Evolution Lecture
Introduction to Evolutionary Biology.

I. Introduction. Evolution change -- i.e., if something has evolved, this usually means that it has been altered over time. The primary question becomes, “Do we live in a changeable world, or is the world actually a static place?” Some examples of evidence for a changing planet
   A. Geology
   B. Atmospheric changes: 1) weather (short-term) and 2) climate (long-term)
   C. Ecological communities change in composition
   D. Species distributions change
   E. Natural populations change in size
   F. Extinctions

Conclusion -- obviously the world indeed is not static and various types of change occur on several time-scales. However, this list does not adequately address the concept of biological evolution, which refers to change of a specific type. What distinguishes biological evolution? (Life!)

So then, what is life? The fact of a changing abiotic (non-living) world is an important element in biological evolution, but evolution in this course refers to changes to or within living organisms (the biota component of the earth or the biota). We therefore have a dichotomy: abiotic vs. biotic. Biological evolution clearly deals with changes to the biotic component, which is obvious in the (necessarily) vague definition of evolution provided by your text:

“All the changes that have transformed life on earth from its earliest beginnings to the diversity that characterizes it today.”

This definition establishes 3 important points in this standard view of biological evolution:
   A. Biological evolution is assigned to units possessing a characteristic called 1.
   B. This life had some beginning.
   C. Life may have had some original form that has changed/diversified over time.

Thus, we can establish a linear time-scale dividing the history of the earth into “pre-life” and “post-life”. Does this mean that evolution started when life arose? The answer is no, evolution can affect abiotic entities. However, biological evolution only affects living things because biology is the study of life. Therefore, all aspects of biology obviously deal with the products of evolution. Consequently, biological evolution is known as the central unifying concept of biology. This brings us back to the question, “what is life?” Unfortunately, this can be somewhat difficult to define. However, you may recall the important properties of life identified earlier in the course:
   A. Order
   B. Reproduction
   C. Growth and development
   D. Energy utilization (metabolism)
   E. Response/interaction to environment
   F. Homeostasis
   G. Evolutionary adaptation

(One important thing to consider is that beneath all these properties underlies a genetic basis. Can you think of how genetics links to these properties?)

It will become apparent that it is the third part of the definition of evolution that is the bulk of the study of evolution because this component implies that there are processes that cause change of living things to occur. What causes things (abiotic and biotic) to change? Is anything immune to change? Understanding the processes that have caused the characteristics we observe in living things is at the
heart of understanding biological evolution. These processes can be studied on a number of different time-scales:

A. Very short (i.e., years: e.g., beak depth in Darwin’s finches)
B. Somewhat longer (i.e., decades: e.g., pepper moths)
C. Very long (i.e., geological time scales -- thousands to billions of years: e.g., phylogenetic relationships)

II. History of evolutionary thought.
A. Pre-Darwinian views.
   1. The classical Greeks -- Platonic vs. Aristotelian thinking.
      a. Plato’s view of the world centered on the concept of the eidos or idea of objects. Under this view, known as essentialism, there is a transcendent, eternal and unchanging essence that is part of all objects, but which we never actually perceive. This creates a dichotomy: the essence of objects which never changes, and our imperfect perceptions of these objects. The important component of this view, however, was clearly meant to be the unchanging nature of the world, and variation in the natural world was therefore meaningless. Such ideas had a profound impact on thoughts about nature for centuries.
      b. Aristotle was an astute observer of the natural world. As a result of his keen examinations, Aristotle perceived a smooth and orderly progression of increasing complexity from inanimate objects to plants to animals to deities. In this “Great Chain of Being” (*scala naturae*), he believed in an orderly sequence from one form to another just like rungs in a ladder with on room for change to occur.
   2. Christianity. The views of the Greeks were incorporated into early Christianity which likewise held a view that biological evolution was not possible. God had created each particular organism and they had remained unaltered since that nine. This view held that there is variability within forms or types, but that there is never change from one type to another (i.e., speciation). Even today, so-called “scientific creationists” hold this view. Such typological thinking -- that variation within types of organisms is unimportant -- was at the heart of the Greek view of the natural world and was the predominant belief influencing evolutionary thought during Darwin’s time. By the time Darwin published *On the Origin of Species*, natural theology, the study of the natural world in order to better understand its creator, was a major focus of Christian thought. Natural theologians viewed adaptations of organisms as evidence that God had created each organism for a special purpose.
   3. Evidence of change. Starting in the mid-1700’s evidence was building that suggested that the earth was both old and a place characterized by great change.
      a. Georges Cuvier founded the science of paleontology, the study of fossils.
      b. In 1788, James Hutton had proposed the Principle of Uniformitarianism which held that the same geological processes that are occurring now have always occurred. The implication was that the earth must be very old (how else could mountains become so eroded?). Uniformitarianism was widely publicized by Charles Lyell in his influential text, *Principles of Geology*.
      c. Before Darwin, by far the most well-known evolutionist was Jean-Baptiste de Lamarck. Lamarck examined countless collections of insects, and came to believe that progressions from one form to another were obvious. However, he held that there was no single “Chain of Being” as Aristotle had proposed, but rather an incredible number of such pathways that led to increasing levels of perfection in organisms. Lamarck’s
proposed mechanism incorporated the idea of the idea of use/disuse of traits with the concept that change acquired during an individual’s lifetime could be passed on to it’s offspring (inheritance of acquired characteristics). Although the prevailing creationist-essentialist thinking during his time kept Lamarck’s unorthodox theory from being taken seriously, his ideas about evolution as the best explanation for the fossil record and the observed diversity of life, with emphasis on the great age of the Earth and adaptation to environment as a primary product of evolution were visionary, and a prelude to the emergence of evolutionary thinking.

B. Darwinism

1. The Voyage of the H.M.S. Beagle. Darwin spends five years as the science officer of the Beagle, during which time he links Lyell’s ideas of geological evolution (a very old and constantly changing Earth) to that of the evolution of life on Earth.

2. The Darwinian view of life. Over the next 12 years, Darwin builds his views of life and evolution, resulting in the publication of The Origin of Species in 1859. This view of life has a dual meaning: first it establishes evolution as the basis of life’s unity and diversity (descent with modification), and second it provides for a mechanism to explain evolution (the processes of natural selection and adaptation).

   a. Descent with modification. Darwin’s condensed view of the unity of life as a historical one of all organisms related by common descent from some unknown ancestral prototype (what biologist may refer to today as the progenote or progenitor cell) that emerged as life in the remote past. This allows the history of life to be viewed symbolically like a tree with each branch fork representing an ancestor common to all evolutionary lines that branch forth beyond that fork. This view has two important implications: first species are related by common ancestors (i.e., closely related species are such because the share many characteristics due to having evolved from a common ancestor), and second, this relationship allows all life to be traced back to a single common ancestor (the base of the tree) from which all lineages of life have evolved.

   b. Natural selection and adaptation. Darwin’s cause for biological evolution.

III. Evidence of Biological Evolution

A. Fossil record

1. Aging organisms/chronological order
2. Extinct species (e.g., dinosaurs)
3. “Misplaced” fossils (e.g., seashells on mountain tops)
4. Transitional forms (e.g., horse evolution)

However, the fossil record is not without problems for some evidence. Often it may be:

1. Incomplete because particular conditions must exist for fossilization to occur (can you think of what would eventually happen if most everything became a fossil?), and
2. Unsuitable for study of some types of organisms (i.e., soft bodies) or features of organisms (i.e., skin color or texture - what do you suppose the skin of a Tyrannosaurus rex was like?)

B. Observation of biological evolution in nature. (e.g., pepper moths, beak depth changes in Darwin’s finches)

C. Comparative anatomy.

1. Based on our definition of biological evolution, the diversification of life means that any particular type (e.g., species) of organism will be closely related to some groups
and more distantly related to others. Just as with individuals that are closely related, closely related groups of organisms may share certain physical or anatomical similarities. Therefore, some of these similarities may be useful for examining the evolutionary relationships among a range of organisms (e.g., forelimbs of mammals). Such structures/features which are shared due to common ancestry, regardless of contemporary function, are called homologous structures.

2. Superficial similarity of some structures can be deceiving by suggesting a possible relationship that does not actually exist -- there may be similar structures that different organisms may seem to share but were not found in their common ancestor (e.g. wings -- do you think the wings of birds, bats and bees are homologous?). Structures which may be superficially similar and serve the same function (but not related by common descent) are known as analogous structures and are the product of convergent evolution (form fits function).

3. Finally, imperfections exist in all organisms and are often evidence of biological evolution:
   a. Imperfect structures. These seem to be the product of a slow but responsive process that is constrained to operate with materials that are available (e.g. Panda’s thumb).
   b. Vestigial structures. These are structures that are rudimentary or of no apparent use (e.g. human appendix).

D. Comparative embryology. You may have heard the phrase “ontogeny recapitulates phylogeny”, meaning the development of an individual clearly reflects the evolutionary “development of the species. The actual relationship is not tight, but organisms do often exhibit as embryos features not present in the fully developed individual (e.g., tails in humans). As well, comparatively different types of organisms often share similar embryonic stages/features.

E. Comparative biochemistry. There are many similarities among organisms at the molecular level.
   1. A common genetic code and mechanism to implement it (all life may in fact be related).
   2. Specific molecules (e.g. cytochrome c, globins, nucleic acid sequences)

F. Biogeography. Evolutionary history often seems to be correlated with geography:
   1. Species in different habitats but in the same geographic area are often more closely related than species in the same types of habitats but in different geographic areas.
   2. Restriction or absence of particular types of organisms to certain areas (e.g., marsupials in Australia).

G. Artificial selection. (e.g., pigeons, dogs, cows, brassica and Fastplants)

IV. Natural Selection and Adaptation -- a mechanism of evolution

A. Ernst Mayr interpreted Darwin’s theory of natural selection as 3 inferences based on 5 facts.

Fact 1: All species have such great reproductive potential that their population size would increase exponentially (without bound) if all individuals that are born reproduced successfully.

Fact 2: Except for seasonal fluctuations, most populations remain stable in size.

Fact 3: Natural resources are limited.

Inference 1: Production of more individuals than the environment can support leads to a struggle for existence among individuals of a population, with only a fraction of offspring surviving each generation (i.e., competition for limiting resources among individuals allow only a few to make it each
Fact 4: Individuals in a population exhibit variation in their characteristics; no two individuals are exactly alike.

Fact 5: Much of this observed variation is heritable (i.e., most variation has a genetic basis)

**Inference 2**: So surviving in the struggle to exist is not random, but depends part on the hereditary constitution of the surviving individuals. Those individuals whose inherited characteristics fit them best to their environment (i.e., best adapted) are likely to leave more offspring than less fit individuals (i.e., better equipped individuals -- more fit phenotypes -- have a better chance of contributing to the next generation of individuals in the population).

**Inference 3**: This unequal ability of individuals to survive and reproduce (i.e., variation in survivability and reproducibility) will lead to gradual change in a population, with accumulation of favorable characteristics increasing over time (i.e., successive adaptation). So, natural selection = differential reproductive success (based on variable survival and reproductive rates) which leads to adaptation of organisms to their environment (i.e., fine tuning of the phenotype over successive generations).

**B. Some fine points of natural selection and evolution:**

1. Populations (e.g., species or subsets of species) evolve. Individuals do not evolve.
2. Natural selection operates on individuals by virtue of their interactions between other individuals and their environment.
3. Evolution can be measured only as change in variation in a population (e.g., species) over a succession of many generations.
4. Natural selection, and thus evolution, is constrained to operate only on heritable variation.
5. Finally, since environmental factors also vary in time and place, so do the specific results of natural selection (in terms of utility in time and space).