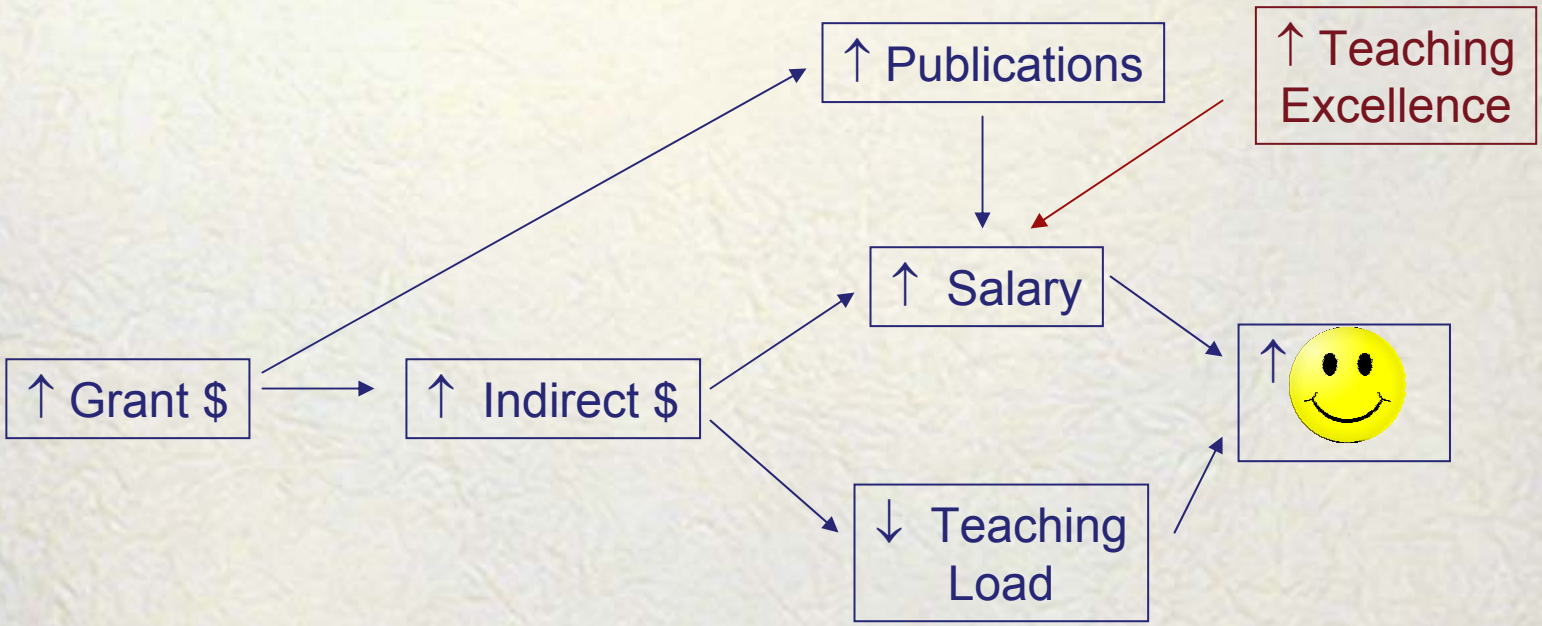
Higher Education: The Current Reward Structure Rewards Research (which is great)



How about adding teaching explicitly into the formula?



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- Nurture creativity
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- Avoid authoritarianism
  - Us/them mentality run amok
  - One size doesn't fit all
- Put the "life" back into biology
  - As teachers reconnect with our passion for why we're here in the first place

A question professional proponents of ID never seem to address

If humans can use random mutation and natural selection to create new designs and improve upon nature, then why couldn't an Intelligent Designer have done the same thing?