- Dr. Rick Michod
- Internet information for my lectures and materials

  http://eebweb.arizona.edu/michod/intro_bio_182.htm

  or go to www.michod.com and click on “teaching” and then “intro bio182”

  or go to class web site
- Contact Information: 621-7509, BSW 306, michod@u.arizona.edu
- office hours Wed and Friday 1-2 while lecturing

1

An Evolutionary Framework for Biology

An Evolutionary Framework for Biology

- What is Life?
- Biological Evolution: Common Descent with change
- Major Events in the History of Life on Earth
- Tragedy of the Commons
- The Hierarchy of Life
- The Tree of Life
- Biology is a Science

Major Events and Characteristics of Evolution

- Non-life to Life
- Cells (Prokaryotic)
- Photosynthesis
- Cells in Cells (Eukaryotic Cell)
- Multicellularity
- Sex
- Homeostasis
- Sex
- Species
- Adaptation
- Social groups

What Is Life?

- Life requires metabolism, reproduction (replication), and evolution.

What is Life?

- An organism’s metabolism is its total chemical activity and consists of thousands of individual chemical reactions.
- These reactions must be coordinated for an organism to function.
- Genes provide this control and coordination.

What is Life?

- The internal environment of an organism must remain within a given range of physical and chemical conditions for that organism to remain healthy.
- **Homeostasis** is the maintenance of a relatively stable internal condition, such as temperature.

What is Life?

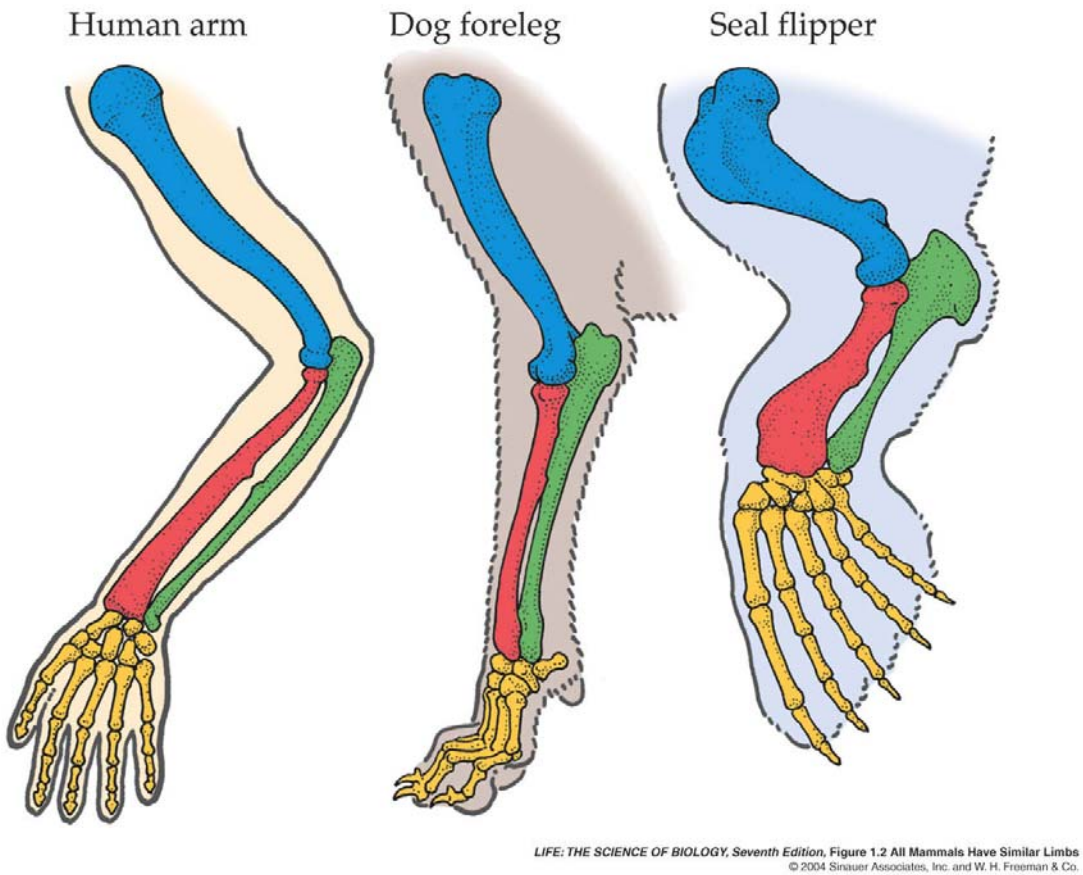
- Reproduction with variation is a major characteristic of life.
- Biological Evolution
  - Reproduction with variation (error in the duplication of the genetic material) results in evolution.
  - Common descent with modification
- Variations in the physical environment have helped drive the diversification of life.
- Adaptations
  - The differences among living things that enable them to survive and reproduce in different kinds of environments are called adaptations.

Biological Evolution: Common Descent and Change over Billions of Years

- Count George-Louis Leclerc de Buffon (1707–1788) wrote *Natural History of Animals* and suggested the possibility of evolution.
- Buffon observed the similarity of different mammals' limbs and suggested that the limbs of mammals were inherited from a common ancestor.

Figure 1.2 *All Mammals Have Similar Limbs*

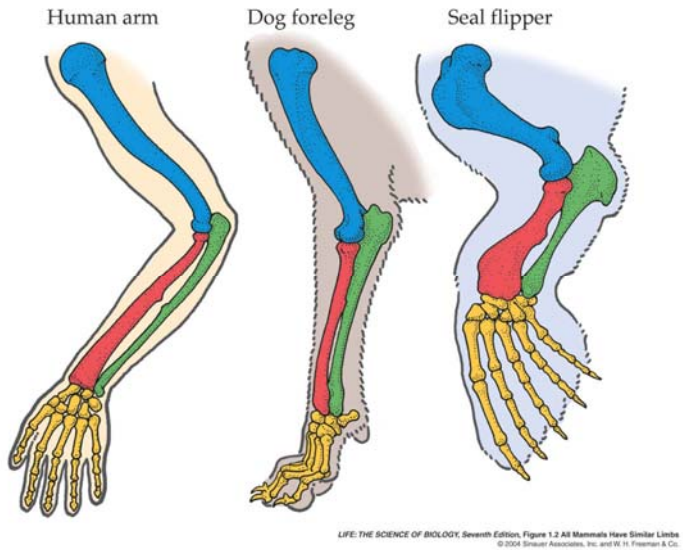
- All mammals have similar limbs but they may have different functions
- Forelimb uses
  - Humans for manipulating objects
  - Dogs for walking
  - Seals for swimming
- Evolved from common ancestor
  - Number and types of bones are similar
  - Common descent
  - Homology

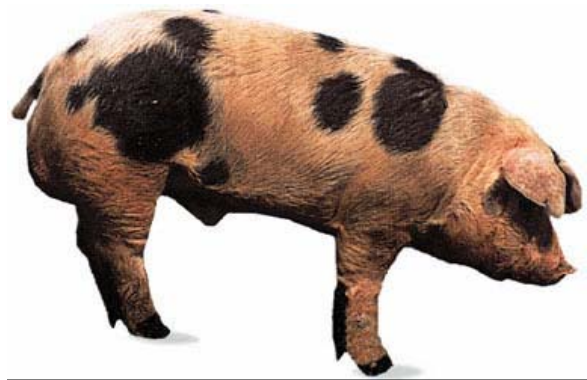


Bones of same type in same color

Evidence for Evolution: Bad Design, History, Atavisms

- Buffon observed the similarity of different mammals' limbs. (See Figure 1.2.)
- He noticed pigs had toes that were too small to be useful.
- He suggested that the limbs of mammals were inherited from a common ancestor.
- He concluded that pigs have functionless toes that were inherited from ancestors with fully formed and functional toes.





Theory Of Evolution Explains Bad Design Because Of Common Descent

- Natural selection can't design from scratch: it can only modify what went before
- Sometimes this leads to "bad design"
  - Pig's toes
  - e.g. every time we swallow, we risk choking because our breathing hole is in the way, and needs to be closed off.
    - The precursors to the breathing and eating tubes were in that order in the lungfish from which mammals evolved
    - We inherited this bad design

Biological Evolution: Common Descent and Change over Billions of Years

- Jean Baptist de Lamarck, a student of Buffon, suggested a mechanism:
  - That with continued use, some structures become larger from generation to generation, whereas others become smaller from disuse
- Though Lamarck made important contributions, this theory of acquired structures is not accepted by scientists today.
- Lamarck's theory was tested and found false

Biological Evolution: Theory of Natural Selection

- Struggle to Survive and Reproduce
  - Populations increase geometrically but the world is finite
  - Not enough room for everybody
- Variation
  - Differences or variations in traits among individuals
  - Some traits influence how well individuals survive and reproduce
- Heritability
  - Offspring resemble parents
- Conclusion: Natural selection will inevitably occur
  - Traits that increase the probability that their bearers will survive and reproduce are passed on to the next generation in greater frequency
- Summary of conditions for natural selection: Heritable variation in fitness

Figure 1.3 *Life's Calendar*

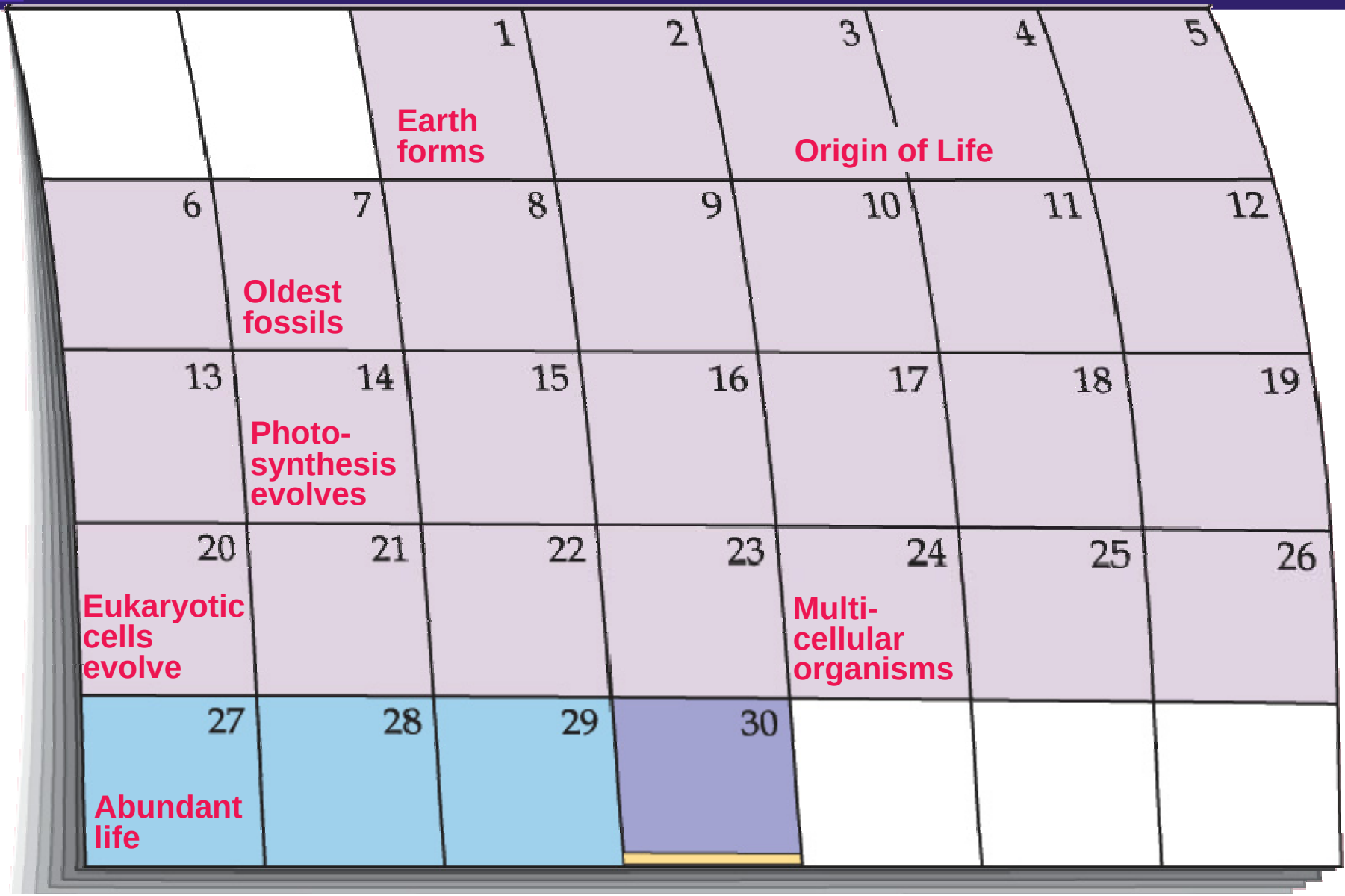


Figure 1.3 *Life's Calendar*

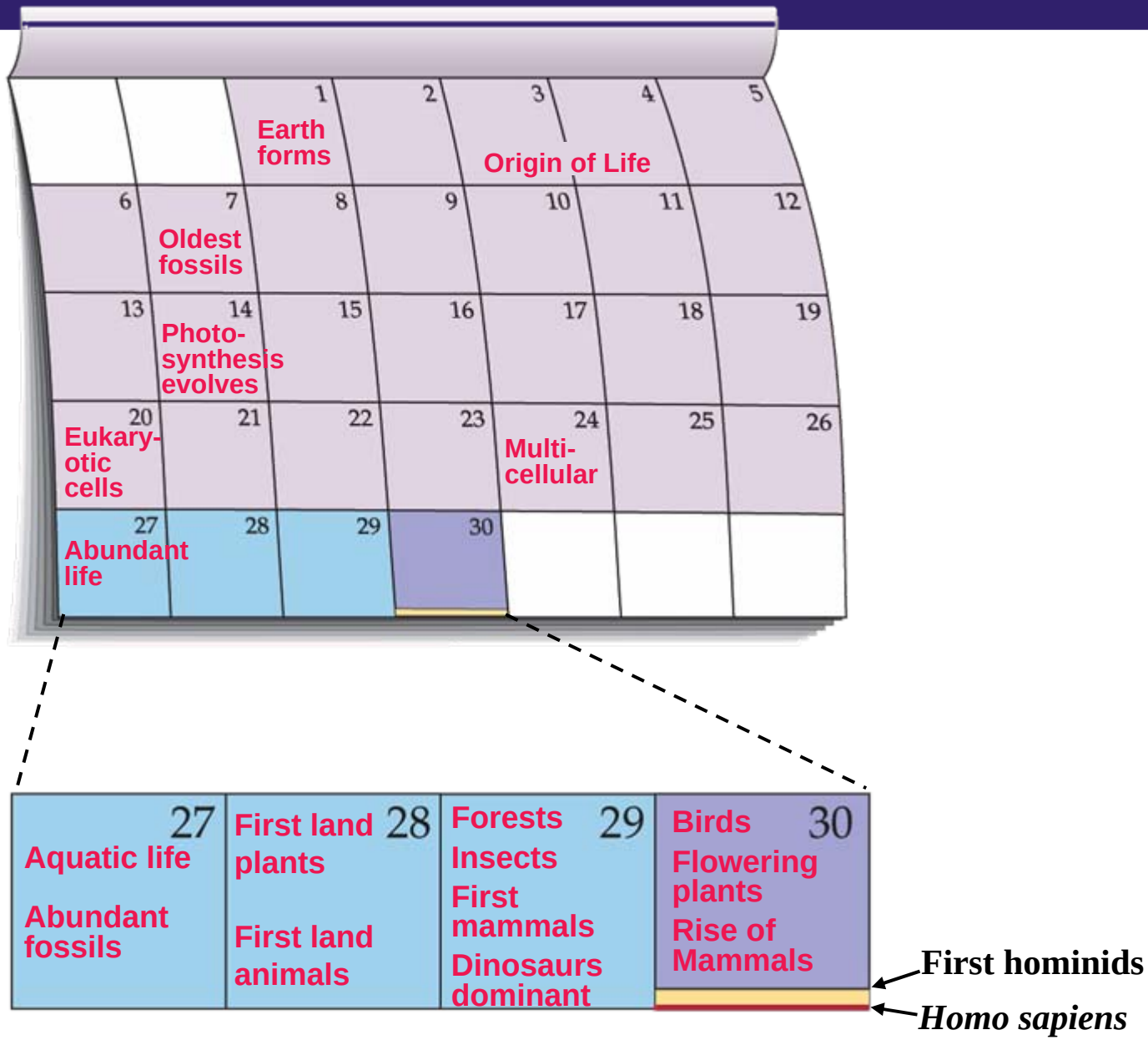
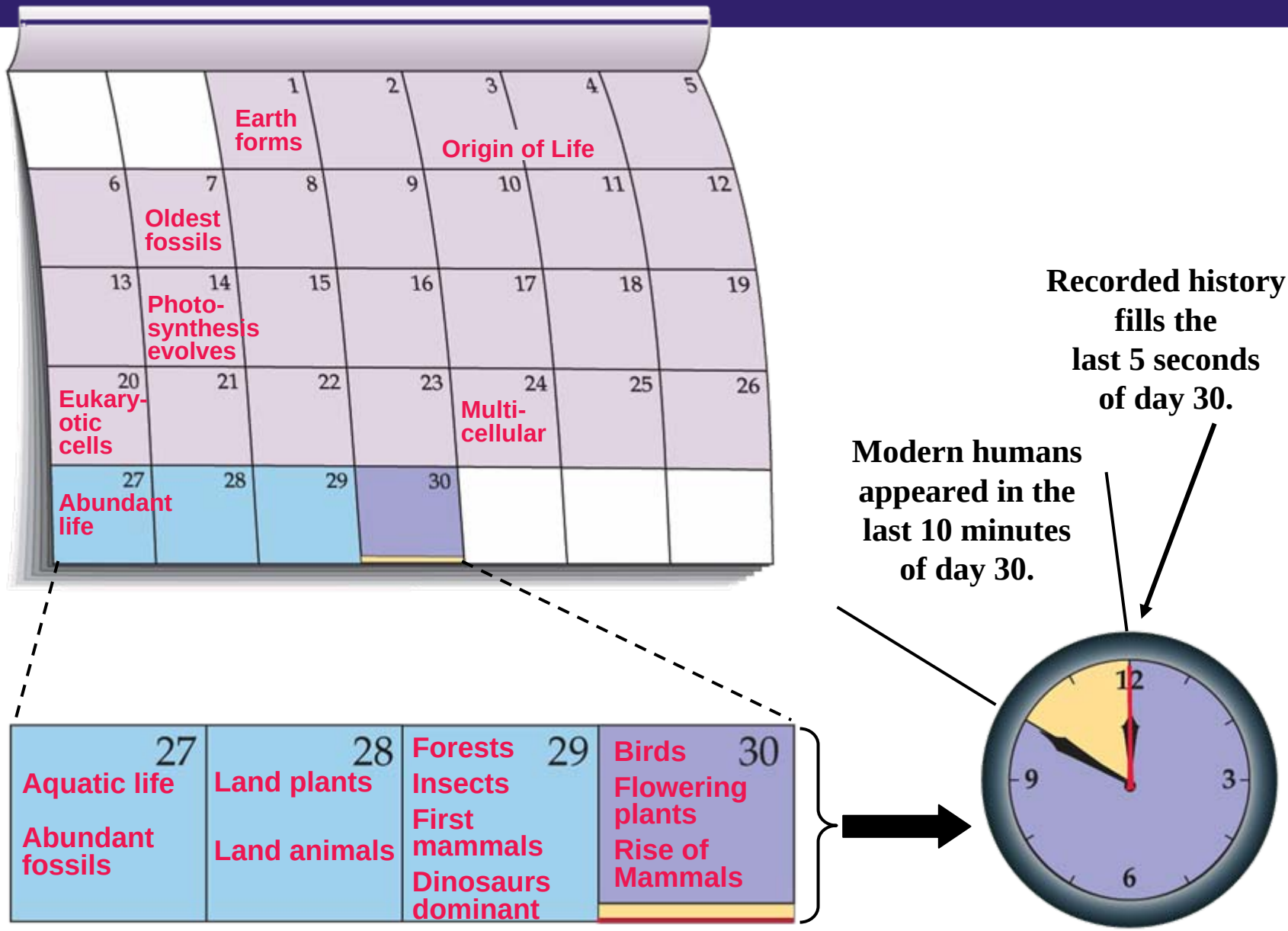


Figure 1.3 *Life's Calendar*



Major Events in the History of Life on Earth

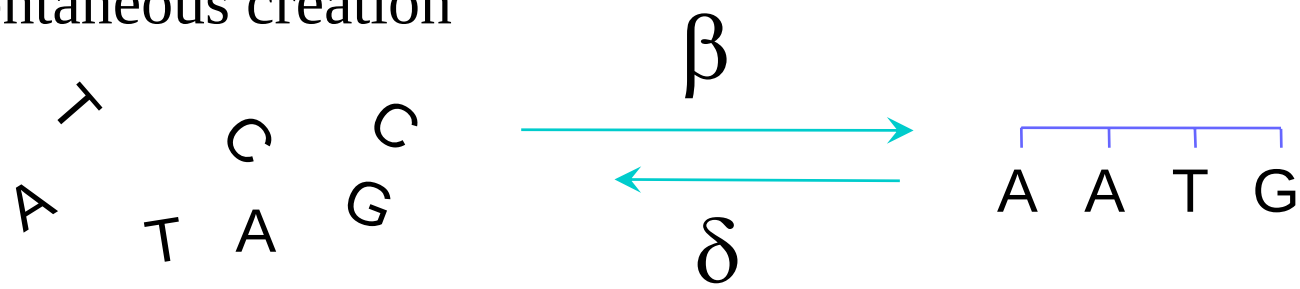
- Life arose from nonlife.
- Chemical evolution led to the appearance of life about 4 billion years ago.
- Random inorganic chemical interactions eventually produced molecules that had the property of acting as templates to form similar molecules (replication)

The First Individuals Were…

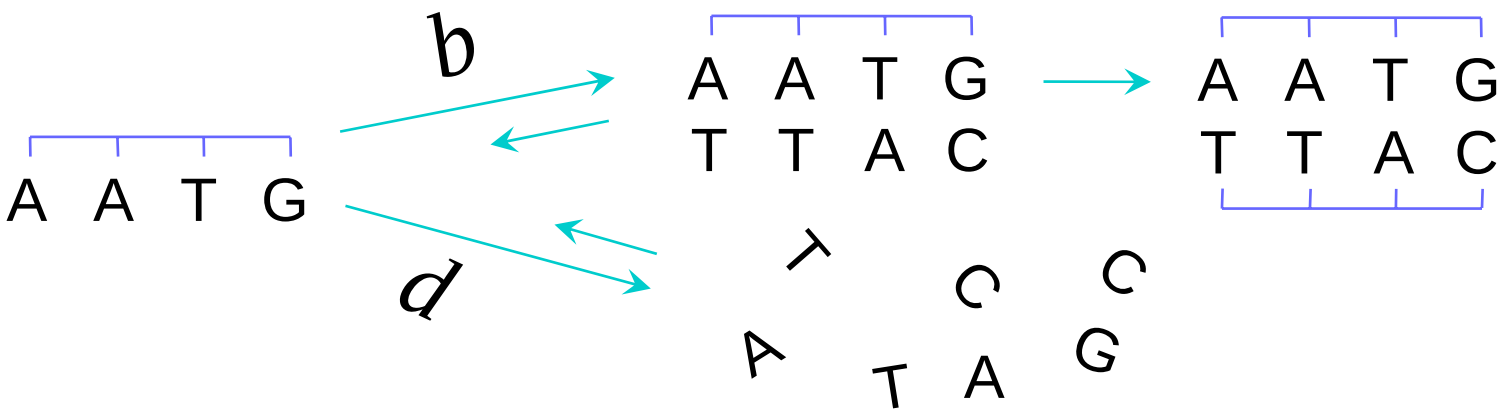
- Molecular Replicators
- Cooperative Groups of Replicators
- The First Cell

In the Beginning…

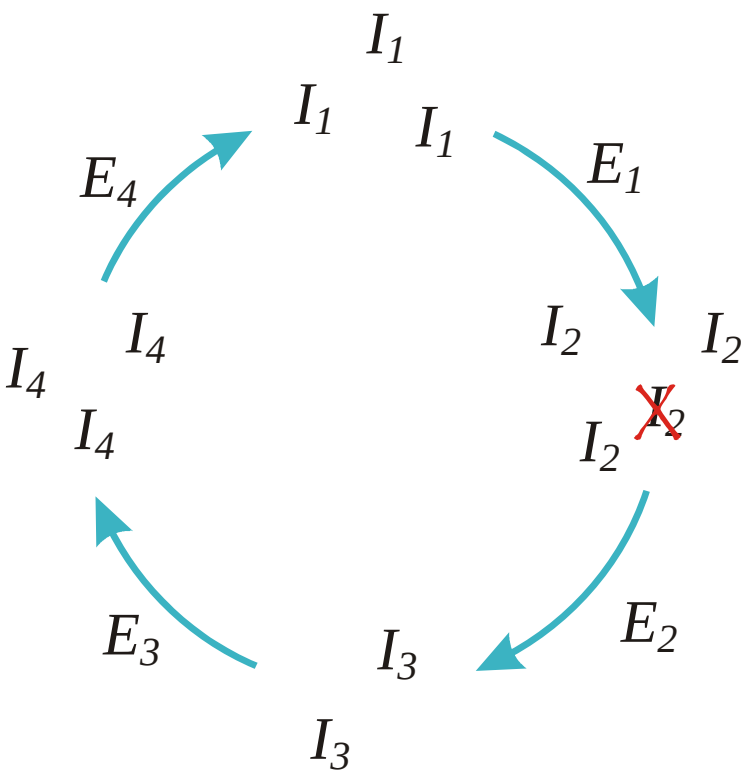
Spontaneous creation



Replication

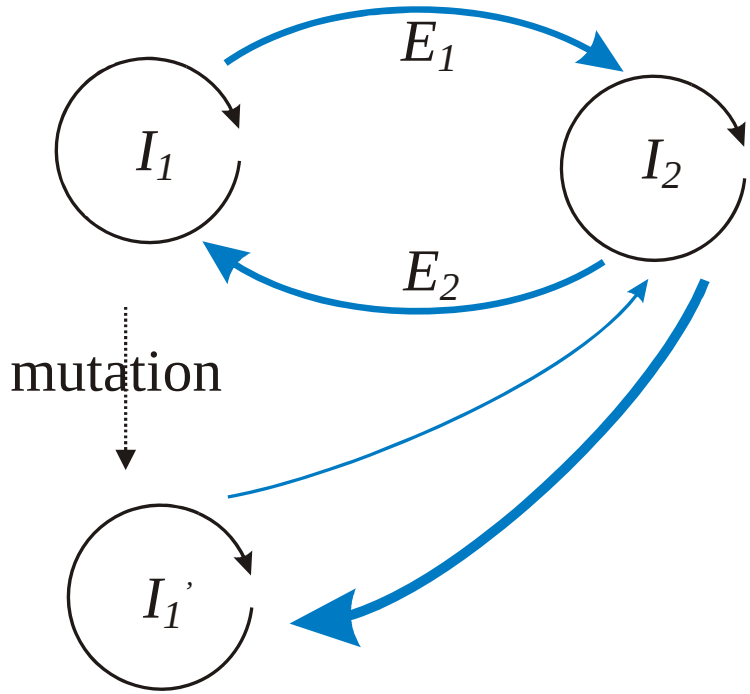


The World Was Born Sexual Without Individuality



- Before cells, little individuality
- Advantage of gene repair
- Cooperation difficult
- Prone to cheating and the tragedy of the commons

Gene Networks are Cooperative, But Cooperation is Prone to Cheating



Selfish mutant: takes more, gives less

"*I* " = informational molecule or gene

"*E* " = enzyme benefits others

Width of line indicates magnitude of effect

- Cooperative gene network
- *Not* evolutionarily stable
  - Parasites
  - Selfish mutants
- Cooperation requires conflict mediation through compartments
- The cell!
  - Mediates conflicts by aligning the interests of its member genes
  - Cells with selfish mutants do worse than cells with cooperators

Tragedy of the Commons

- Cooperation
- Conflict (temptation to cheat)
- Conflict mediation = ways to reduce conflict and enhance cooperation

Major Events in the History of Life on Earth

- Around 3.8 billion years ago certain molecules became enclosed in compartments, or cells.
- Cells capture energy and replicate themselves, two fundamental characteristics of life.
- For 2 billion years, all organisms were unicellular (prokaryotes), confined to the oceans.

Major Events in the History of Life on Earth

- About 2.5 billion years ago some prokaryotes acquired the ability to photosynthesize.
- The energy of sunlight was captured, and oxygen was generated as a waste product.
- Oxygen increased in concentration in the atmosphere, making aerobic metabolism possible.

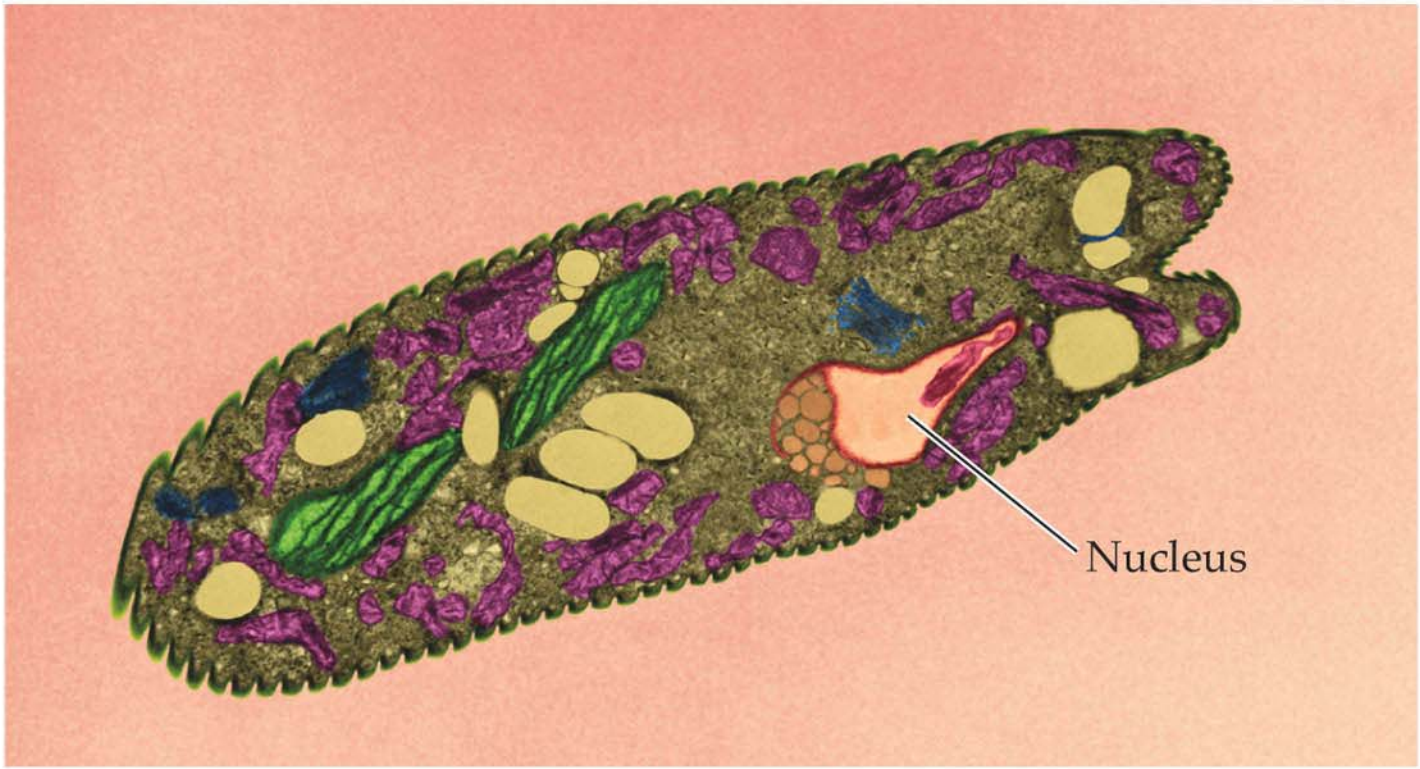
Major Events in the History of Life on Earth

- Another effect of oxygen was O_3 (ozone) accumulation in the upper atmosphere.
- Ozone has the property of preventing excess ultraviolet light from the sun from reaching Earth.
- Around 800 million years ago, ozone accumulation shielded the landmass from radiation enough to allow the movement of organisms to land.

Major Events in the History of Life on Earth

- Some prokaryotic cells became large enough to attach, engulf, and digest smaller cells.
- About 1.5 billion years ago, some cells had surviving smaller cells within them: These were early eukaryotic cells.

Eukaryotic cells look like cells within cells



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 1.5 Multiple Compartments Characterize Eukaryotic Cells**

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Major Events in the History of Life on Earth

- Two developments made the evolution of multicellular organisms possible:
  - The ability of a cell to change its structure and function to meet the challenges of a changing environment
  - The ability of cells to stick together after they have divided and to act in a coordinated manner
- Once organisms became multicellular, it became possible for certain cells to specialize.

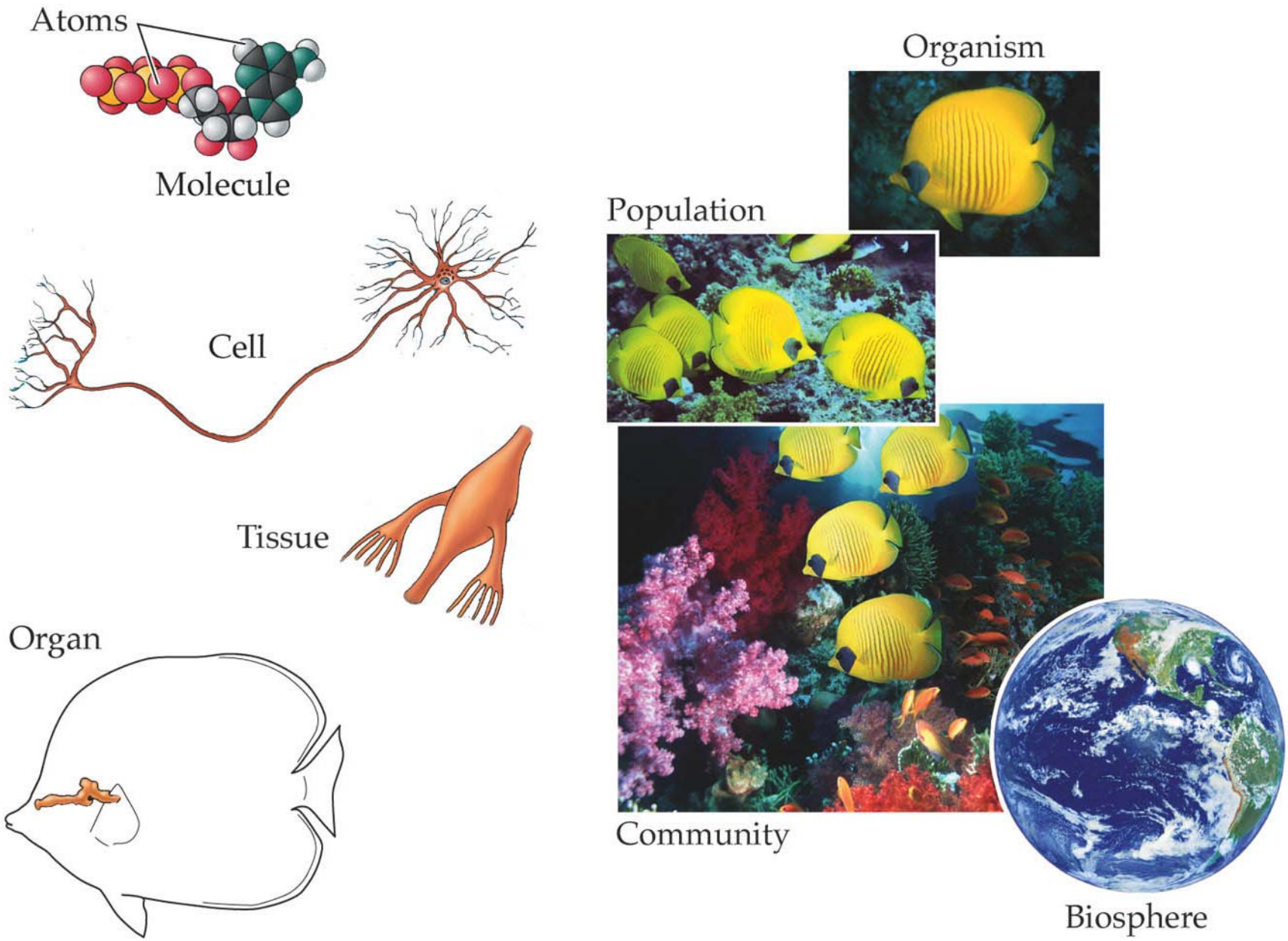
Major Events in the History of Life on Earth

- Sex (sexual recombination), the combining of genes from two cells, appeared early in the evolution of life.
- Sex increased the rate of evolution:
  - Organisms that exchange genetic information produce offspring that are genetically variable.
  - Because environments are constantly changing, organisms that produce variable offspring have an advantage over those that produce genetically identical clones.
- Recombination also functions to repair genes and keep them healthy
  - Recombinational repair

Levels of Organization of Life

- Hierarchy of life
  - Biology can be visualized as a hierarchy of units that include molecules, cells, tissues, organs, organisms, populations, communities, and the biosphere.
- To understand organisms, biologists must study them at all levels of organization, from low to high.

Figure 1.6 *From Molecules to the Biosphere: The Hierarchy of Life*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 1.6 From Mole

LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 1.6 From Molecules

© 2

The Evolutionary Tree of Life

- All organisms on Earth today descended from an original unicellular organism that lived around 4 billion years ago.
- Major evolutionary events have led to more complex organisms with larger quantities of information and more complex mechanisms for using it.
- Genetically independent and generally phenotypically distinct groups, called *species*, have evolved.

The Evolutionary Tree of Life

- The terms *simple* and *complex* refer to an organism's level of complexity.
- The terms *ancestral* and *derived* distinguish characteristics that appeared earlier in evolution from those that appeared later.
- All organisms alive today have survived because of appropriate **adaptations** to their environments.

Figure 1.7 *Adaptations to the Environment (Part 1)*

(*a*)

***LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition,* Figure 1.7 Adaptations to the Environment (Part 1)**

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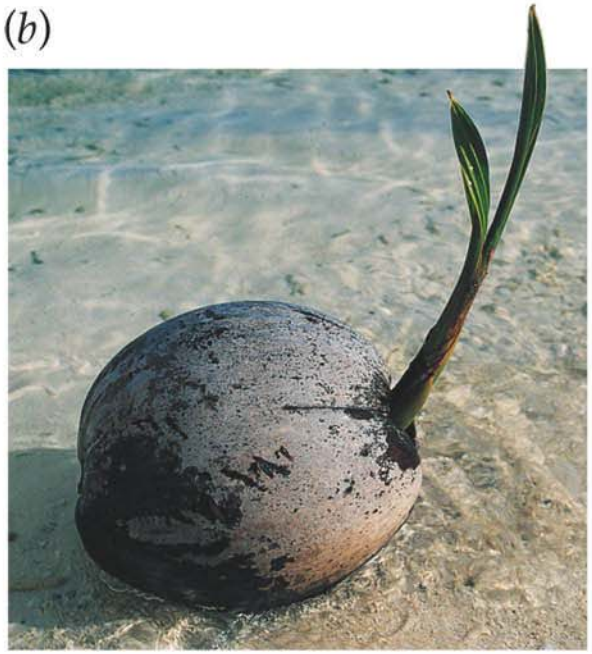
Figure 1.7 *Adaptations to the Environment (Part 2)*

(b)



***LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition,* Figure 1.7 Adaptations to the Environment (Part 2)**

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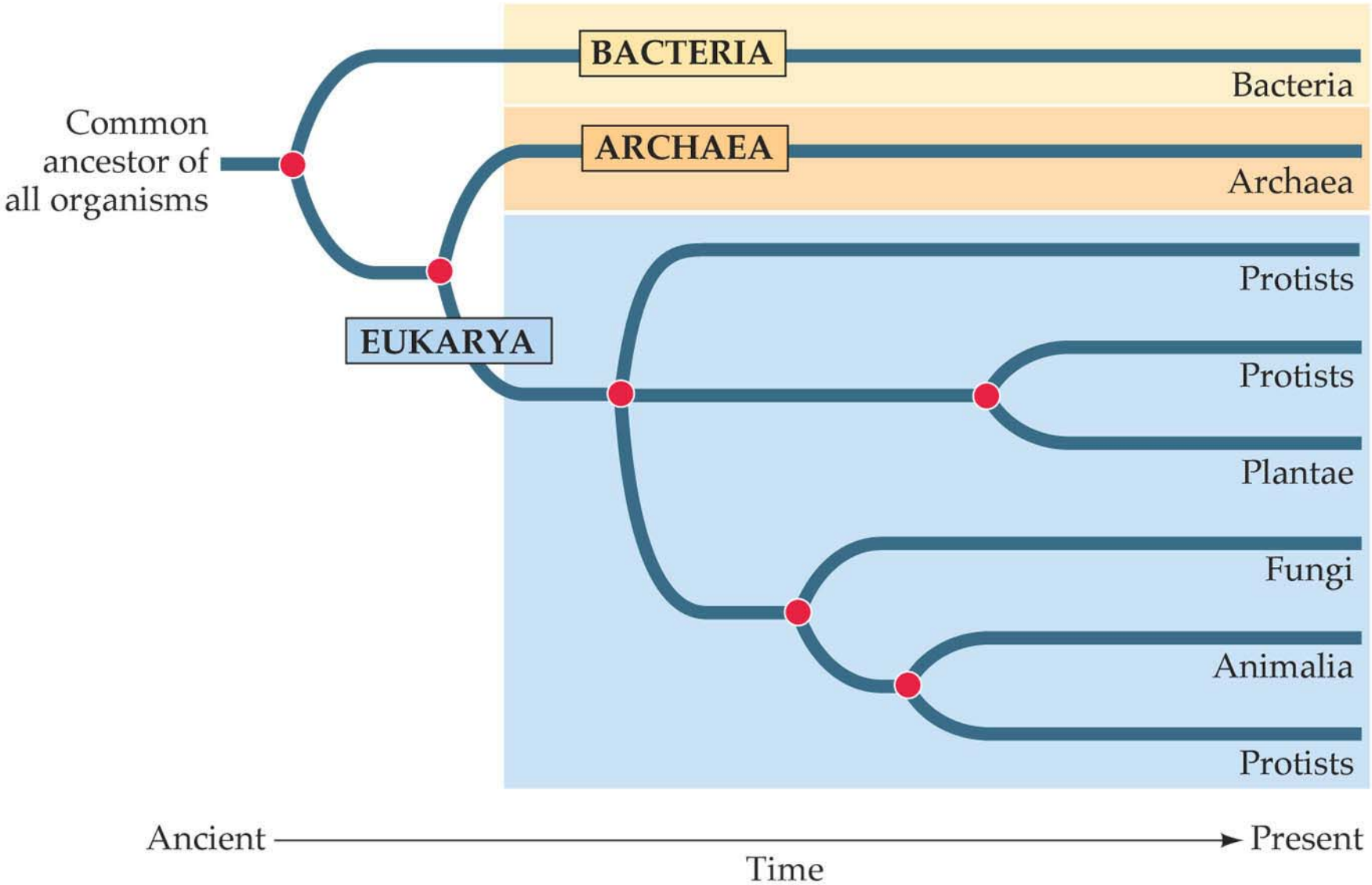
The Evolutionary Tree of Life

- Biologists have assembled a **Tree of Life** using data from a variety of sources, including the fossil record and modern techniques of DNA sequencing.
- Three major life domains form the hierarchical scheme: Archaea and Bacteria (prokaryotes), and Eukarya (eukaryotes).

Figure 1.8 *A Provisional Tree of Life*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 1.8 A Provisional Tree of Life

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The Evolutionary Tree of Life

- Each species is identified by two names:
  - The first, the genus name, refers to a group of species that share a recent common ancestor.
  - The second name, the species name, identifies a single species with the genus.
- For example, the scientific name of modern humans is *Homo sapiens.*

Biology is a Science

- There are five parts to the **hypothesis-prediction** (H–P) system:
  - Making observations
  - Asking questions
  - Forming hypotheses, or tentative answers to the questions
  - Making predictions based on these hypotheses
  - Testing the predictions by making additional observations or conducting experiments
- If the results do not support the hypothesis, it may be modified or abandoned

Biology is a Science

- Most tests of hypotheses are of two types:
  - Controlled experiments
  - The comparative method
    - Study example in text of global warming and decline of amphibian populations

Biology is a Science

- If the results of continued testing support the hypothesis, it may come to be considered a **theory**.
  - “Theories” are well established sets of principles, ideas and facts
  - Theory of gravitation
  - Theory of relativity
  - Theory of evolution

Biology is a Science

- It is important to distinguish science from nonscience.
- Science begins with observations and the formulation of hypotheses that can be tested and that will be rejected if significant contrary evidence is found.
- Science is
  - A particular way of understanding the world
  - *Not* democratic, or fair, in the sense that all hypotheses deserve equal time. We don't vote on what is true and is science.
  - *Not* amoral, anti-religion. Tells us what "is" not what "ought" to be. "Is" does not imply "ought"

What About “Intelligent Design”?

- Religious teaching in state schools is restricted by the Constitution.
- Adaptations created by an “intelligent designer”
- Intelligent design is creationism masquerading as science in order to be taught in schools.
- It is not science, as the US District Court has ruled in Kitzmiller vs. Dover.

http://coop.www.uscourts.gov/pamd/kitzmiller_342.pdf

So called “Irreducible Complexity”

Intelligent design’s alleged scientific centerpiece.

Certain biological structures appear to require multiple components to come together simultaneously, with no selection until all of them are in place.

This combination is too unlikely to come together by chance and they are produced by an “intelligent designer” according to intelligent design.

Answer to Irreducible Complexity

Intermediate stages were, in fact, selected for.

Sometimes we have good evidence for them, sometimes not.

These intermediate stages, which were useful for something else, were co-opted to produce a new, more complex structure, sometimes with a different function.

Darwin Already Answered This

The *Origin of Species*, Chapter 6 “Difficulties of the theory” and see the section “Organs of extreme perfection and complication”

“To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree…”

What Darwin Said Next

When it was first said that the sun stood still and the world turned round, the common sense of mankind declared the doctrine false; but the old saying of *Vox populi, vox Dei* ["the voice of the people = the voice of God "], as every philosopher knows, cannot be trusted in science. Reason tells me, that if numerous gradations from a simple and imperfect eye to one complex and perfect can be shown to exist, each grade being useful to its possessor, as is certain the case; if further, the eye ever varies and the variations be inherited, as is likewise certainly the case; and if such variations should be useful to any animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection, should not be considered as subversive of the theory.

What Darwin Said After That

- Darwin then went on to discuss intermediate eye forms found in nature
  - light sensitive cells
  - depression that gives an indication of direction without being so precise as a lens
- Even more intermediate forms have been studied since

Summary: What Evolution *Is*

The overarching framework for all of biology

A scientific theory and area of active and growing inquiry

Change in a population over time

Common descent with modification over time

Variation, selection and inheritance

Change in a population over time

An explanation for

- Good design
- Bad design

An explanation for our species and ourselves

Summary: What Evolution Is *NOT*

A completely random process

Change in an individual over time

An inevitable form of “progress”

A moral or amoral system

A system of belief or absolute truths

Proof that there is no purpose or meaning to life

Proof that God does not exist

Justification for immorality
(remember “is” does not imply “ought”)

Are Their Problems in Evolutionary Theory?

Definitely. Within the theory of evolution there are interesting questions and controversies. These are exciting times.

Science never explains everything, there are always interesting problems.

The more we do research, the more we understand.

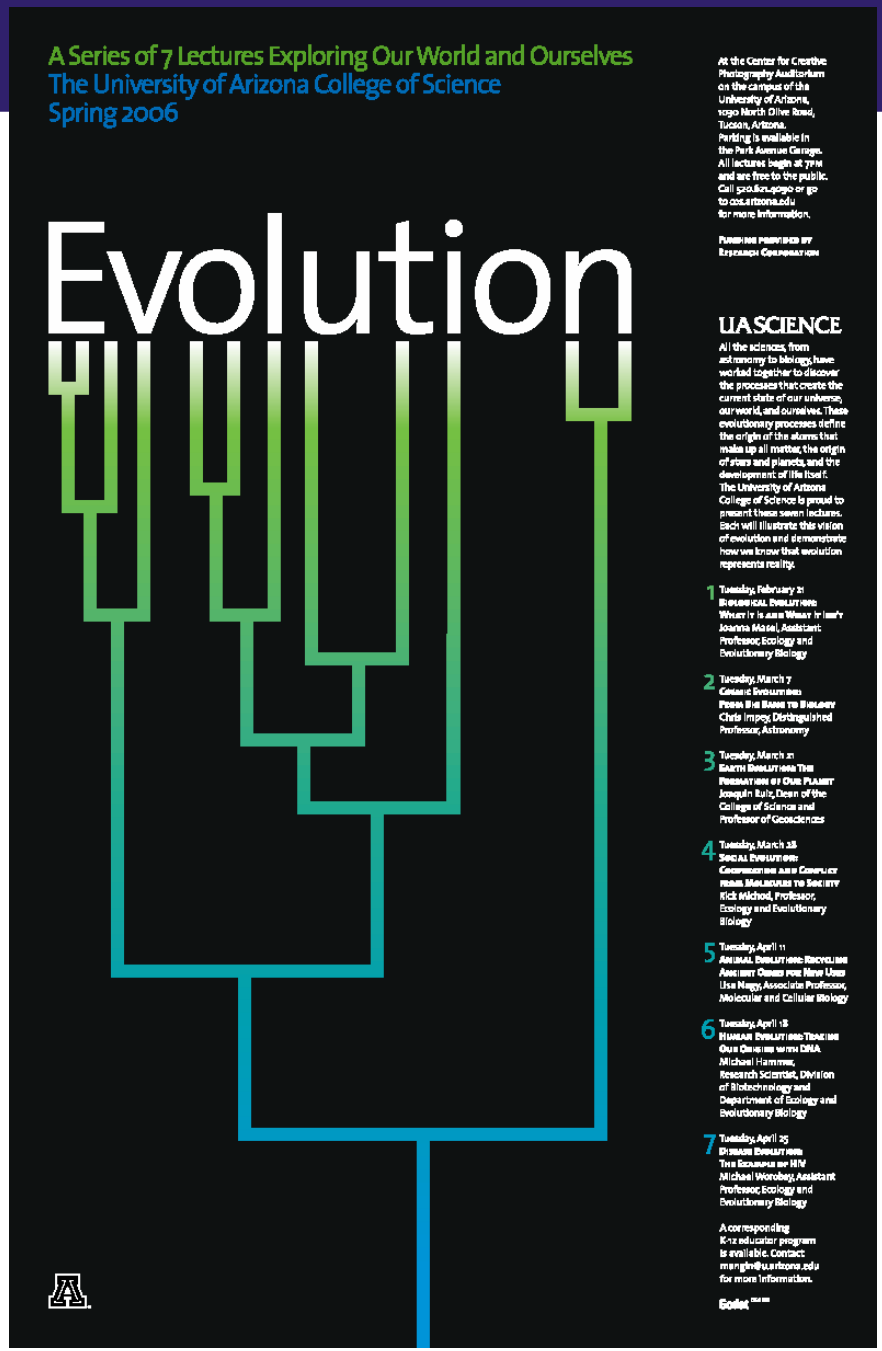
But we do know some things about evolution,

The facts of evolution (common descent with change); the tree of life is generally correct; natural selection, history and chance have all played dominant roles; life can be understood by natural causes (no need for an intelligent designer)

Biology is a Science

- The study of biology has major implications for human life.
- The development of genetics provides a means to control human disease and agricultural productivity, capabilities that also raise important ethical and policy issues.
- The study of biology also helps us to understand the human impact on the biosphere.
- Currently, biological science is positioned at the forefront of many ethical, ecological, social, and medical challenges and dilemmas.
  - e.g., global warming, “intelligent design”, stem cell research, what is life, biotechnology...

CoS Evolution Lectures



- Tuesday, February 21. Biological *Evolution: What It Is and What It Isn't* (Joanna Masel, Assistant Professor, EEB)
- Tuesday, March 7. *Cosmic Evolution: From Big Bang to Biology* (Chris Impey, Distinguished Professor, Astronomy)
- Tuesday, March 21. *Earth Evolution: The Formation of Our Planet* (Joaquin Ruiz, Dean of COS and Professor, Geosciences)
- Tuesday, March 28. *Social Evolution: Cooperation and Conflict From Molecules to Society* (Rick Michod, Professor, EEB)
- Tuesday, April 11. *Animal Evolution: Recycling Ancient Genes For New Uses* (Lisa Nagy, Associate Professor, MCB)
- Tuesday, April 18. *Human Evolution: Tracking Our Origins with DNA* (Michael Hammer, Research Scientist, ARL/EEB)
- Tuesday, April 25. *Disease Evolution: The Example of HIV* (Michael Worobey, Assistant Professor, EEB)