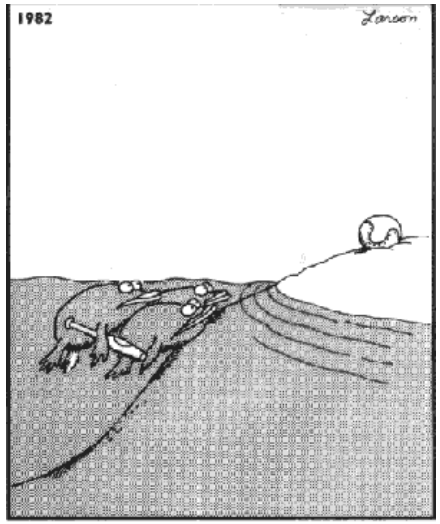
Life on Earth: Evolution



Great moments in evolution

What is evolution?

- Genetics and inheritance
- Natural variability
- Natural selection
- Studying evolution using biochemistry

Terminology

Evolution - change in genetic structure of populations of organisms over time. Can result in the development of new species (speciation).

Species - all members of a natural group of interbreeding populations.

Taxa/Taxon - a group of evolutionarily related organisms, e.g., species, genera, families, phyla, etc.

Phylogeny - sequence of events involved in the evolutionary development of taxonomic groups (e.g., species) of organisms.

Phylogenetic tree - diagram showing lines of descent among taxa.

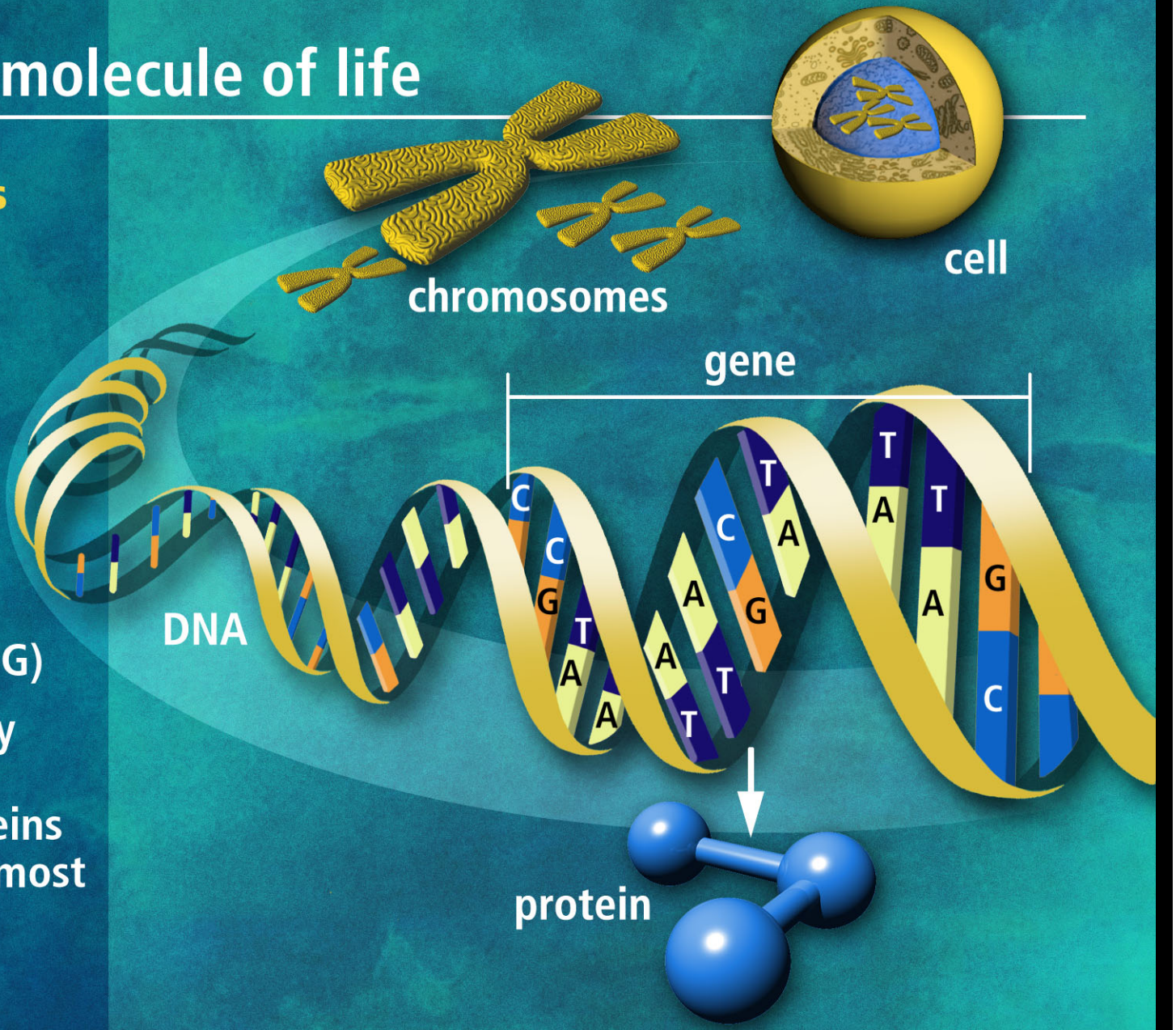
Living organisms

All organisms on Earth have a central operating system that includes the information needed to develop and maintain their own lives. Reproduction information is also included.

This information is encoded in sequences of nucleic acids we call “genes” encoded in either DNA or RNA

The nuclei of eukaryote cells contain the complete genome of its organism – and controls the biochemical reactions that make life live.

DNA the molecule of life



Trillions of cells

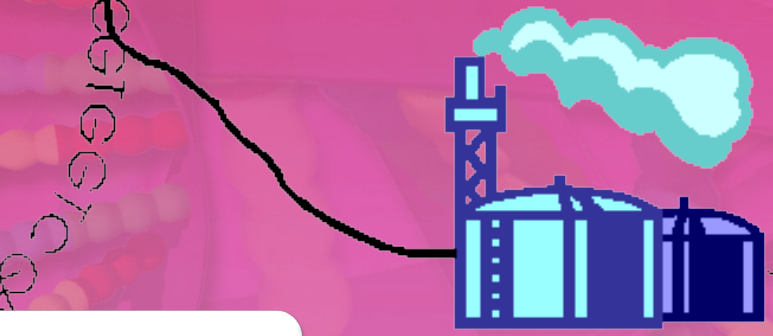
Each cell:

- 46 human chromosomes
- 2 meters of DNA
- 3 billion DNA subunits (the bases: A, T, C, G)
- Approximately 30,000 genes code for proteins that perform most life functions

Y-GG 01-0085

U.S. Department of Energy Human Genome Program, http://www.ornl.gov/hgmis.

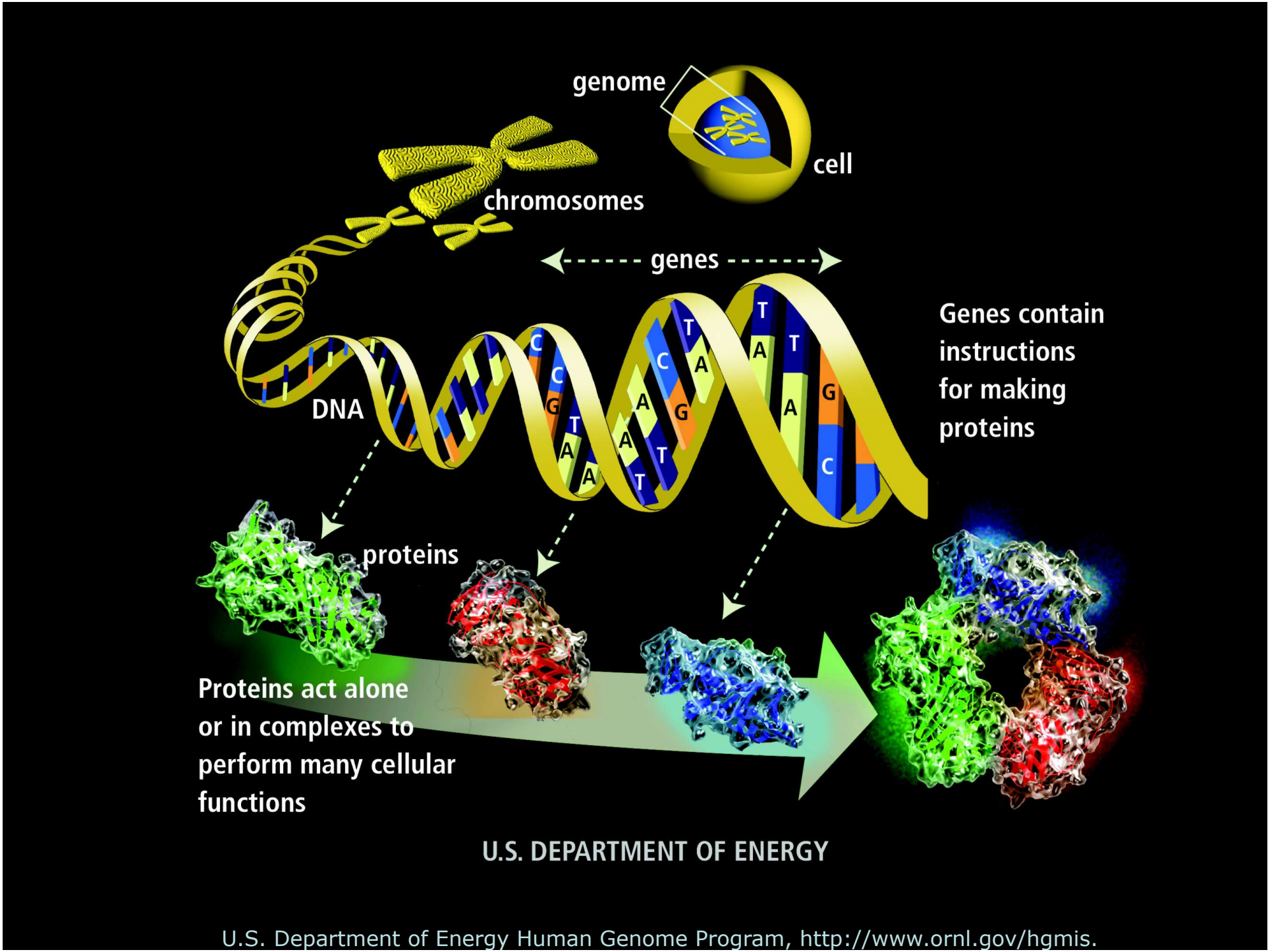
Protein Production within Cell



DNA - genetic code with 4 nucleotides

Proteins - made from 20 amino acids

http://www.uni-mainz.de/~cfrosch/bc4s/students/project/



U.S. Department of Energy Human Genome Program, http://www.ornl.gov/hgmis.

Evolution

Every population within a species contains individuals with genes that cause different traits (e.g., smaller tail, purple eyes, longer legs) to be expressed. This **natural variation** between individuals is the raw material for evolution. If every individual were a genetic carbon-copy of every other individual, evolution would not happen.

New species arise when (for whatever reason) these aberrant traits become the norm within successive populations due to **differential reproductive success**.

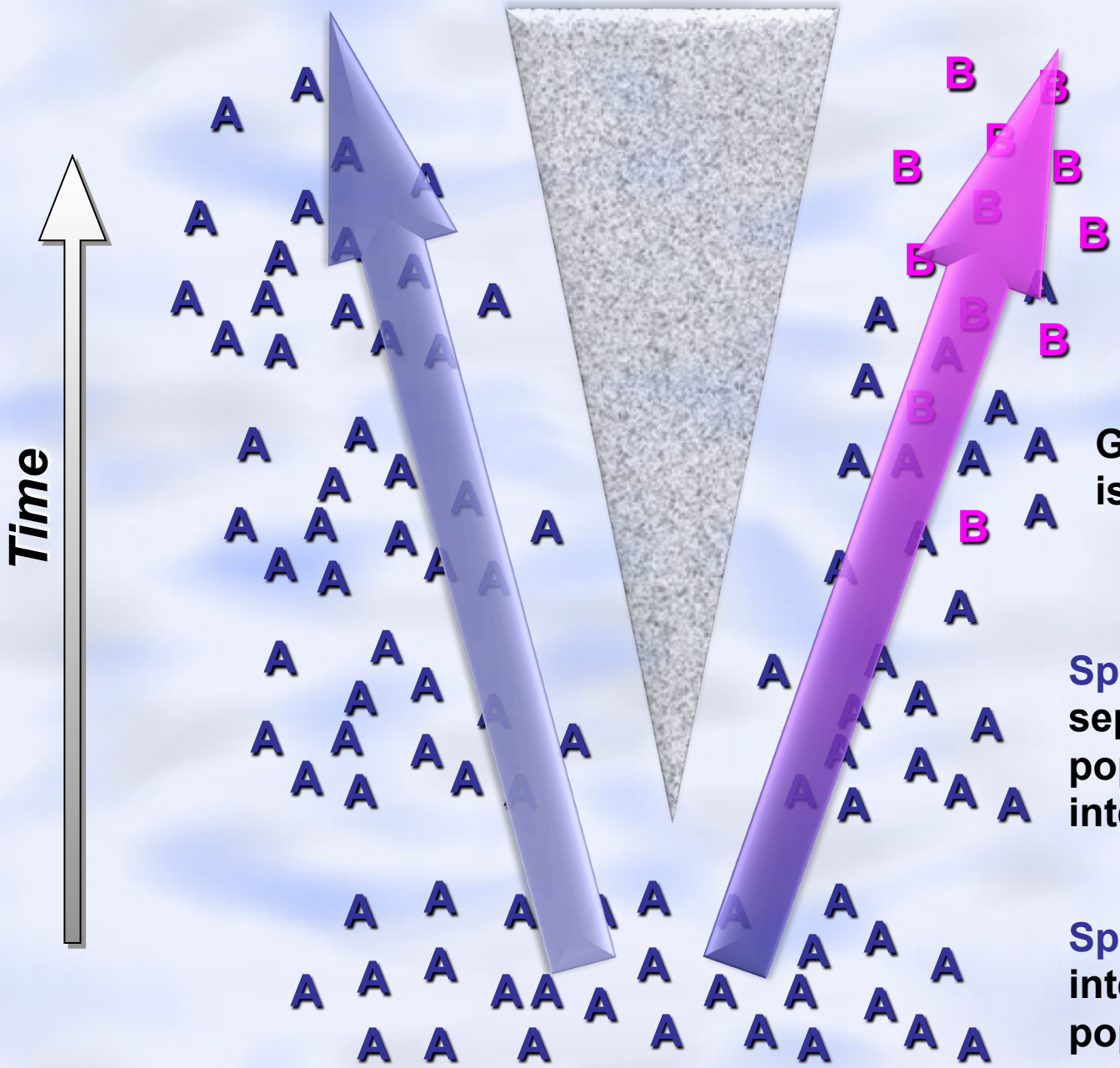
Evolution is a population-level process.

Genetic Mutations

Genetic mutations (changes in the DNA sequence due primarily to copying error) are the source of heritable variation in natural populations. Every newborn human has ~700 mutations in their genetic code.

Most mutations have no effect on the organism that has it. Some have detrimental effects. Others turn out to be beneficial either immediately, or when conditions change.

Allopatric Speciation – caused by physical separation of populations



Evolution of B, a new species.

Genetic change in isolated population.

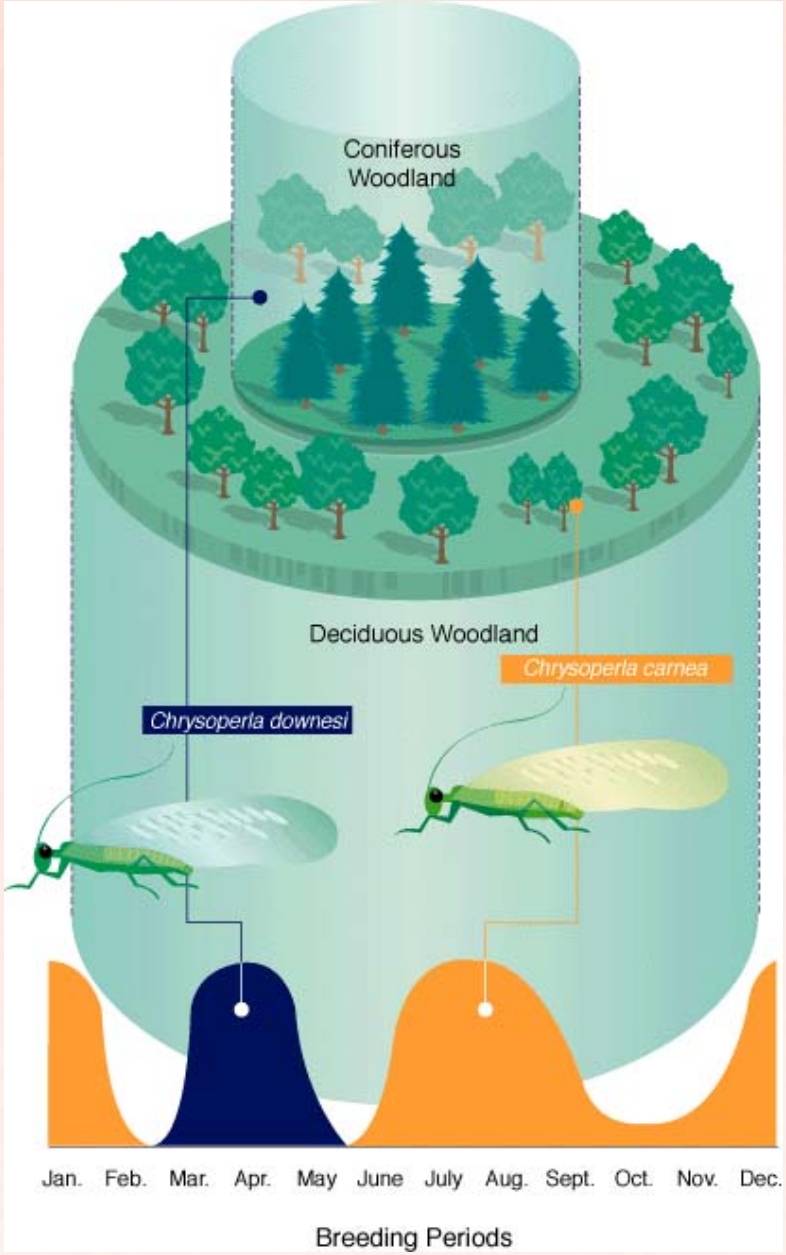
Species A - separation into two populations; limited interbreeding

Species A - single interbreeding population

Abert's squirrel

Kaibab squirrel

A combination of climate change and the opening of the Grand Canyon separated the common ancestor of these two squirrel species ~10,000 years ago. Other isolated populations of the original species have evolved into sub-species.



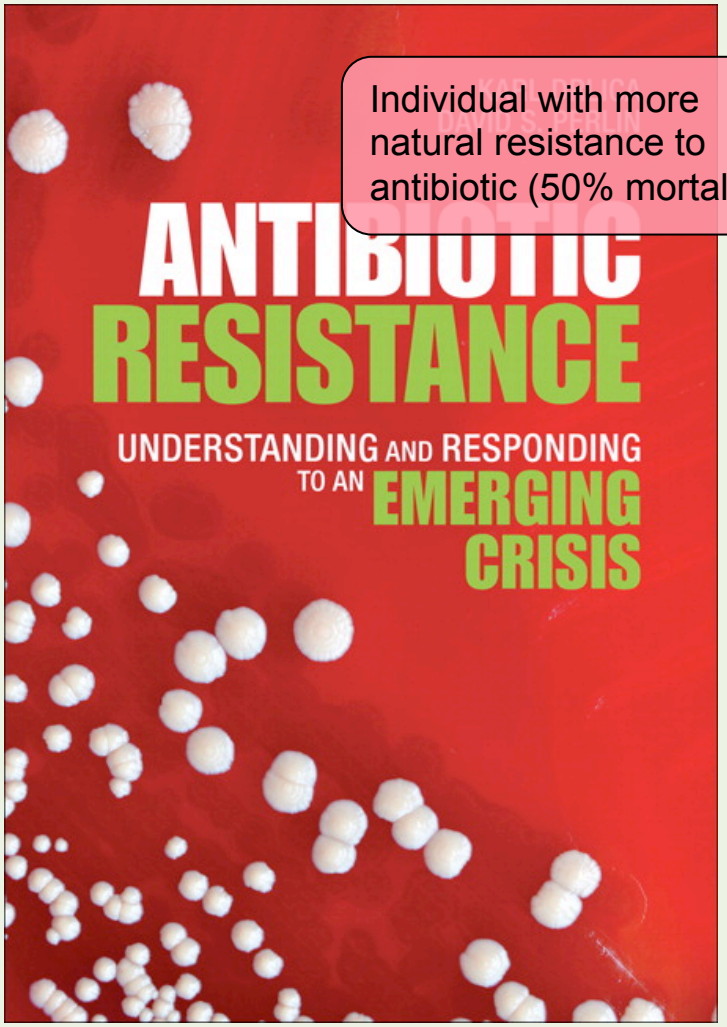
Isolation in Lace Wings

These two closely related insect species have different (but often adjacent) habitat preferences.

The lack of overlapping breeding season keeps the two species genetically isolated from each other.

Natural Selection

Evolution of Antibiotic Resistance

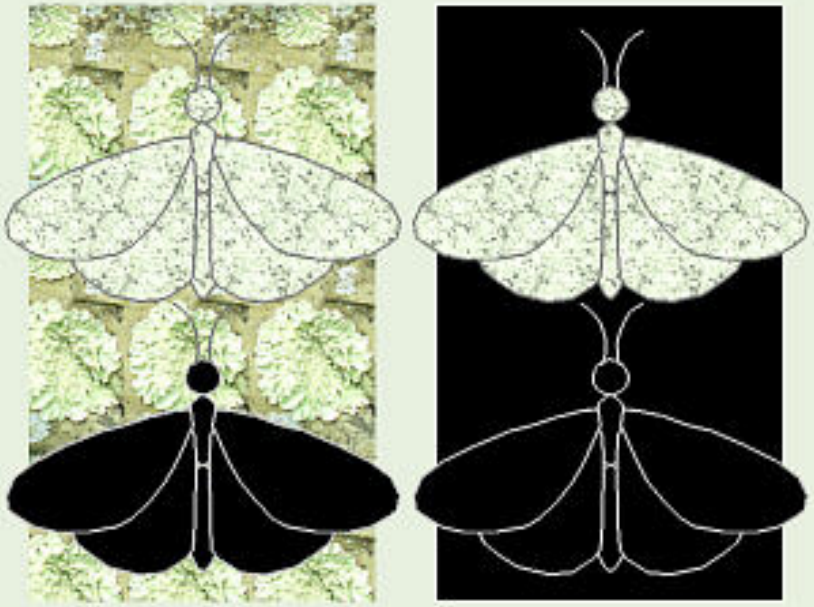


Individual with more natural resistance to antibiotic (50% mortality)

Individual with less natural resistance to antibiotic (90% mortality)

Bacteria

Natural Selection



English Peppered Moth

This species comes in two colors:

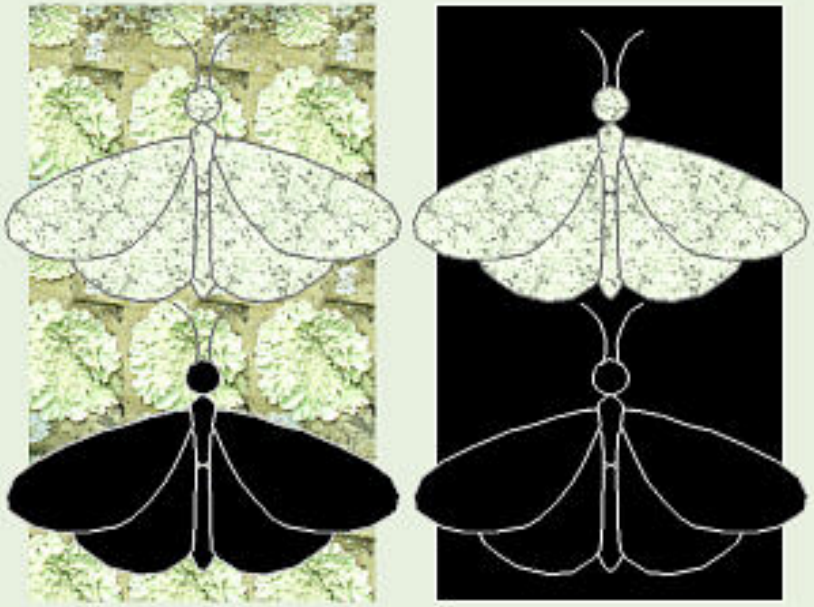
- ***white with black spots***
- ***dark gray to black***

Light-colored moths were more common when the species was named (before the Industrial Revolution), although populations did have some dark moths.

During the Industrial Revolution, woods near factories became caked with soot from coal-burning plants. Around the same time, dark-colored individuals became more common in populations.

http://biology.clc.uc.edu/courses/bio106/nat-sel.htm

Natural Selection



English Peppered Moth

This species comes in two colors:

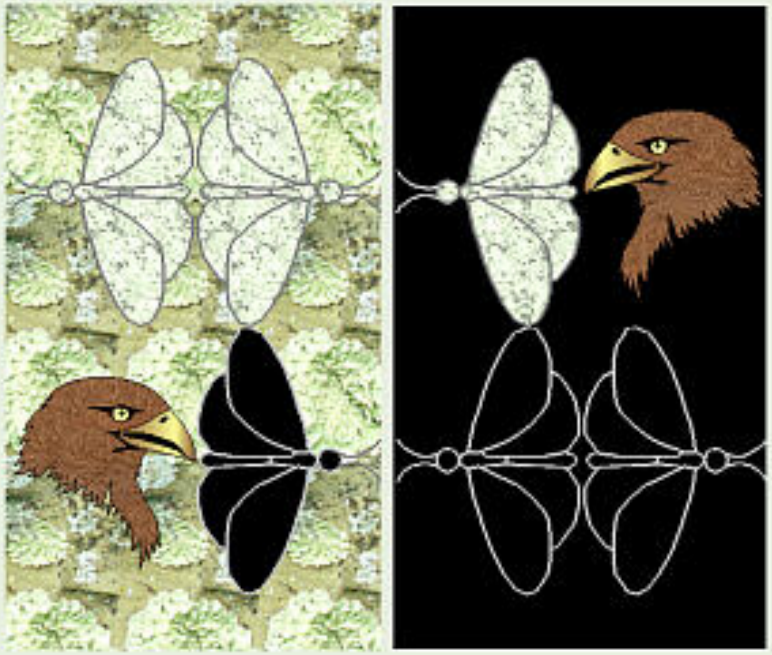
- *white with black spots*
- *dark gray to black*

When surveys were done in the early 20th Century, populations with the highest percentage of dark moths were found in the most polluted areas. The darker morphology became the most abundant overall.

In the later 20th Century this trend reversed, as new pollution standards reduced the amount of soot in the woods.

http://biology.clc.uc.edu/courses/bio106/nat-sel.htm

Natural Selection



English Peppered Moth

This species comes in two colors:

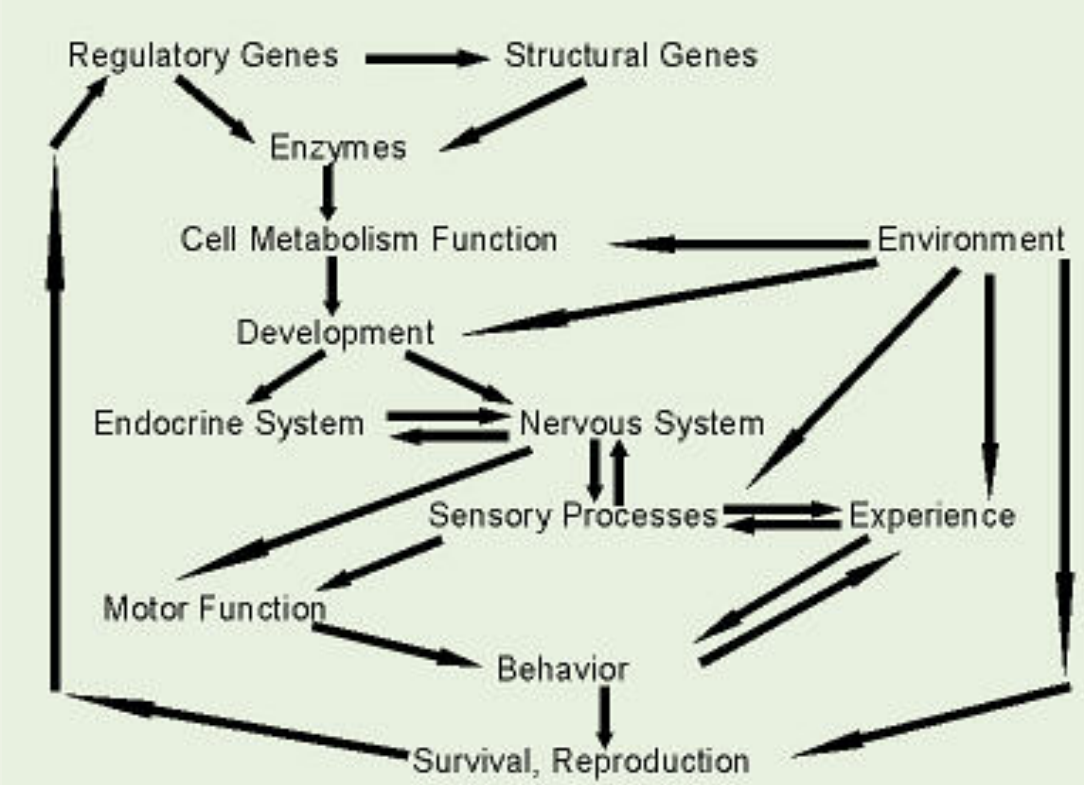
- ***white with black spots***
- ***dark gray to black***

The populations trends were interpreted to be the result of a difference in predation success of birds (and thus natural selection). A light-colored moth is easier to see on a dark surface, and thus more likely to be picked off by a predator – and vice-versa.

Recent studies have pointed out the story is not this simple, but still agree with the original conclusion that this is a case of natural selection.

http://biology.clc.uc.edu/courses/bio106/nat-sel.htm

Keys to Success

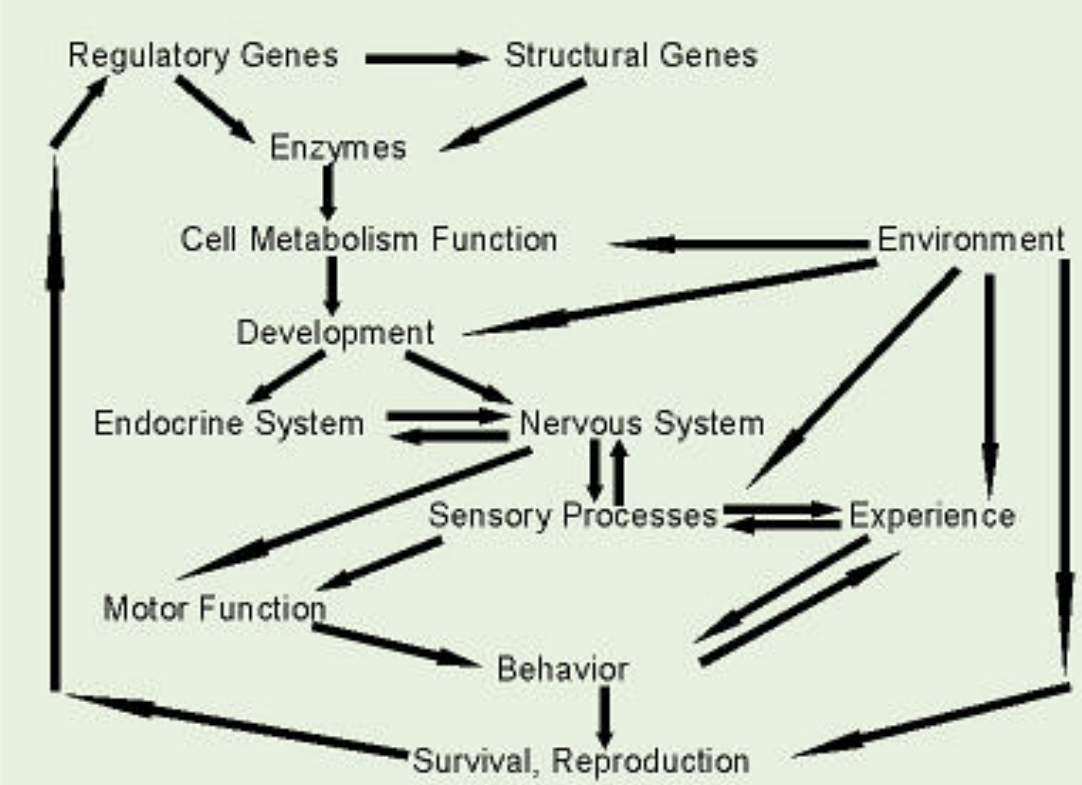


The factors leading to success or failure in an *individual* are a complex mix of genetics, environment, and dumb luck

While a genetic advantage should increase survival, it does not necessarily increase reproduction.

http://biology.clc.uc.edu/courses/bio106/nat-sel.htm

Keys to Success



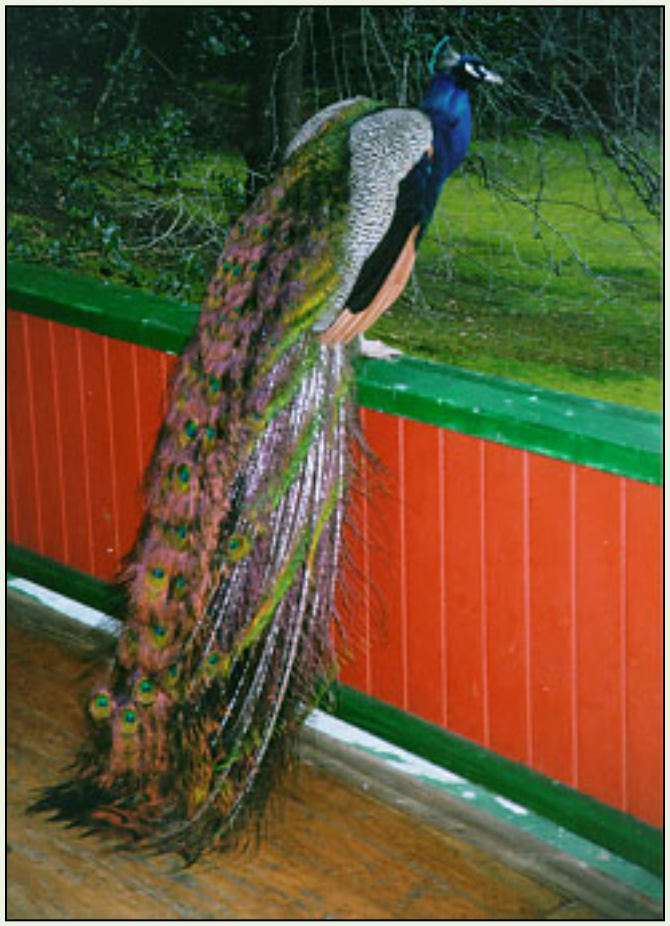
Factors leading to the success of a *population* include the same mix as for individuals.

However, natural selection within the population will tend to eliminate the less successful from the all-important gene pool.

Natural selection tends to favor beneficial traits for survival and reproduction within a population, and individuals with those traits become more abundant over time.

http://biology.clc.uc.edu/courses/bio106/nat-sel.htm

Natural Selection



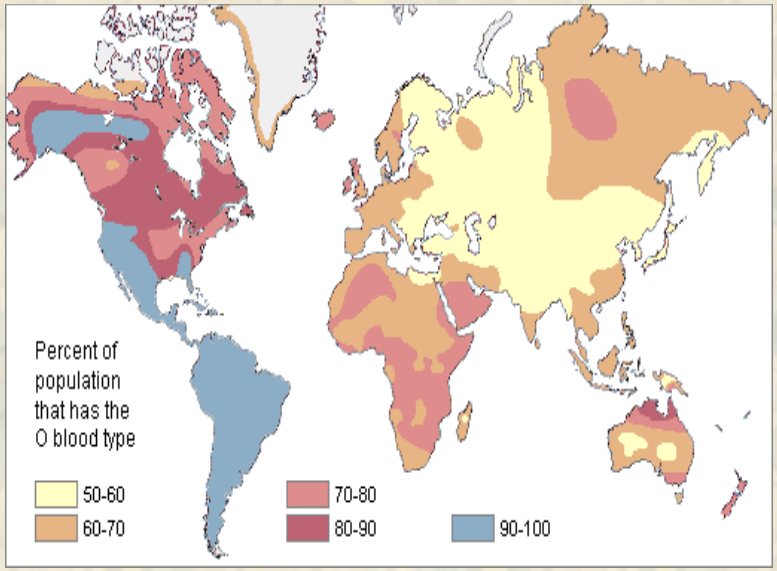
Not all natural selection is due to differential predation ("x eats y but not z, z survives to breed") – although this cause is the easiest to document.

Sexual selection is also relatively easy to document. Peahens, for instance, prefer peacocks with spectacular plumage. An individual with a great tail display is more likely to reproduce than those without.

Other natural selection pressures are more subtle, and sometimes involve complex interactions with individuals within a species, interactions between species, and environmental change.

http://doors.stanford.edu/~sr/tasmania/

Studying Evolution

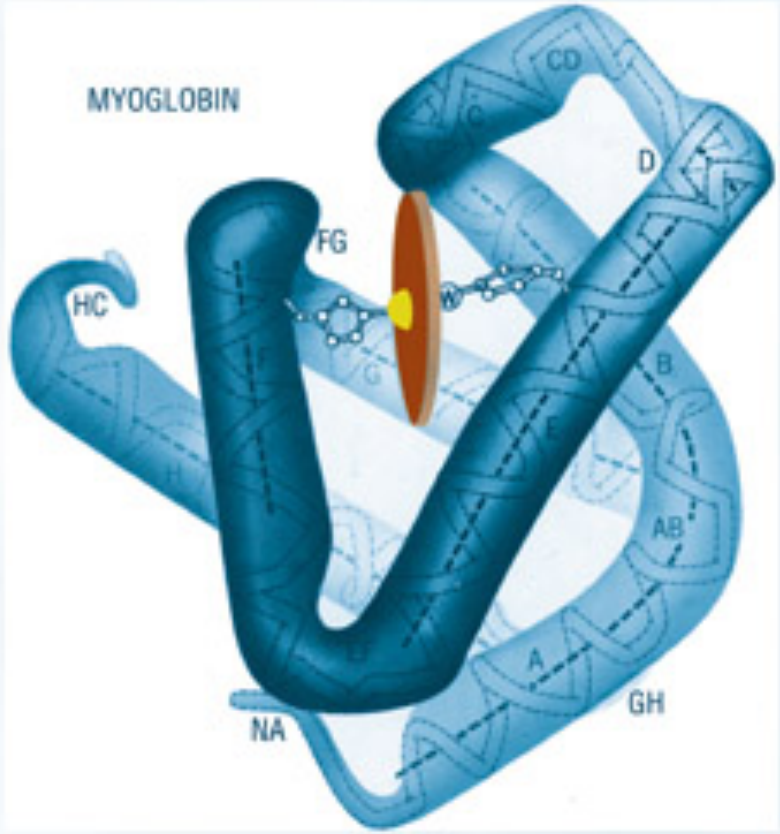


Not all genetic material is subject to natural selection. For instance, substitutions of one amino acid for another in a protein can cause no appreciable difference in how well the protein works.

Random mutations of this material should occur randomly. The longer the elapsed time, the more mutations are expected simply by chance.

Two taxa with more recent common ancestor should have more similar molecular structures than a pair with less recent common ancestor.

http://anthro.palomar.edu/vary/vary_3.htm

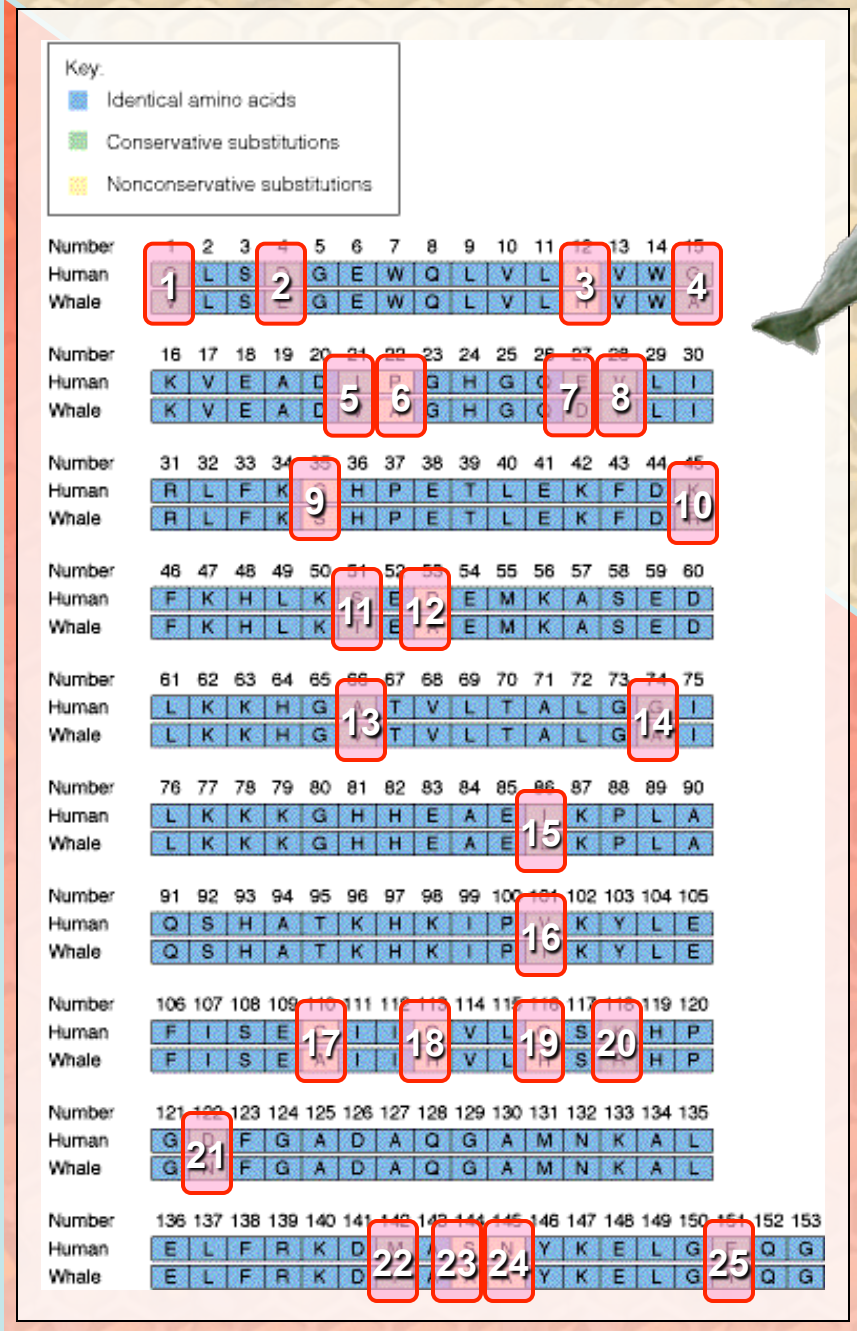


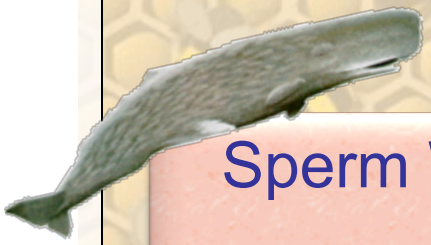
Myoglobin, which stores oxygen in muscles, consists of a chain of 153 amino acids wrapped around an oxygen-binding molecule. The sequence of amino acids in myoglobin varies from species to species, revealing the evolutionary relationships among organisms.

Myoglobin, © Irving Geis

The amount of difference between the biochemistry of two taxa is a measure of the time since those taxa diverged.

http://books.nap.edu/html/creationism/evidence.html





Sperm Whale and Human Myoglobin

Total amino acid differences = 25

100,000,000 years

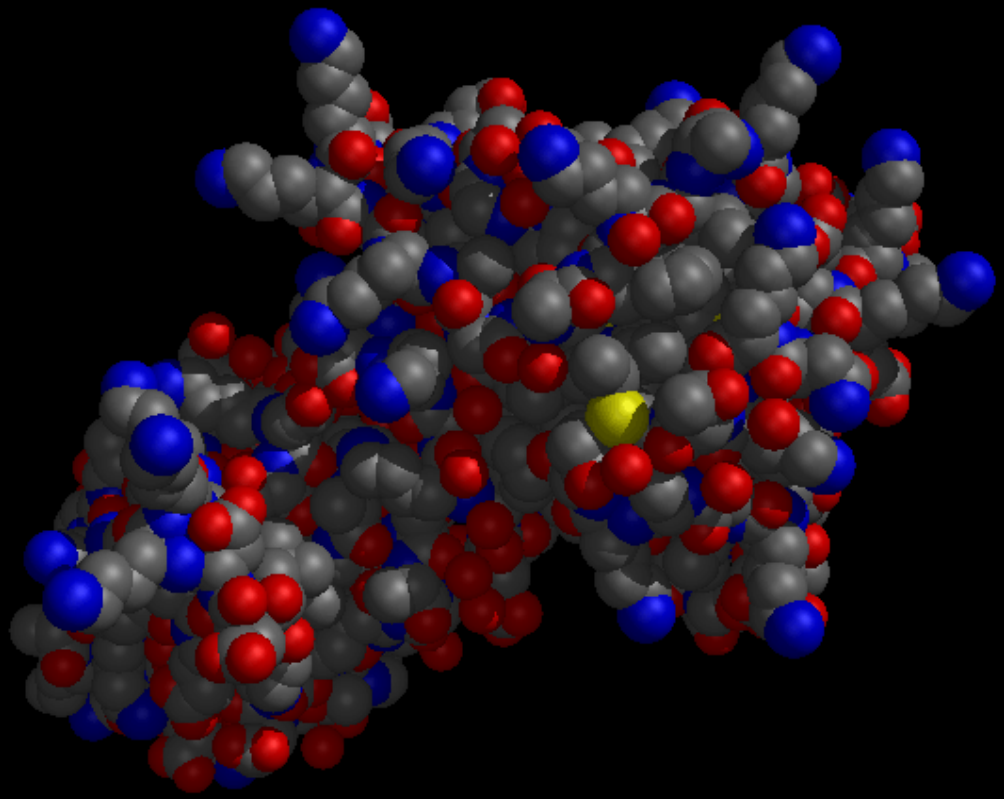
Shark and Human Myoglobin

Total amino acid differences = 88

400,000,000 years

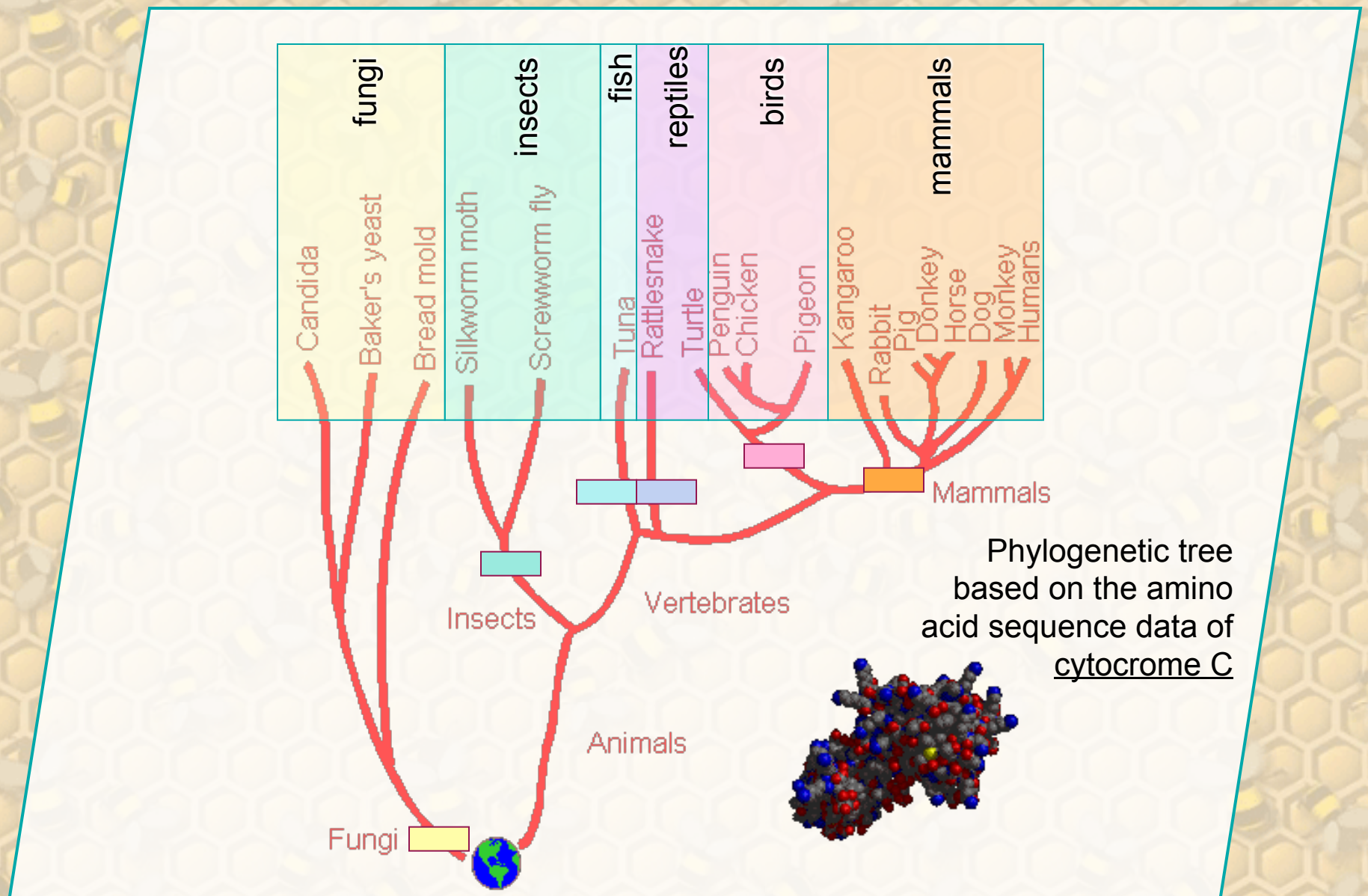
http://www.aw-bc.com/mathews/ch05/fi5p14.htm

The amount of difference between the biochemistry of two taxa is a measure of the time since those taxa diverged.



Cytocrome c

http://www.uni-mainz.de/~cfrosch/bc4s/students/project/



Phylogenetic tree based on the amino acid sequence data of cytocrome C

http://www.uni-mainz.de/~cfrosch/bc4s/students/project/

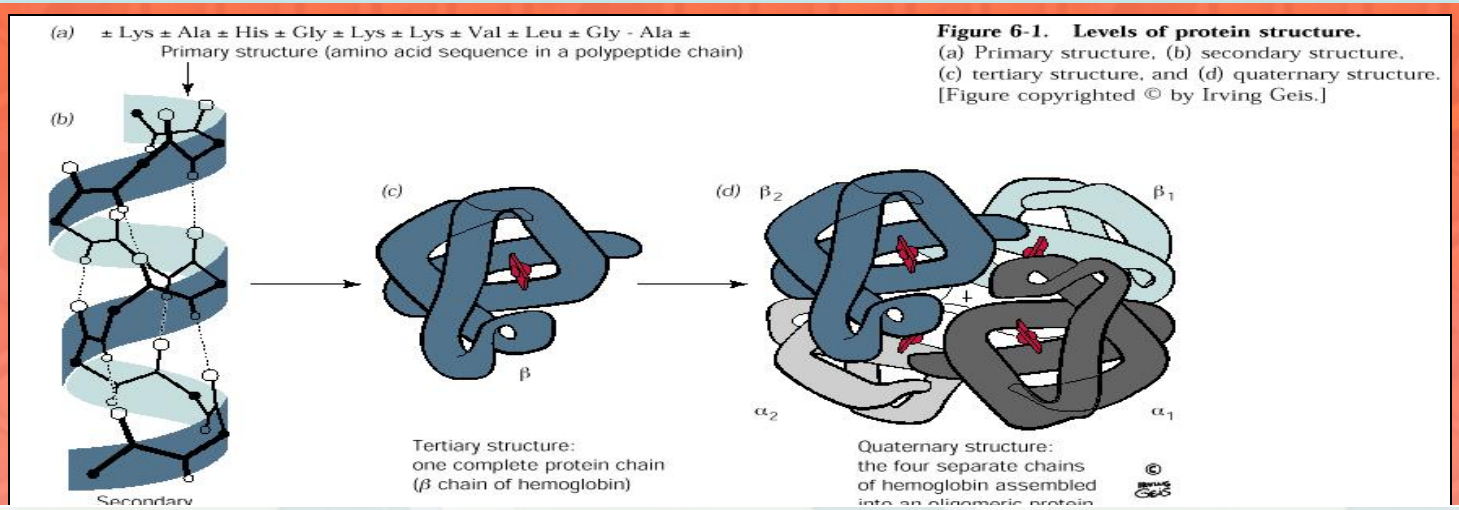


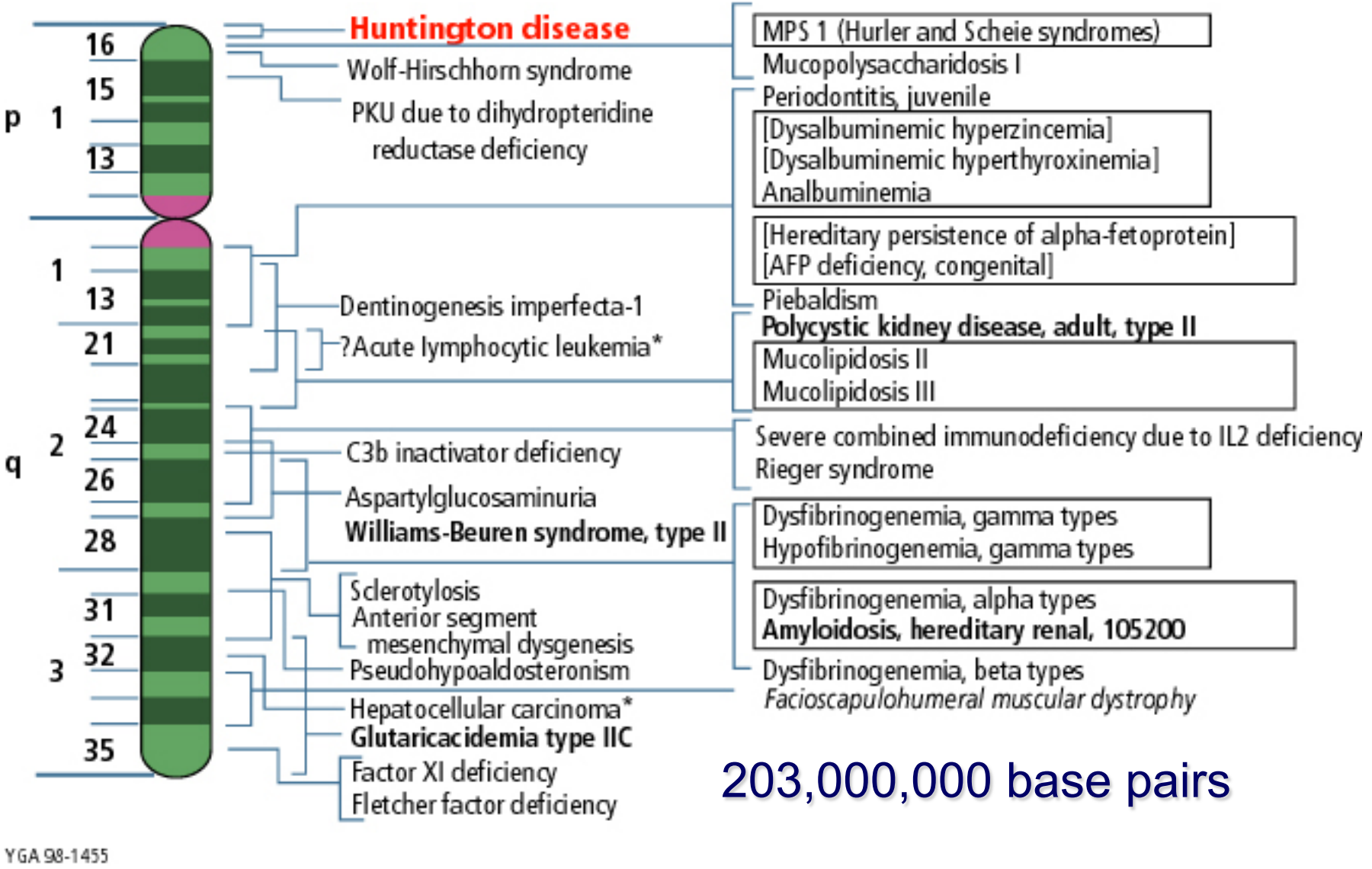
Figure 6-1. Levels of protein structure.
(a) Primary structure, (b) secondary structure, (c) tertiary structure, and (d) quaternary structure.
[Figure copyrighted © by Irving Geis.]

The number of molecular comparisons between organisms that can be done is limited by the number of structures like myoglobin found in those organisms. The potential number is simply ***vast***.

Technological advances in recent years have allowed researchers to tackle the genetic code itself. This has allowed direct comparisons of the genes that control traits in different species.

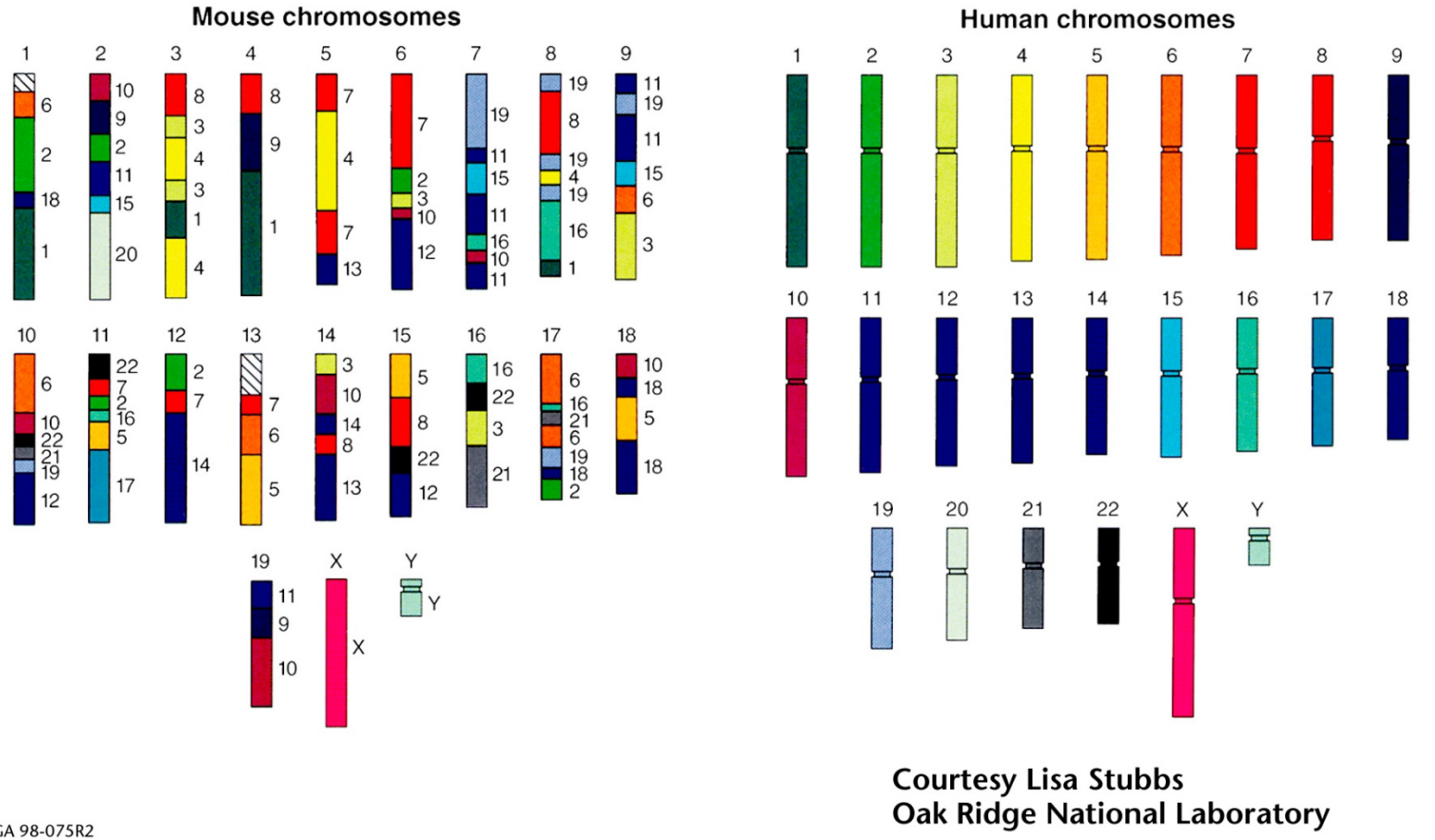
http://cmgm.stanford.edu/biochem201/Slides/Protein%20Structure/

Chromosome 4



U.S. Department of Energy Human Genome Program, http://www.ornl.gov/hgmis.

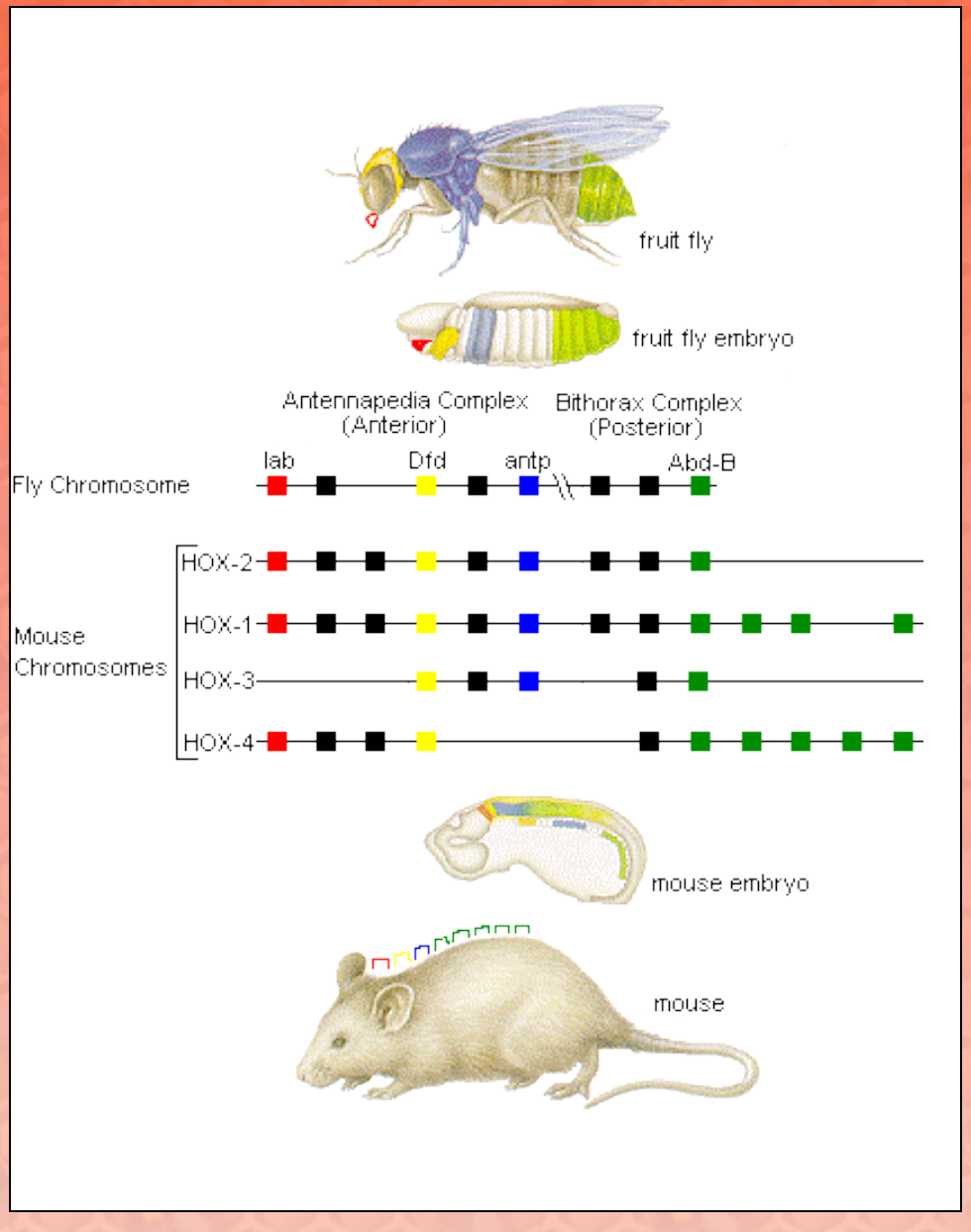
Mouse and Human Genetic Similarities



There are many genetic similarities in mouse and human genetics (~85%) - although the material is frequently found on different chromosomes. Each species has ~3,000,000,000 base pairs.

U.S. Department of Energy Human Genome Program, http://www.ornl.gov/hgmis.

http://www.pbs.org/media/evolution/library/03/4/l_034_04_ref.mov



One of the big surprises has been the discovery of homeobox, or HOX genes.

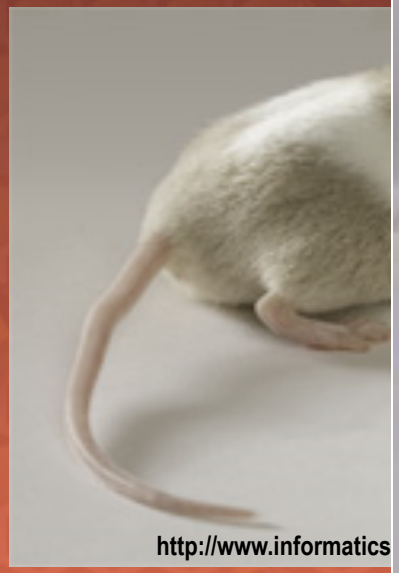
Hox genes are extremely conservative sections of DNA found in many animals that control when, where, and how many times a trait will be expressed.

Any significant change to a HOX gene sequence could cause a fundamental flaw to development, and would therefore most likely be fatal.

http://www.people.virginia.edu/~rjh9u/homeo.html

Piebald in Mice (s) – lacks pigment on some external fur (usually spotty), as well as internall potentially fatal disease th with feces.

Humans share an are also susceptible to n



ball
piebald
arily due to
the same genetic disorder.