

# Darwin's Theory of Evolution

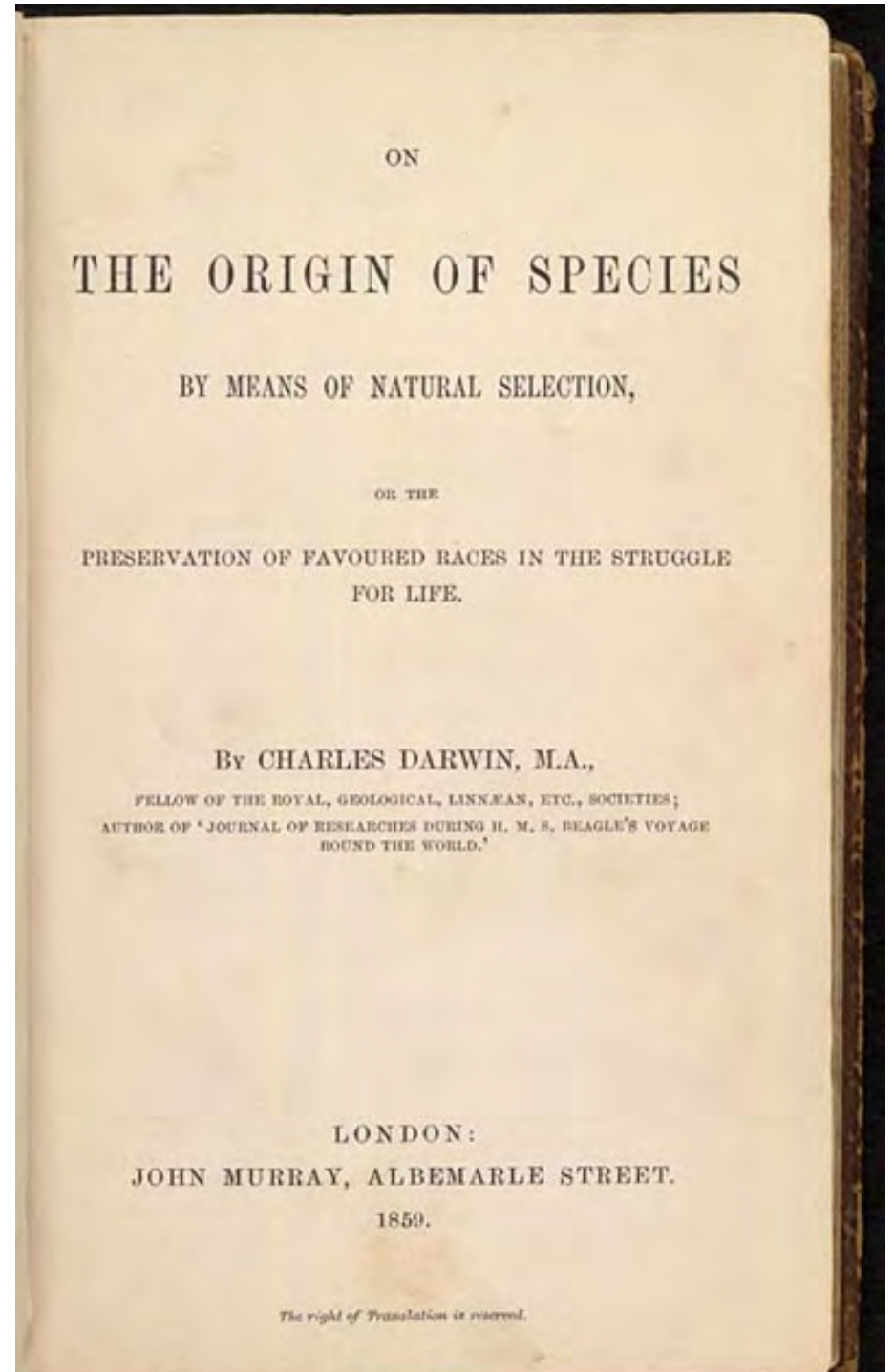
“Nothing in biology makes sense except in the light of evolution”

-Theodosius Dobzhansky



# Charles Darwin

- Synthesized these areas to establish modern evolutionary biology.
- Most important theory in biology.
- Provides loose framework for this course.



# The History of Evolutionary Thought

- What led Darwin to conclude that organisms evolve and are related by descent?
- Old World View
- The enlightenment
- The lead-up to Darwin
- Darwin

# The Old World View

- Plato & the Essence
- Philosophical view that all things have an essence, or type.
- Individuals are a deviation from this type.



# Aristotle & the Scala Naturae

- Life arranged in a scale from simple to complex with *humans on top*.
- Developed the idea of a 'final cause' to explain everything.
- Everything served a purpose to strive toward perfection.

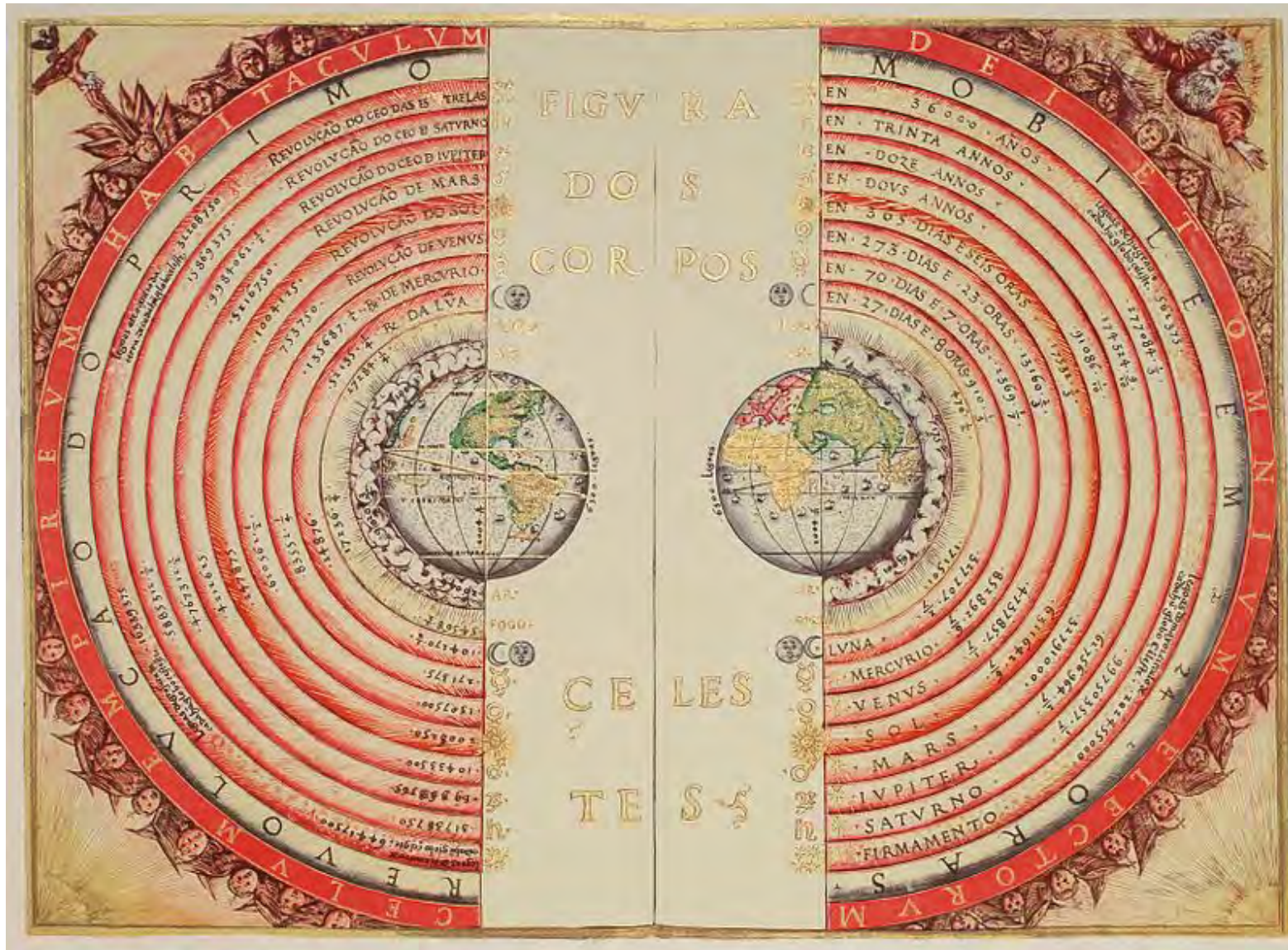
IDEE D'UNE ECHELLE  
DES ETRES NATURELS.

L'HOMME.	Sensées.
Onag-Onag.	PLANTES.
Singe.	Lichens.
QUADRUPÈDES.	Mouffiers.
Ecurrai volant.	Champignons, Agarics.
Chauve-souris.	Truffes.
Asne.	Coraux & Corallodes.
OISEAUX.	Lithophytes.
Oiseaux aquatiques.	Amanche.
Oiseaux amphibies.	Talcs, Gyps, Sulfures.
Foisons volant.	Arbores.
POISSONS.	PIERRES.
Foisons rampans.	Pierres figurées.
Anguilles.	Cryballisations.
Serpens d'eau.	SELS.
SERPENS.	Vitols.
Limacs.	METAUX.
Limacons.	DEMIMETAUX.
COQUILLAGES.	SOUFRES.
Vers à taton.	Bitumes.
Togues.	TERRES.
INSECTES.	Terre pure.
Quillottes.	EAU.
Terra, ou Solitaire.	AIR.
Plantes.	FEU.
Ones de Mer.	Materia plus subtilis.
Sensées.	
PLANTES.	



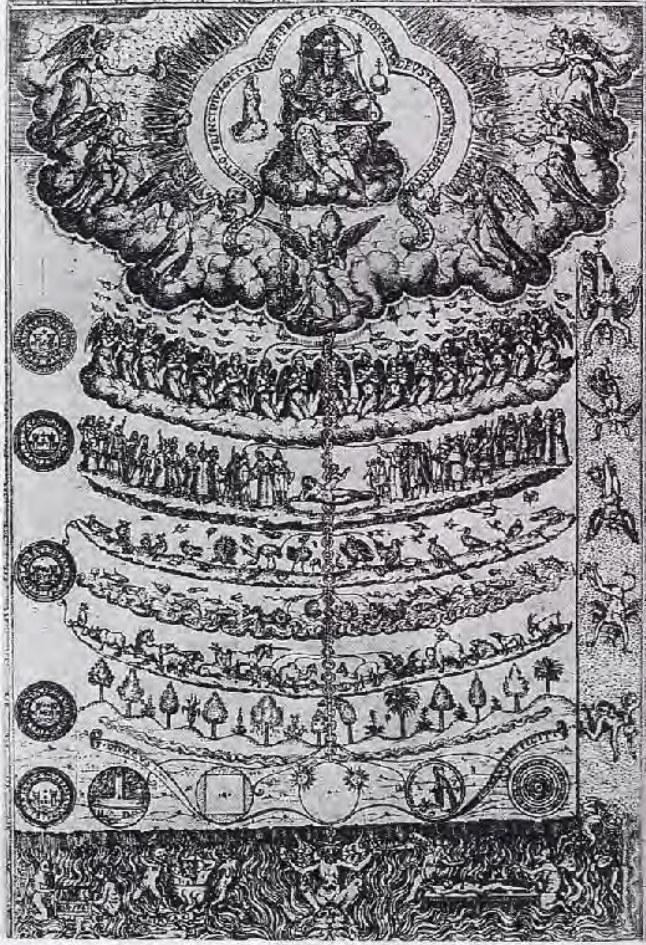
# Ptolemy & geocentrism

Coincided nicely with humans as *the center of the universe*





# The Judeo-Christian tradition



- Formalized/institutionalized all of this.
- Final purpose was to glorify God.
- Humans (and the universe) were created perfectly, therefore any suggestion of *evolution* was heresy.
- World was young (origins described in the bible).
- Unchanged for 5,000 years.

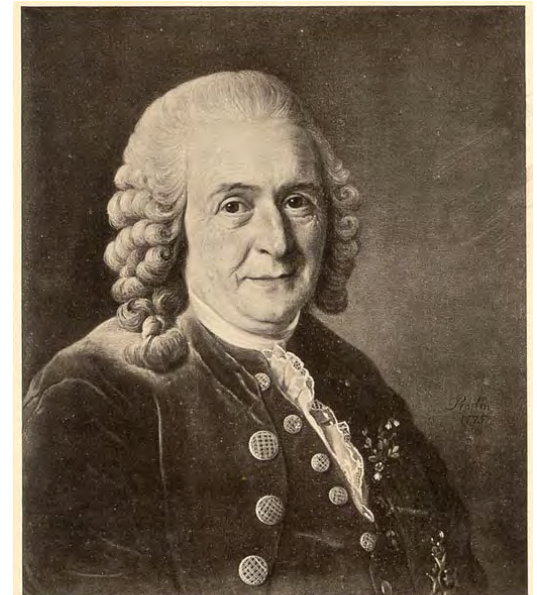
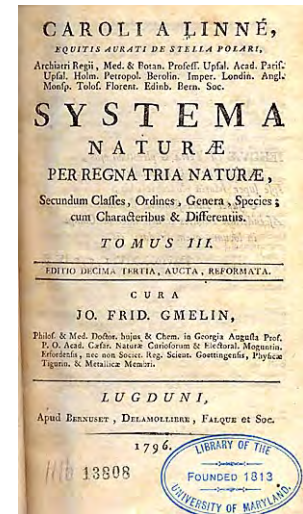
# The Renaissance & Revolutions

- Increased wealth allowed for increased freedom to stray from the dictates of **authority** (especially in Italy).
- The world was getting smaller!
  - Discovery of the New World.
  - People began to realize that the world was not exactly the way they were told that it was.
  - Again, a challenge to **authority**.
- Followed closely by the Reformation.
  - Again, a fundamental challenge to ***The Authority***.
  - All of these caused certain people to begin thinking outside of dogma.
  - Including challenges of dogma in observations of the physical world.
  - E.g. Copernicus & Galileo & Heliocentrism, Newton and modern physics.
- Followed by Revolutions: English, American, French. All challenges to **authority**.



# Evolution before Darwin (Charles, that is)

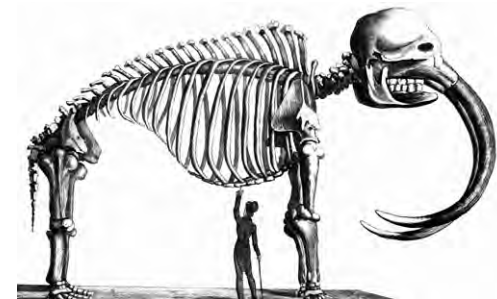
- **Carl Linnaeus** published Systema Naturae in 1796.
- Hierarchical classification of living organisms.
- Still essentialist, but insights into unity of life.



Carl von Linné  
Painting by A. Roslin, 1775

# Evolution before Darwin (Charles, that is)

- **George Cuvier**
- Father of paleontology
- Noted decreasing similarity to modern fauna as found deeper and deeper strata.
- Established **extinction** as fact
- Catastrophism



## Evolution before Darwin (Charles, that is)

- **Erasmus Darwin** publishes Zoonomia 1794.
- Suggests unity of life and recognizes the struggle for existence as cause of evolution.
- Charles Darwin's grandfather.



# Evolution before Darwin (Charles, that is)

- **Jean Baptiste de Lamarck** publishes Theory of Inheritance of Acquired Characteristics in 1801.
- First proposal of *mechanism* of evolution.
- Died poor and obscure.





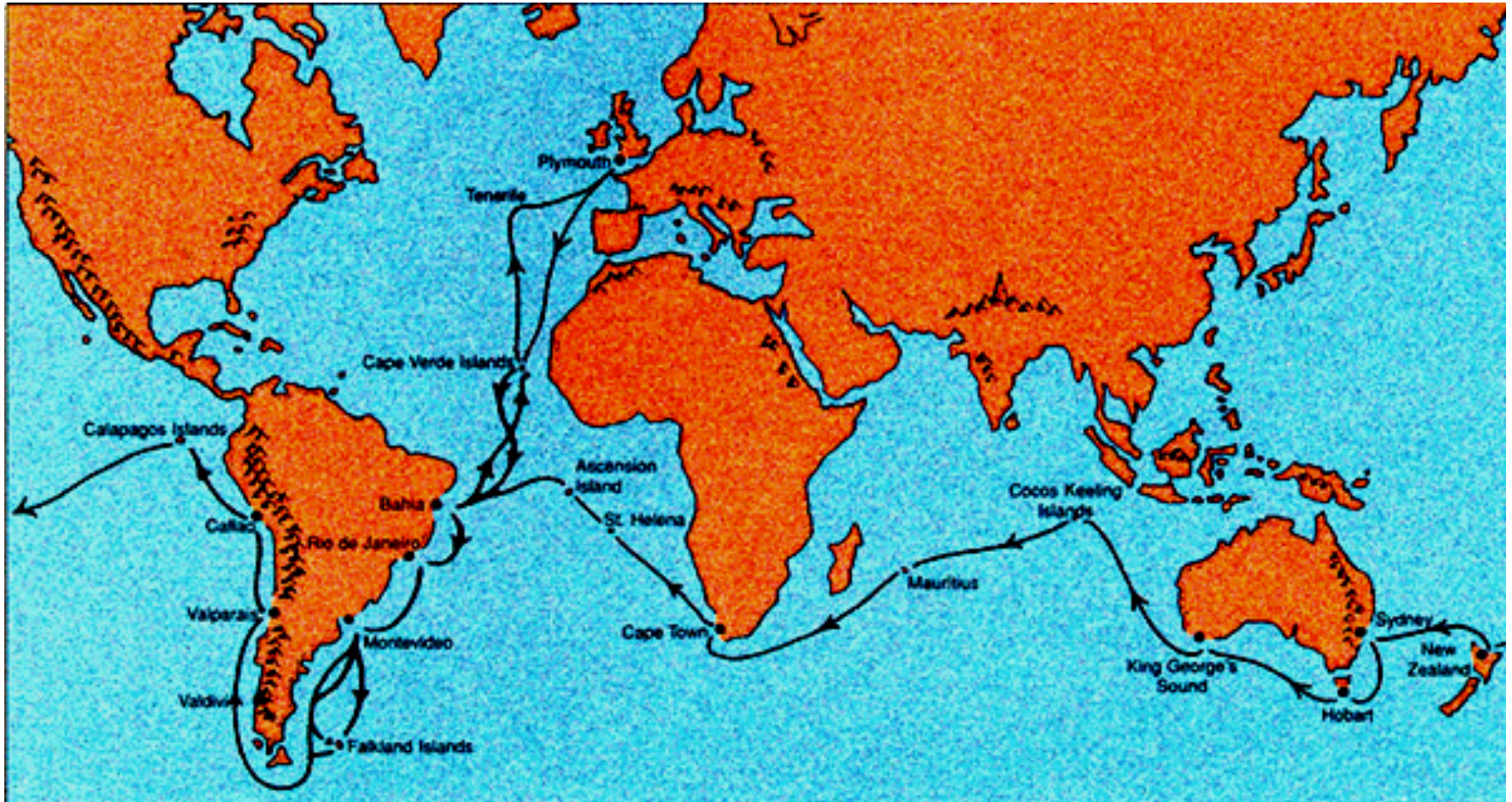
# Darwin: Early influences

- Born 1809. Natural History all the rage during childhood.
- Hated medical school.
- Became involved with premier naturalists of the day and studied numerous diverse taxa.
- Educated during a scientific revolution that placed the sciences (including biology) into the realm of physical, not meta-physical explanations.
- Finally, he found theology too boring.



# The Voyage of the Beagle

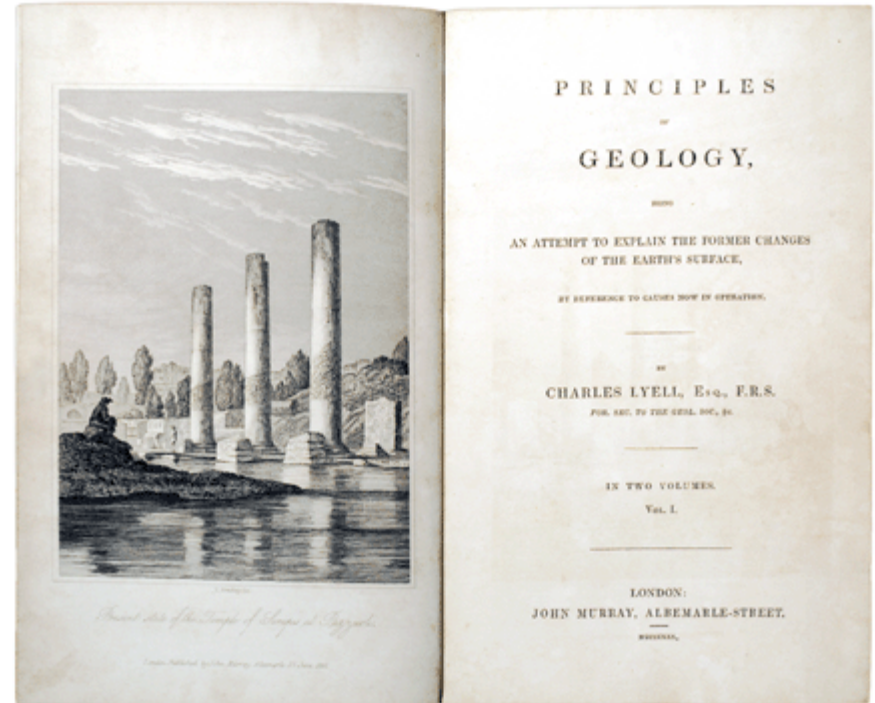
## 1831-1836





# Uniformitarianism

- Principle originally proposed by James Hutton.
- Developed and argued by Charles Lyell (1830).
- Contrasted against catastrophism.



- Earth is a steady-state system.
- Events in the past were the same as those occurring in the present day.
- Fossils were laid down as sediments slowly accumulated in areas of deposition;
- Exposed sediments were subjected to erosion. Endless cycle of subsidence and sedimentation, followed by uplift and erosion.
- Organisms became extinct and were replaced.

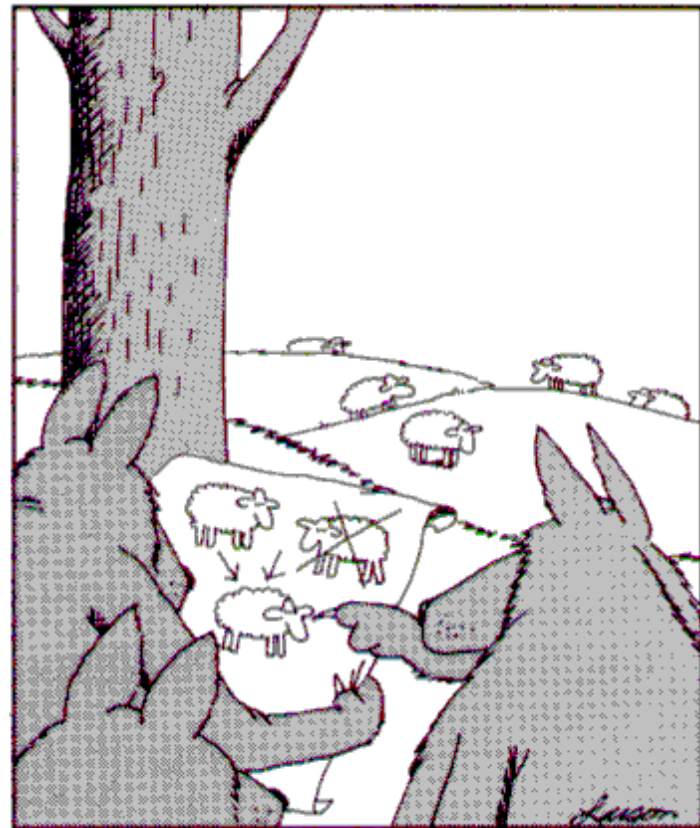


# Observations

- Geological upheaval at the Cape Verde Islands & Chile
- The fossil record
- Biogeography

# The Origin of Species

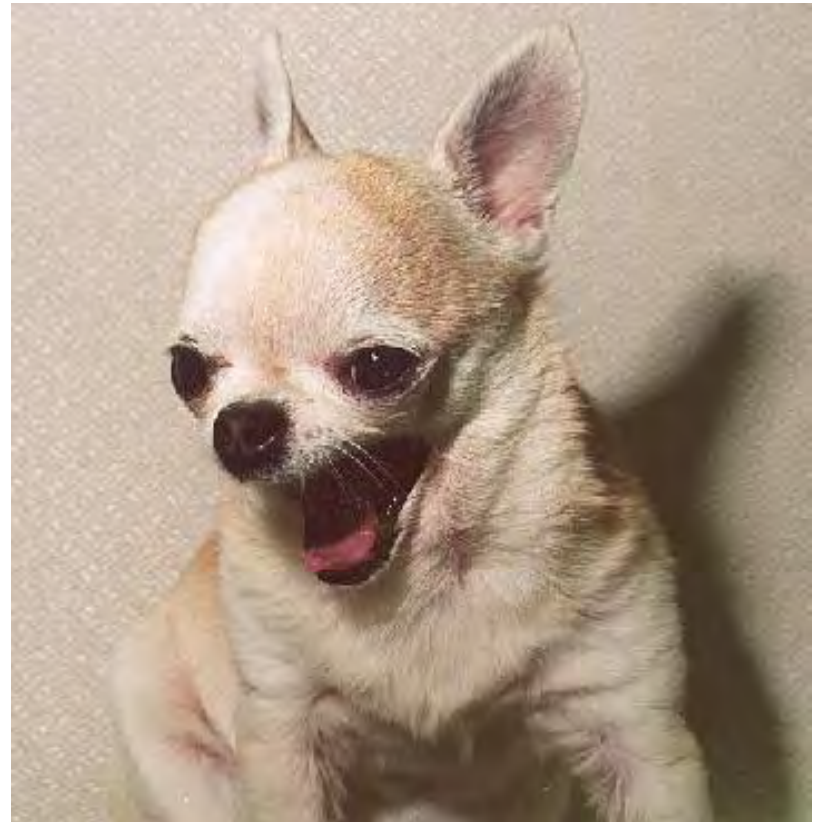
- Main theses:
- (1) characters of species are not fixed.
- (2) natural selection is the agent of change.
- (3) all organisms are related by descent.



Natural selection at work

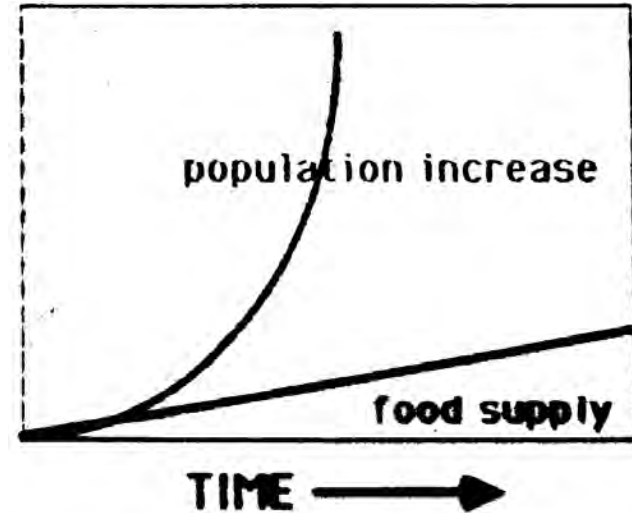
# Characters of species are not fixed

- Variation under domestication.
- Variation in nature.
- Variation heritable.



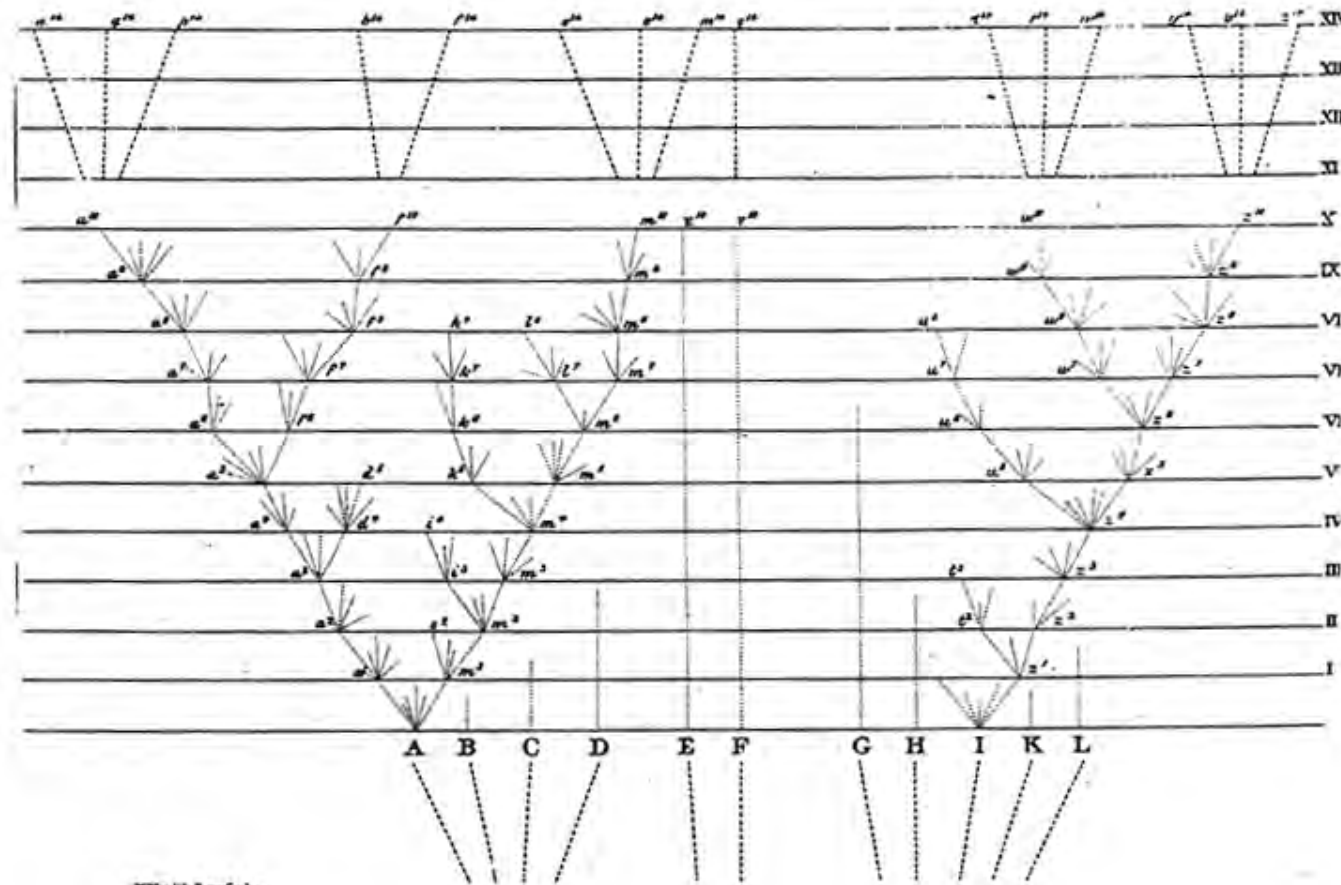
# Theory of Natural Selection

- Influenced by Thomas Malthus' s Essay on the Principle of Population (1798).





# All organisms related by descent



# Necessary and sufficient conditions for natural selection

- There is variation in the population in that trait.
- The variation must have some genetic basis.
- New variation is created all the time.
- There are limits to population growth.
- Variation in that trait is correlated with 'reproductive success'.

# Darwin's biggest dilemma...

- First edition, admitted profound ignorance on mechanisms of inheritance.
- Later editions, introduced blending inheritance and use and disuse of structures.

# Darwin's biggest dilemma...

- Blending inheritance incompatible with natural selection.
- Variation eliminated, not preserved.
- Evolution would be driven by mutation, not natural selection.



# Darwin's challenges

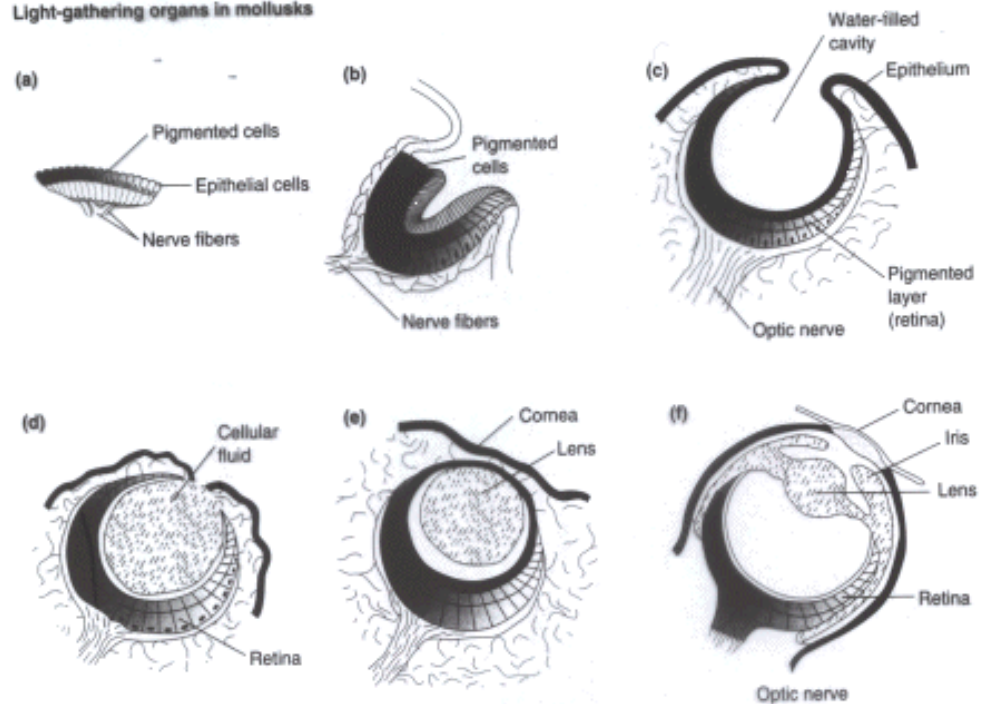
- The absence of intermediate forms.
  - Competition and extinction.
  - Taphonomy and incompleteness of fossil record.



# Darwin's challenges

- Evolution of organs of extreme perfection.
  - Numerous transitional forms found in other organisms.
  - Given time and power of NS, could go through these forms.

Light-gathering organs in mollusks



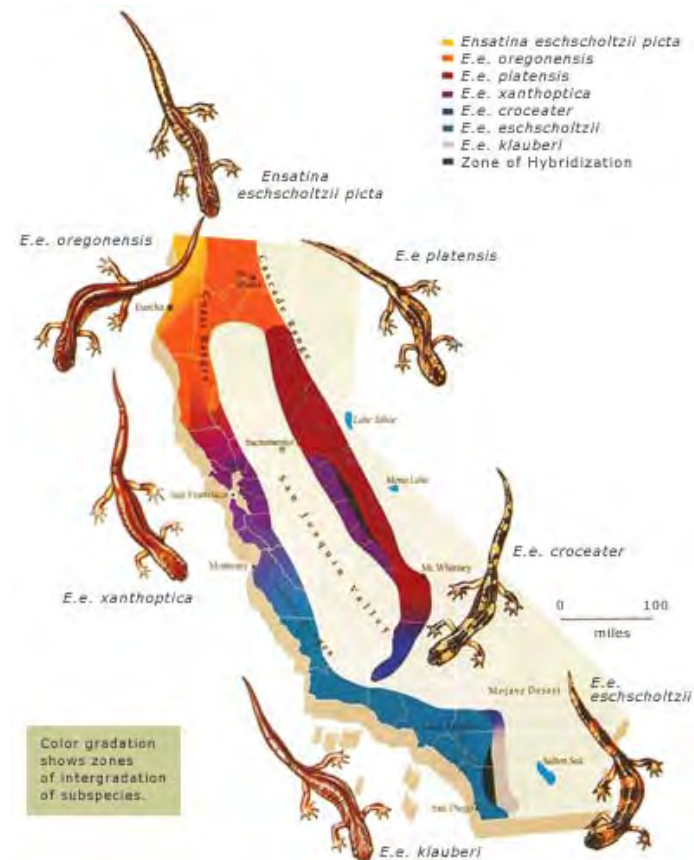
# Darwin's challenges

- The evolution of instinct (especially sterile individuals)
- Variation in behavior, as well.
- Could operate at higher level than individual.



# Darwin's challenges

- Production of new species.
- Noted that species were not discrete entities.
- Gradation between varieties and species not distinct.



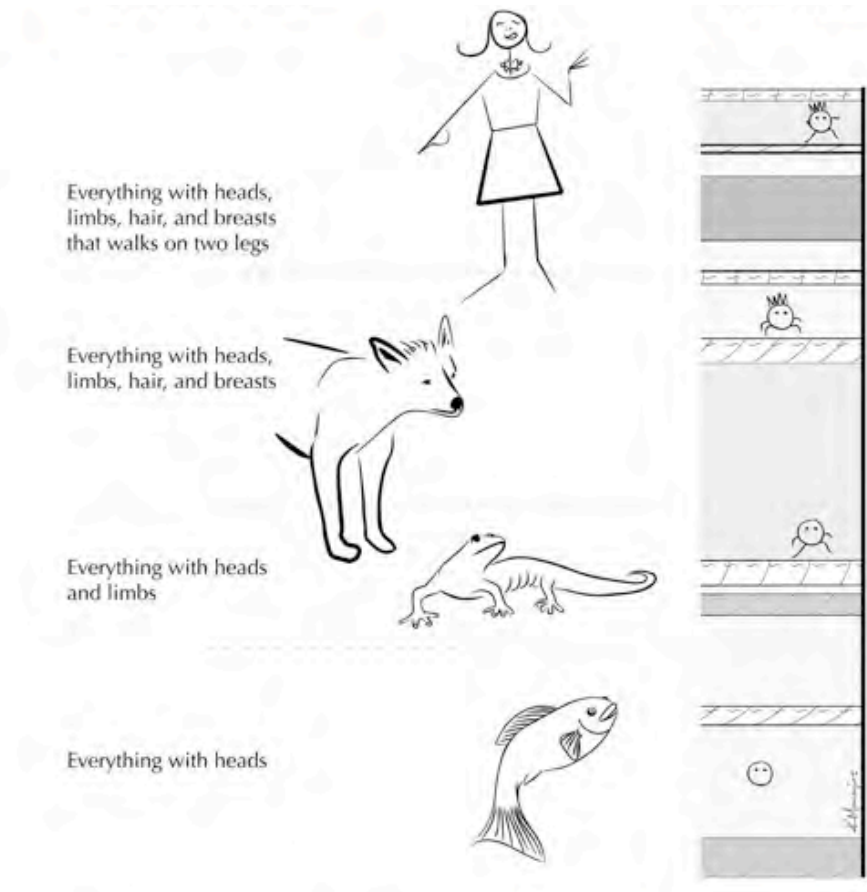
# Logical consistencies

- Earth must be very old.
- Given rates of deposition, estimated an age of hundreds of millions of years.



# Logical consistencies

- Fossils should show logical transitions.
- Recent fossils more similar to present-day fossils than older, deeper fossils.
- Logical transitions from fish to amphibian to reptile and mammal.





# Logical consistencies

- Geographic distribution.
- Present distribution determined by geography, not physical conditions.
- Adaptations determined by physical conditions.



# Logical consistencies

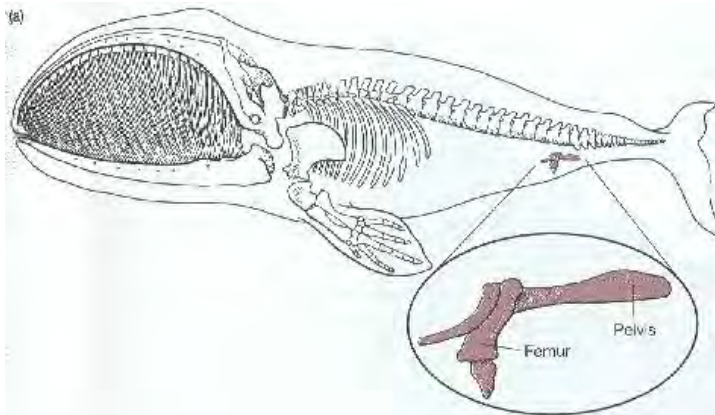
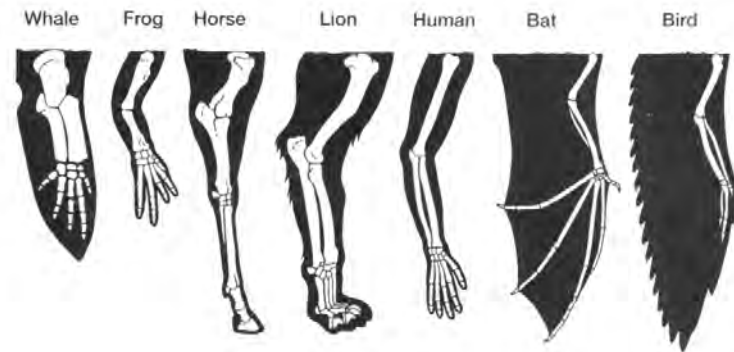
- Geographic distribution.
- Boundaries determined by limits to dispersal.
- Distribution of organisms on islands.
  - Bats only terrestrial mammals on oceanic islands.
  - No amphibians on oceanic islands.
  - Island species show clear affinities with mainland species.





# Logical consistencies

- Structure and development.
  - Homology (features sharing identity by descent).
  - Embryonic development.
  - Rudimentary organs.



# What came next

- Darwin hesitated to publish. Finished book in 1844.
- Didn't publish.
- Correspondence from A.R. Wallace.
- Both submitted papers to the Linnaean society.
- In 1859 published The Origin of Species



# Understanding Natural Selection

1. Individuals in a population vary in their characteristics and these variations are heritable.
2. New variation is created generation after generation.
3. Parents produce on average more offspring than is present to replace them.
4. Resources are limited, therefore only a fraction of offspring survive to reproduce.
5. Survival is correlated with heritable variation.

# Natural Selection, considerations

- Newly created variation (mutation) must be random with respect to need.
- Otherwise mutation drives evolution, and this is unstable.



# The philosophical content of natural selection is scientific

1. Evolution has no purpose.
  2. Evolution has no inherent direction.
  3. Natural Selection is materialistic.
- Does not mean that natural selection is an attack on religion.
  - Because it is materialistic, cannot address faith-based knowledge.
  - Provides explanations and predictions for the physical world.

# Criticisms and misconceptions

- Is natural selection a valid scientific theory?
- Claim: natural selection is a tautology:
- Evolution is the survival of the fittest;
- The fittest are those that survive.

# Criticisms and misconceptions

- Is natural selection a valid scientific theory?
- Argument for natural selection takes form:
  - A statement of facts regarding variation.
  - A statement of facts regarding population growth and limiting resources.
  - Logical inferences based on these facts.
  - If the facts or inferences are incorrect, then theory is false.

# Criticisms and misconceptions

- Is natural selection a valid scientific theory?
- Claim: Natural Selection is unscientific because it cannot be disproved.
  - Can explain everything, and therefore nothing.

# Criticisms and misconceptions

- Is natural selection a valid scientific theory?
- Testable AND falsifiable questions:
  - Do individuals vary in their characteristics?
  - Does variation have a genetic basis, at least in part?
  - Is new variation created by copying errors in the duplication of DNA in the germ cell line?
  - Is new variation random with respect to need?
  - Do populations have the potential to increase exponentially?
  - Blending inheritance, no natural selection.
  - Very young earth.
  - E.g. Lord Kelvin's estimate of age of earth (scientific hypothesis) vs. Darwin's theory of the unity of life.

# Criticisms and misconceptions

- The argument from design
- William Paley (1802): “Natural Theology, or Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature”
- Analogy of the watch.
- Raised difficult theoretical questions about the nature of the designer.
- Malaria and sickle-cell anemia.
- ‘Design’ of respiratory tract.



# Criticisms and misconceptions

- The argument from design
- Arises from confusion between 'function' and 'purpose'.
  - Tend to link 'purpose' with 'design'. Do not do so with 'function'.

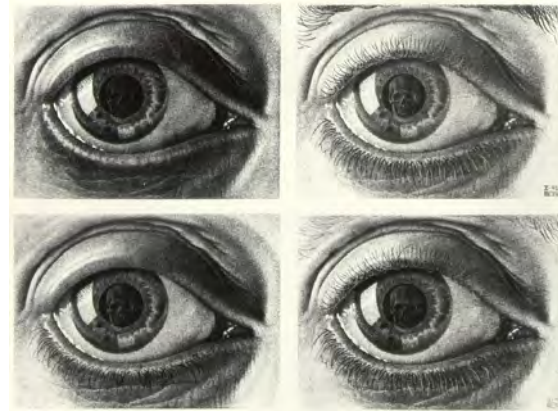
# Criticisms and misconceptions

- The argument from design: Explaining the seemingly impossible.



# Criticisms and misconceptions

- The argument from design: Explaining the seemingly impossible.
- Built on characterization of natural selection as chance.



# Criticisms and misconceptions

- The argument from design: Explaining the seemingly impossible.
- But:
  - Natural Selection the opposite of chance.
  - Natural Selection works gradually.
  - Natural Selection acts cumulatively.







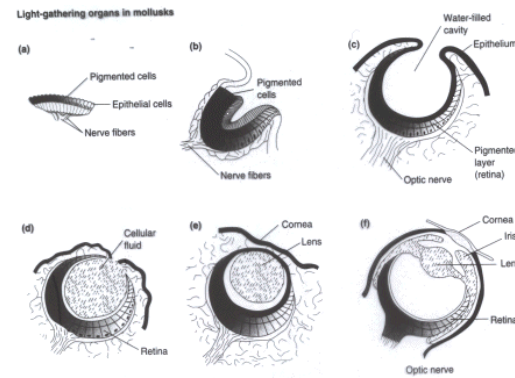
# “What good is half an eye?”

- Natural Selection is important when variation is considered within populations, not ideally.



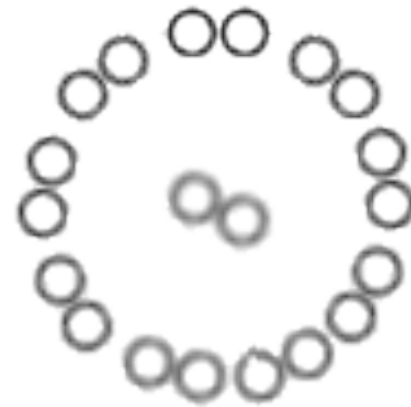
# “What good is half an eye?”

- Variation in molluscs from light-sensing cells to image-forming eyes.
- Across animals, eyes have evolved 40-60+ times.



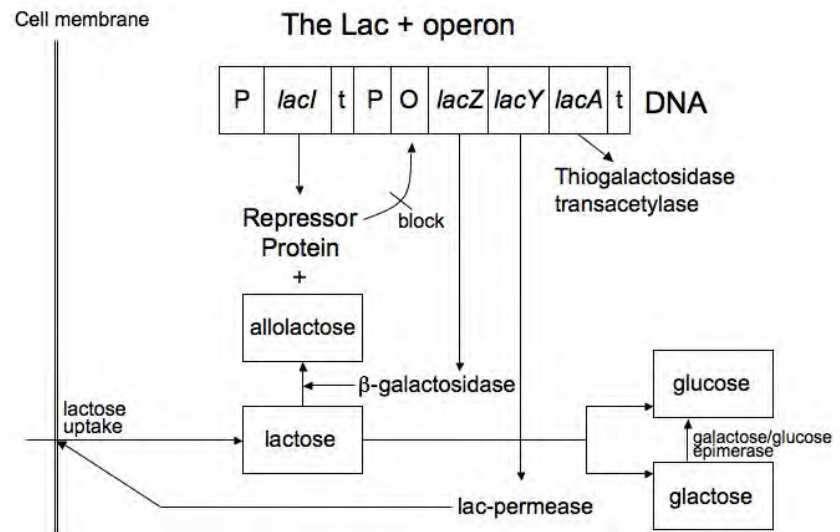
# Irreducible complexity

- Michael Behé (1996):  
Darwin's Black Box
- “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.”
- Refers to molecular organization.



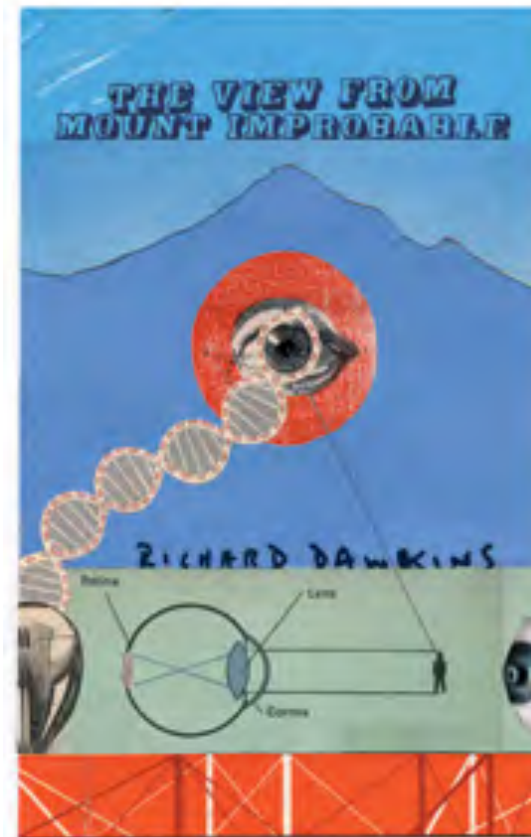
# Irreducible complexity

- What about assembling parts, combining different sources?
- Barry Hall performed knockout experiments with *E. coli* to test the Irreducible Complexity of the Lac + Operon.



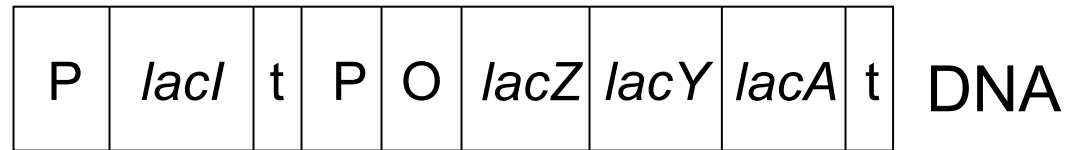
# Climbing Mt. Improbable

- Arguments from design rely on the fallacy of natural selection as chance.
- Also rely on the fallacy of evolution as immediate.
- Arguments from incredulity are not scientific...



Cell membrane

# The Lac + operon



Repressor Protein

block

Thiogalactosidase transacetylase

+

allolactose

lactose

$\beta$ -galactosidase

glucose

galactose

galactose/glucose epimerase

lac-permease

lactose uptake