Can Organisms Drive Their Evolution?

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New ideas in evolutionary science differ greatly from the gene-centric view of NeoDarwinism

- Epigenetics
- Symbiogenesis
- Niche construction
- Gene transposition and genome reorganization
- Plasticity and "phenotype-first" evolution
- Horizontal gene transfer
- "Evo-devo" – evolutionary developmental biology
- Inclusive inheritance
  - ecological effects, social learning, parental effects during development, epigenetics
- "Cultural drive"

Scientists at meeting on "New Trends in Evolutionary Biology", The Royal Society, London, November 2016

Perhaps we are witnessing a paradigm shift

- But that is quite controversial
- NeoDarwinian processes certainly occur
- Much more research is necessary

Carl Zimmer, "The Biologists Who Want to Overhaul Evolution", The Atlantic Magazine, 28 November 2016
K. Laland, G. Wray, et al., "Does Evolutionary Theory Need a Rethink?", Nature 514, 161 (2014)

A number of biologists argue that evolutionary biology has become too “gene centric” – too focused on the modern synthesis principles of random mutation, heritable variation, and natural selection.

Proponents of the “extended evolutionary synthesis”

- Slide from Dennis Venema
  - Lecture #2
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Proponents of the EES point to several areas that they feel are marginalized by standard evolutionary theory (SET):

Extragenetic inheritance

Niche construction

Developmental / phenotypic plasticity

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These areas of evolutionary biology are somewhat "frontier" areas.

There is broad agreement that these features of evolution exist, and are important (in varying degrees for different organisms).

The dialogue hinges on just how important these issues are, and whether or not standard evolutionary theory encompasses them adequately.

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Yet the mere mention of the EES often evokes an emotional, even hostile, reaction among evolutionary biologists. Too often, vital discussions descend into acrimony, with accusations of muddle or misrepresentation. Perhaps haunted by the spectre of intelligent design, evolutionary biologists wish to show a united front to those hostile to science.

We invite Laland and colleagues to join us in a more expansive extension, rather than imagining divisions that do not exist. We appreciate their ideas as an important part of what evolutionary theory might become in the future. We, too, want an extended evolutionary synthesis, but for us, these words are lowercase because this is how our field has always advanced[16].

162 | NATURE | VOL 514 | 9 OCTOBER 2014

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Last time, Glenn Magelssen introduced several ideas

- Epigenetic inheritance
  - Study of heritable changes in gene function that do not involve changes in the DNA sequence
- Symbiogenesis
  - Evolutionary theory of the origin of eukaryotic cells (having nuclei and organelles) from prokaryotic (primitive one-celled) organisms
- Niche construction theory
  - Idea that organisms do not passively adapt through selection to pre-existing conditions, but actively construct important parts of their ecological niches
  - Also known as *gene-culture coevolution* or *dual-inheritance theory.*

Niche construction implies continual feedback between organism and environment, over generations

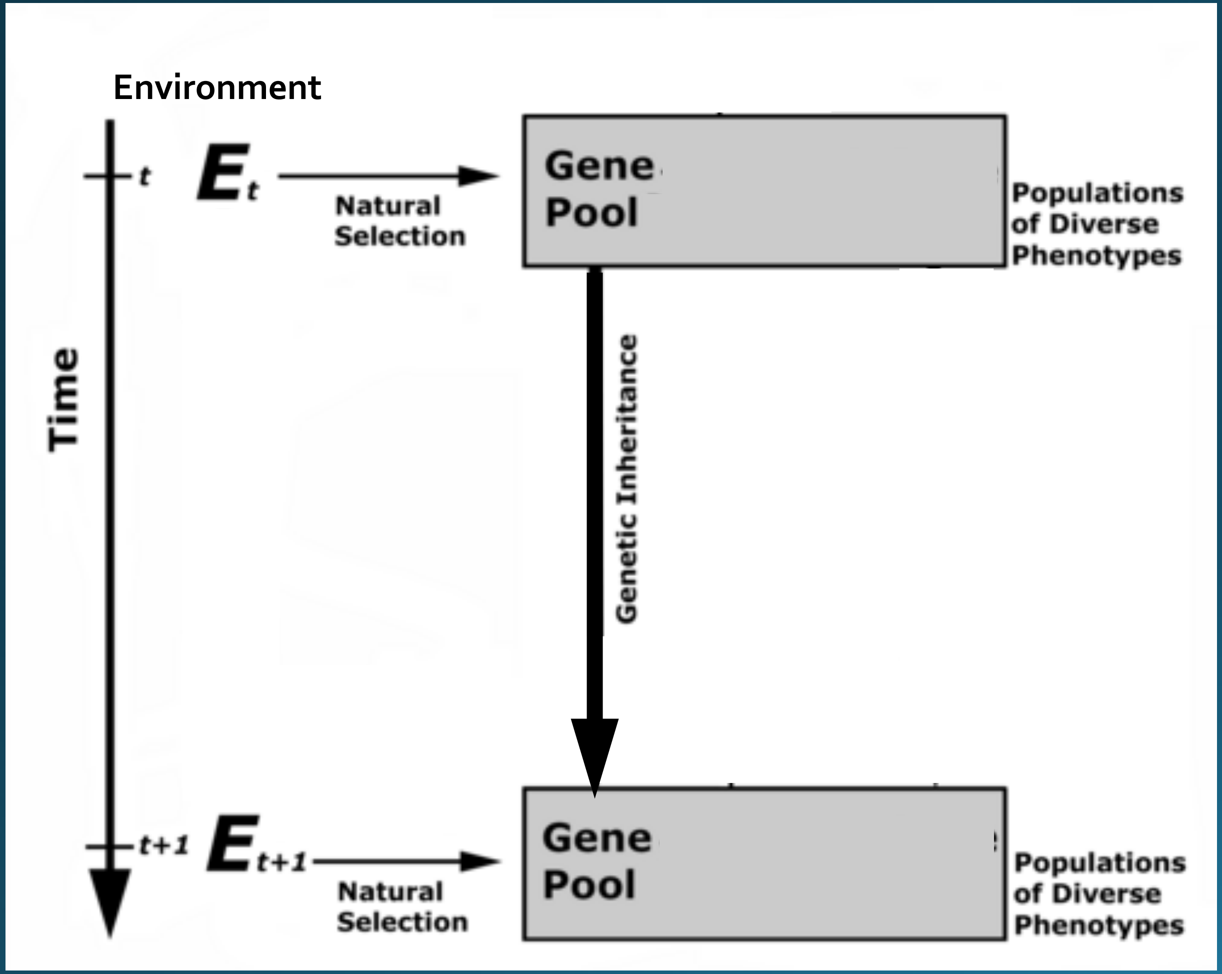
makes

organism

environment

makes

Neo-Darwinian mechanisms involve only genes

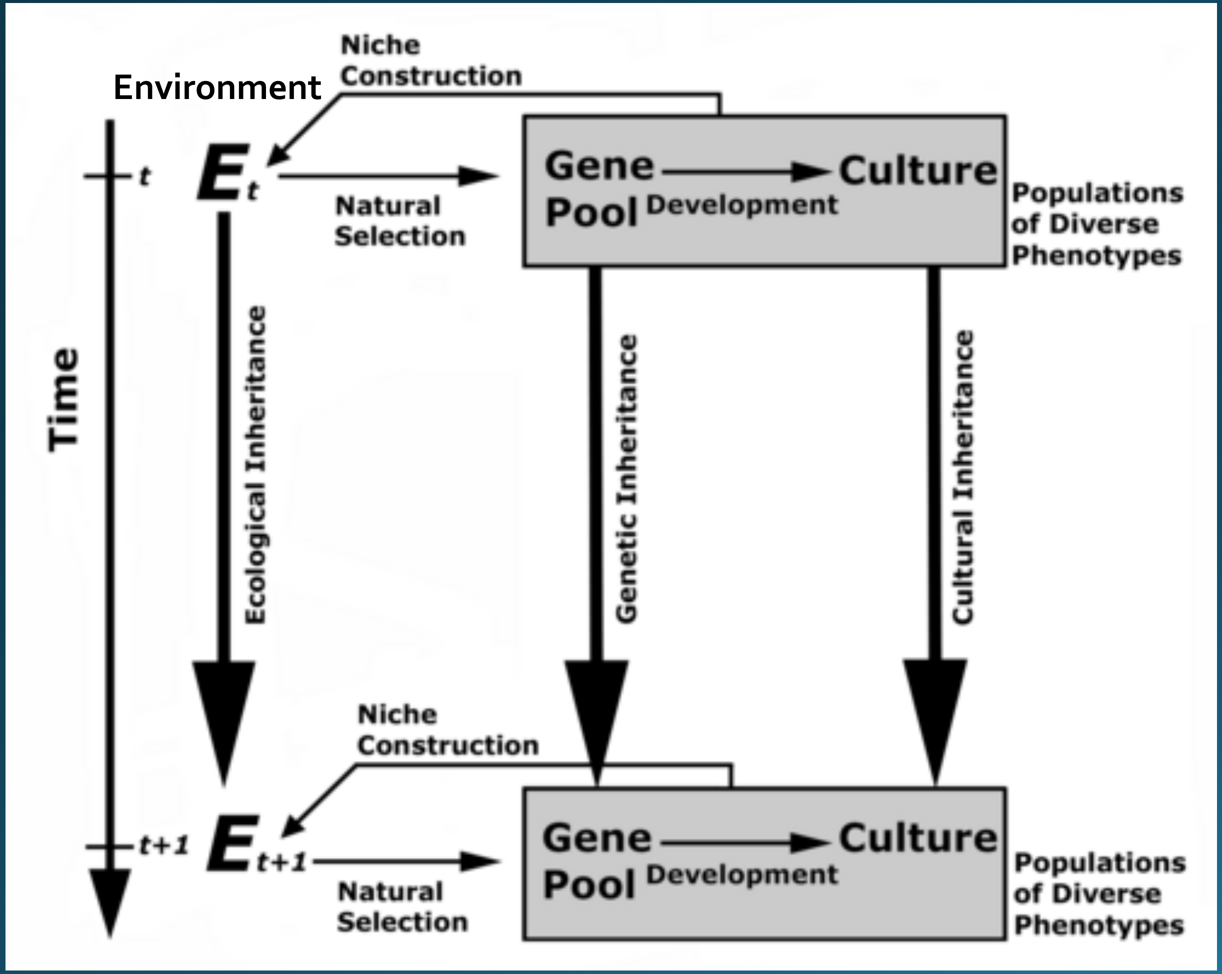


https://semioticon.com/seo/N/niche.html#

https://synergy.st-andrews.ac.uk/niche/niche-construction-and-evolution/

- *Natural selection*
  - the process whereby organisms better adapted to their environment tend to survive and produce more offspring
- So natural selection is the result of environment acting on the population

"Inclusive inheritance" includes more than genes



- "Culture" is a kind of "environment" based on social behavior, tool use, learning, imitation, and innovation
- You could view culture as merely part of behavioral phenotype
  - But much of culture is transmitted through social learning, not genes

https://semioticon.com/seo/N/niche.html#

https://synergy.st-andrews.ac.uk/niche/niche-construction-and-evolution/

https://steamregister.com/evolution-shaped-the-new-caledonian-crows-beak-ability-to-use-tools/

In the 1940s and 1950s, Barbara McClintock discovered *gene transposition* – "jumping genes"

- Parts of genetic material (in corn) can move from one location to another
- Can even move to other chromosomes
- Her work was received with deep skepticism
- But by the 1970s, her work was being replicated

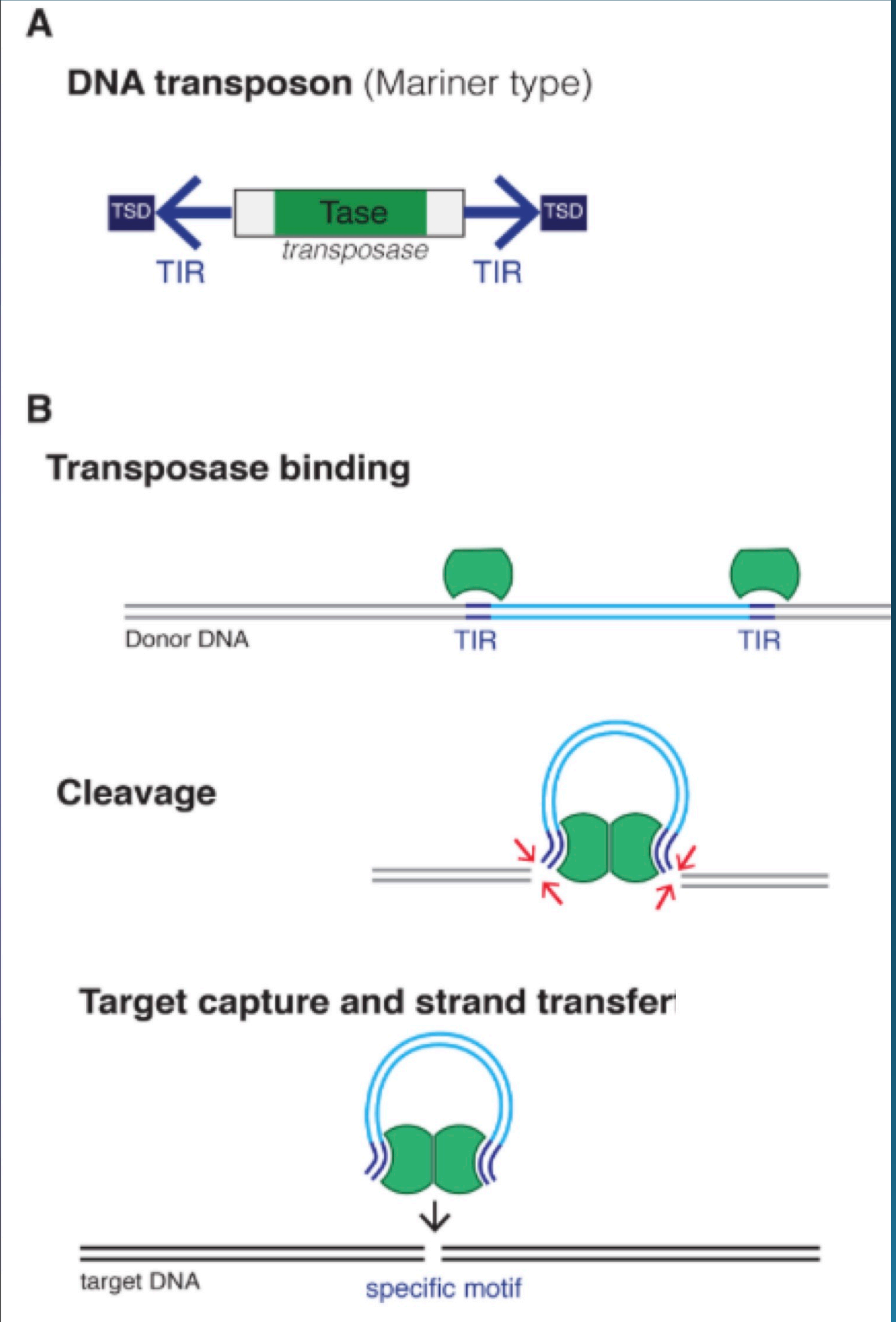
Barbara McClintock in her laboratory (1947)

Mobile DNA elements (transposons) have been studied for decades:

Transposons do not insert randomly into DNA – they have biases for different areas (due to chromatin architecture and other factors)

Transposons do have the ability to initiate DNA breaks and reshuffling of chromosome segments.

https://upload.wikimedia.org/wikipedia/commons/3/33/DNA_Transposon.png



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McClintock regarded genome as an "organ of the cell"

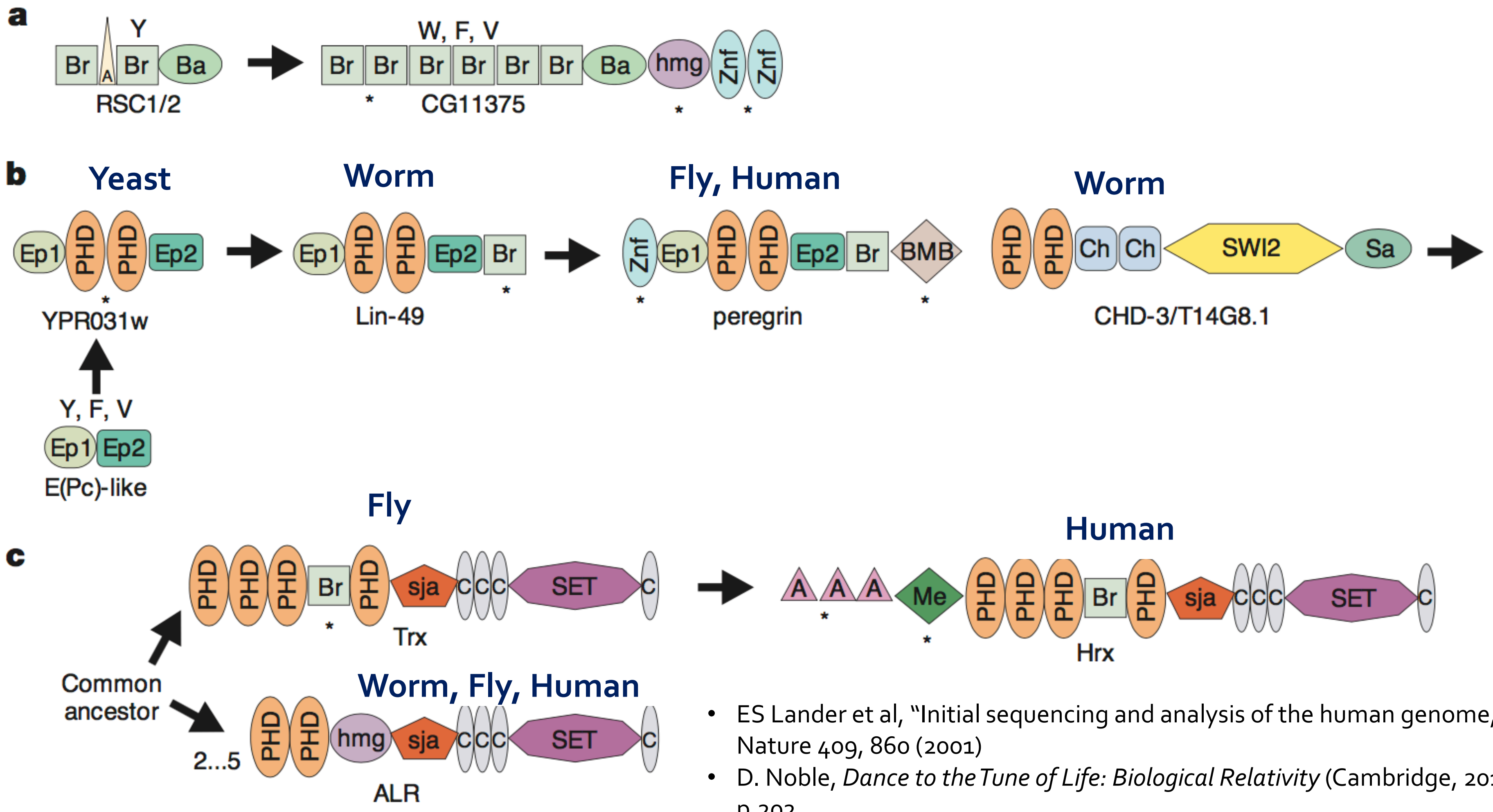
- She received Nobel Prize in Physiology or Medicine in 1983
- Her ideas:
  - Cell is able to restructure the genome, perhaps in response to stress
  - Cell is the active agent, not the genes
    - Cells experience stress
    - Genes do not

We now know that there are many kinds of transposable elements (TEs) in the genomes of all organisms

- The field is changing rapidly:
  - 1999: TEs make up more than 40% of the human genome [Smit (1999) Curr. Opin. Gen. Dev. 9, 657]
  - 2008: “TEs make up approximately 50% of the human genome” (Pray, 2008)
  - 2016: “TEs probably account for more than two-thirds of the human genome …” [Lesage et al. (2016) Mobile DNA 7:19]
- It is hard to know what TEs are doing, if anything
  - Some may play a role in genome function and evolution, and development
  - Some are associated with genetic diseases, e.g., hemophilia and some kinds of cancers
  - It is very difficult to look at a stretch of DNA and figure out what it is or what it does
    - It is much easier to start with a function or protein and find the stretch of DNA that encodes it

https://en.wikipedia.org/wiki/Transposable_element

Large gene domains have moved around during the course of evolution



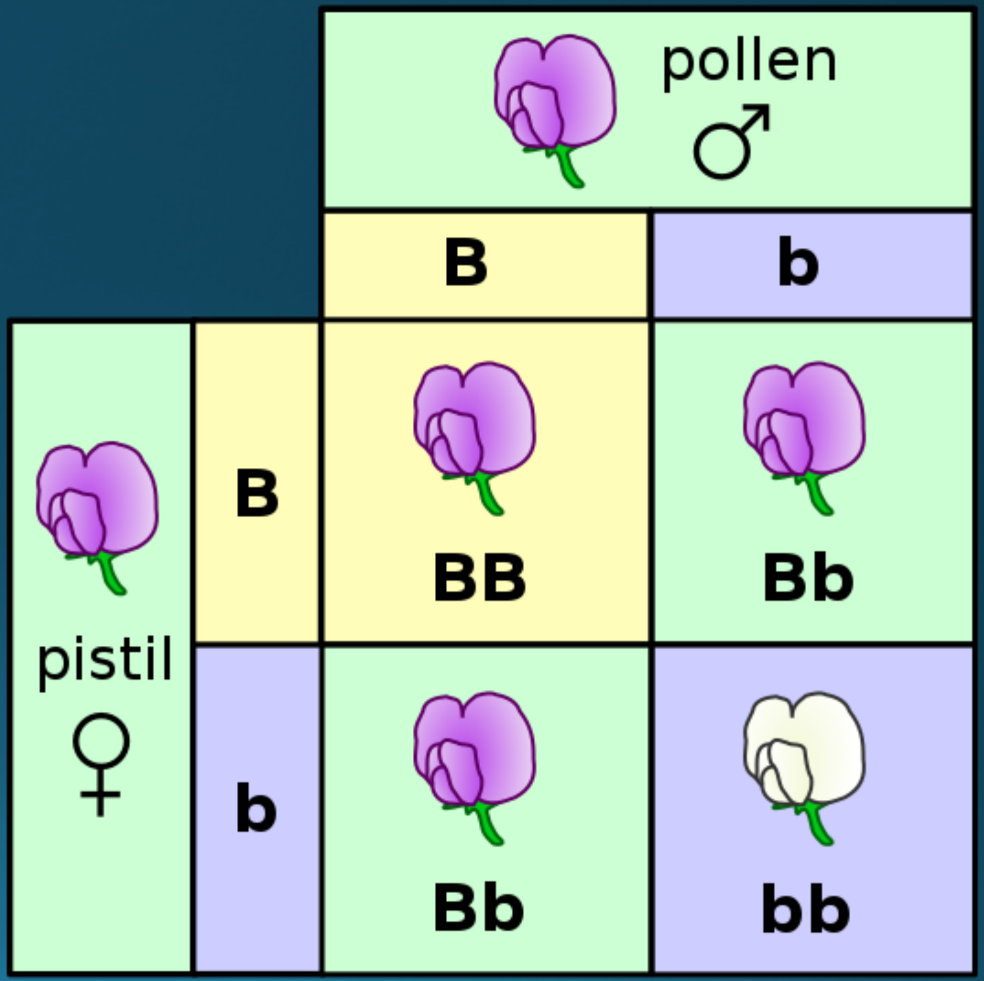
Entire domains, hundreds of amino acids in length, have come together to form new proteins

This does not look like gradual accumulation of small random mutations

- ES Lander et al, "Initial sequencing and analysis of the human genome," Nature 409, 860 (2001)
- D. Noble, *Dance to the Tune of Life: Biological Relativity* (Cambridge, 2017), p.202

Quick review of some definitions

- Phenotype
  - Morphology -- what you look like
  - Behavior -- how you act
  - Physiology -- how your body works
- Genotype
  - The set of genes you have



Developmental plasticity: ability of an organism to change aspects of its phenotype* in one generation, in response to environmental conditions

- Can produce profound changes in phenotype
- Allows organism to accommodate severe changes in environment, *via* compensating adjustments in form, behavior, physiology
- May produce new species and rapid evolutionary changes
  - All members of a population might change simultaneously

Plasticity is different from natural selection slowly operating on initial range of variation of trait

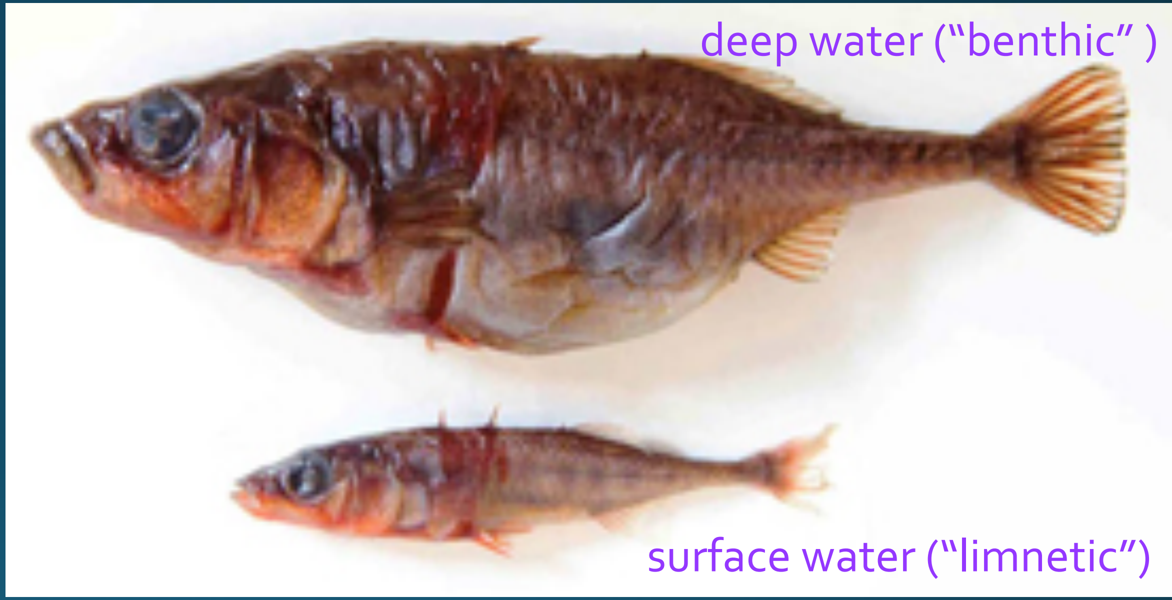
- Daphnia (water fleas) lose color in response to fish predators
  - Plastic response initially
  - Later becomes genetically fixed via “genetic accommodation”

**Phenotype*: physical features of an organism – form, behavior, physiology

https://evolution.berkeley.edu/evolibrary

Freshwater stickleback fish are a well studied species showing plastic variation between two forms

- Phenotype can be induced by diet
  - Diet of plankton induces shallow-water form
  - Diet of benthic arthropods induces deep-water form



http://www.natureconservancy.ca/en/blog/archive/ghosts-of-fishes-past.html#.Wy1VB1MvyCQ

Huang J-P (2015) Front. Ecol. Evol. 3:47. doi: 10.3389/fevo.2015.00047