Evolution:

Evolution is the foundation of biology.

It explains why animals (and other organisms) look the way they do, how they are related, and even why they do what they do. Basically it can explain just about anything in biology.

So what is evolution?

The change in organisms over time. Or more precisely, a change in the genetic makeup of a population over time.

(But we're not done for a while!)

Note:

This definition says nothing about fossils, mimicry, adaption, etc. These are the results of evolution. The definition merely talks about genetics.

So let's delve into evolution in more detail. Five parts:

I - History II - Mechanism III - Evidence IV - Genetics
V - Evolution in action/examples

I - History

[Fig. 22.2, p. 453 & several Figures, not in book (mostly pictures of the following folks)]

Linnaeus -

- First organized animals into some kind of cohesive structure.

- Grouped similar animals into similar categories, and established a hierarchy of groups, where the higher up one goes, the more diverse the animals in each group.

- "Father of taxonomy". More on this tomorrow.

Lamarck -

- First to propose evolution as a concept. But his mechanism was weird.

- If an animal uses a particular part of its body a lot, then that part will develop more (e.g., athletes).

- Thus, animal "acquires" certain characteristics.

- These are then passed on to the offspring (this idea is basically wrong).

- But Lamarck had great foresight - the idea of evolution was a breakthrough - it explained the fossil record, and opened up the possibility of a long period of time for things to happen (e.g. animals to change)..

Cuvier -

- opponent of evolution, but first to recognize that the age of fossils varies in different rock strata. Assumed that these represented species that had died out in "that location", but were still alive elsewhere.

- father of paleontology - made many contributions to anatomy as derived from fossil material.

Hutton and Lyell -

- Scottish geologists.

- Hutton noted that rock formations, landscapes, etc. can all be explained by processes going on today. Formation of river valleys (Grand Canyon probably the most spectacular example), mountains, etc.

    - Gradualism - big changes can take place over long periods of time.

- Lyell developed uniformitarianism, as well as elaborated and polished Hutton's ideas.

    - Hutton was an awful writer, and it took Lyell to "translate" his ideas into readable English..

    - Uniformitarianism - Things happen today in the same way as they did years ago. For example, the action of wind, water, volcanoes was (and is) the same throughout history. It is true that this is an assumption of evolution.

- IMPORTANT implication - The earth is much older than was thought up until then.

Summary up until now.

- The age of the earth is very old.

- Evolution as a concept had been considered, though the mechanism didn't make sense..

Darwin

- See text for some more details of his life.

- "Darwin and the Beagle" by Moorehead.

- In brief:

    - Was born in 1809.

    - Grew up with an intense interest in biology.

    - Entered Cambridge to become a member of the clergy (most naturalists were clergy at the time).

    - Shipped out on a five year voyage aboard the Beagle in 1831.

[Fig. 22.5, p. 455]

- While traveling across South America, particularly the Galapagos, he started to notice similarities and differences in animals and plants. Started to develop some of his ideas.

- Published many papers on his return to England, but even though he wrote up a large "essay" on evolution, he did not publish this until much later.

- In 1859, spurred by Wallace, he finally publishes "The Origin of Species".

- Major breakthrough in biology. Carefully argued, with extensive notes, examples, etc.

- What was different? The mechanism. There was finally a mechanism that could explain evolution - natural selection. More on this in a moment.

- Lived for many more years, publishing numerous more books, including the first treatise on human evolution. Also an expert on worms (will come up again later!). Died in 1882, and was buried in Westminster Abbey.

Two more people you should know:

Wallace - another great naturalist that independently developed evolution through natural selection (did most of his work in Southeast Asia). Spurred Darwin to write up his essay for publication.

Mendel - Darwin could not explain how characteristics were passed on from one generation to the next. Only that they were.

Mendel showed how, though his work was not "rediscovered" until much later.

Considered the "Father of genetics". With genetic understanding, all the pieces of how evolution works were finally in place.

Darwin had a copy of Mendel's paper on his bookshelf (similarly, Mendel read the "Origin of Species"), but neither put the pieces together.

II. Mechanism of evolution

Natural selection - Darwin's (and Wallace's) great insight:

1) Organisms vary. In any group of animals (organisms), not all are the same (look around room). Incidentally, most differences, but not all, are due to genetics.

2) All organisms produce more offspring than can survive. (Roach display at Museum of Natural history). Malthus - first to realize this - attributed much misery to populations outstripping food supply; populations can't keep growing indefinitely (even today, population growth is considered a major problem).

3) Therefore only some offspring survive. Which ones?

The ones best suited to their environment. For example, the quickest, the ones with the best camouflage, (or the least clumsy), the most intelligent, etc. The number of organisms with this trait will then increase at the expense of others - in other words, the population can change (particularly if the environment changes (# 4)). The organisms with these genes will survive to pass on their genes to the next population (Darwin didn't know about genes, this last bit comes from Mendel's work).

4) If the environment changes, then the population will respond by changing with it (or die!). Thus, if a new predator is introduced, population will hopefully become faster (NOT by "wanting" to be faster, but because faster individuals survive).

See page 458 in your text for a different breakdown (it's the same thing, but explained a little differently).

III. Evidence of evolution

Already mentioned:

- antibiotic and insecticide resistance - Evolution is an ongoing process and is happening right now!

- both insecticide & antibiotic resistance are major problems right now:

- **[Fig., not in book]**

Fossil record:

- probably the most obvious evidence.

- Fossils are records of past life. What kind?

- most obvious, bones or hard parts.

- often preserved by being submerged in areas with low oxygen - prevents/slows rotting. Compressed, then bones are often replaced by minerals seeping in from the surrounding rock. Literally turns tissues into rock **[Fig. 22.3, p. 453]**.

- under rare circumstances may preserve soft parts. (Mammoth - obvious example) **[Fig., not in book]**.

- As one examines fossil record, one sees organisms changing as one moves from older rocks to newer rocks **[Fig. 25.25, p. 530]**.

Comparative anatomy.

- Similar structures in living organisms. As one looks at animals which are more closely related, one sees structures that are more similar. Well see several examples of this in lab (both the taxonomy and evolution labs).

- Gives rise to some more concepts:

- Convergent evolution - animals that are different evolve similar structures due to similar environmental pressures. A classic example is the body shape of fish, dolphins & ichtyosaurs (extinct). These animals are unrelated, yet have very similar body shapes.

- Homologous structures - structures that have a ***common origin***, but may be used for different things **[Fig., similiar to 22.17, p. 463]**.

- Analogous structures - structures that look similar, but have different origins (e.g. wings in birds and insects).

- An example: Wings in birds and bats are analogous. BUT, most of the bones that make up these wings are homologous. If you understand this, you have a decent grasp of the concepts involved.

- the bones can be traced to a common ancestor.

- the wings can not **[Fig., not in book]**.

Embryology.

- Embryos show common ancestry, for example, gill slits in human embryos. Many embryos from totally different species look identical at various stages in their development **[Fig., not in text, but see fig. 22.18, p. 463]**

Biochemistry.

- Mostly (but not entirely) DNA. Similar species have DNA (i.e. genes) that are very similar.

- This can be used to establish lineages and other relationships.

- Used even in society to establish identity of criminals as well as parentage (DNA fingerprinting is based on this idea), etc. For example, children will have DNA more similar to their parents. This works even on a larger scale such as between species.

[Fig., not in text (proteins are based directly on DNA)]

Biogeography.

- Good schools(!) offer courses in this. This is one of the things Darwin noticed:

- The further away he got from "home", the more different the species were from those he recognized. In particular, older animal groups often were more widespread.

- The closer (geographically) related animals were, the more likely they were to be similar.

- The further apart two animals, the more time they've had to evolve in their own direction.

- Additionally, using fossil evidence and evidence from geology (e.g. continental drift), we can explain the distribution of organisms (e.g, why llamas occur in South America, and their closest living relatives (camels) live in Asia).

Artificial selection **[Fig., not in book and Fig. 22.9, p. 458]**.

- One of Darwin's more powerful arguments.

- Humans have been breeding plants and animals for thousands of years. Today, many are completely different from ancestral species.

- Dogs, Cats, Horses, Wheat, etc. are all good examples.

- Humans decide which organisms are "allowed" (or encouraged) to reproduce.

Other evidence.

- Camouflage/adaptation **[Fig. 22.12, p. 459]**.

Moths in northern England - industrial pollution. [OVERHEAD (2), not in book]

- dark moths started appearing with the onset of pollution in the 1850's.

- population studies have confirmed that birds are the selecting force.

- recently, with new environmental regulations, the trend is being reversed.

- Mimicry.

Details in lab.

Some animals have evolved to look like other animals. Why?

Classic example - One animal is toxic or venomous (e.g., Coral Snake). Other animals take advantage of this by looking (or sounding) like the dangerous one so they won't be bothered (e.g., Scarlet King Snake). See section on mimicry on page 1179 - 1180 in your text (there are also a couple of illustrations on these pages).

IV. Genetics (a lot of the following was discovered by Mendel).

We won't go into the details here - in Genetics class.

But in general we need to know the following:

Appearance is controlled by:

1) Genes (genetic makeup)

2) Environment (e.g. suntan)

Environmental factors (suntan) are not passed on to offspring (Lamarck).

Genes are passed on to offspring.

What are genes?

gene - basic unit of heredity (which doesn't say much!)

- determines traits about an individual.

- eye color, hair color, size, even folding hands.

- melanism in cats (often a single gene (or allele))

- corn color, flower color, etc.

- coat color in mice.

to figure out the specific trait, we need to know about alleles.

- different (alternative) forms of genes.

- allele for brown or an allele for black coat color in mice.

- A, B, O, blood types (in this case three alleles, A, B, and "O" (meaning neither A or B).

- Sickle cell anemia (question - why do we have sickle cell anemia??).

- allele for normal, allele for "sickling".

So, in general (details in genetics), if an individual (or mouse) has a black coat color, it is likely some of his offspring will have a black coat. Why not all offspring?

Most organisms we're familiar with have two copies (diploid) of everything. In other words, two copies of genes for blood type (e.g. an allele for blood type A, and an allele for blood type B), or two copies of genes for coat color, etc.

ONLY ONE ALLELE (from each parent) IS PASSED ON TO THE OFFSPRING (in sexual reproduction).

- Parents pass one allele for each trait to the offspring in an egg or sperm. When sperm fertilizes the egg, the fertilized egg now has two alleles for each trait.

So, next question, if an individual has two different alleles, what does he look like? Depends on how genes interact.

- Most likely, you have heard of dominant/recessive.

- Coat color in mice - Black is dominant, brown recessive.

- Brown is *not visible* (it's impossible to tell brown is there without DNA analysis) unless black is absent.

BB - black Bb - black bb - brown

- Other possibilities - blood groups in human

AA - type A	BB - type B	OO - type O
AB - type AB	AO - type A	BO - type B

(in my notation, "O" means neither A nor B. Note that neither A or B are dominant over each other, but both are dominant over O).

Suppose that a recessive allele is lethal (all mice with brown coat colors die). What happens to frequency of brown allele?

--> Evolution! (change in genetic makeup of population)

- Tay Sachs (a human disease) often works in exactly the same way.

What about sickle cell anemia?

Neither is dominant:

SS - no sickle cell
S'S' - sickle cell
SS' - some sickling (under stress).

Now note:

The only way one can be SS' is if one gets one of each allele from each of his parents.

SS folks suffer from malaria
S'S' folks suffer from sickle cell
SS' folks are less susceptible to both!

When you take genetics, you will learn that it is impossible (in a probability sense) to always produce heterozygotes every generation.

Last bit for genetics:

Hardy-Weinberg (see the text for some of this, though it's a bit confusing):

Suppose there are just two alleles (e.g. coat color in mice).

Let's assume that in mice we have the following:
BB - black, Bb - black, bb - brown.

But let's just think about the alleles for a minute (B - black, b - brown).

Now, let's call the proportion of black alleles 'p'.

The proportion of brown alleles well call 'q'.

Obviously, p+q = 1 (or 100%).

(and p = 1-q, and q = 1-p)

So, the probability of being:

BB = p^2 (read p "squared")

$bb = q^2$

(why? - “rule of multiplication, or simply pxp)

$Bb = 2pq$ [why? there are two ways you can be heterozygous - or - remember the binomial expansion from algebra].

But now note that everybody is either BB, Bb or bb.

Therefore, $BB + Bb + bb = p^2 + 2pq + q^2 = 1$.

So, we can figure out how common alleles are in populations.

How? Measure people on a trait. If it is dominant/recessive, then we know (BB + Bb), and bb (can’t tell the difference between BB and Bb). Thus:

If we know # of recessives (bb)

Square root (bb) = q (or # of b alleles).

p = 1-q, so we know p,

Now we can just plug everything in:

$BB = p^2$
$Bb = 2pq$,
and we already know bb.

Specific example (see page 475 in text):

PKU (genetic disease in humans) occurs once out of every 10,000 births.

$q^2 = 0.0001$ (1/10,000 = 0.0001)

$q = \text{sqrt}(q^2) = 0.01$

$p = 1-q = 1 - 0.01 = .99$

$p^2 = .9801$

$2pq = 2(.01)(.99) = .0198$ or aprx. .02

=> 2% of human population is a carrier for PKU.

(and that’s about as bad as math gets in Bio303!)

Hardy-Weinberg equilibrium, however, implies that the genetic makeup of a population does not change. Why is this useful?

1) This is sort of backwards, but it shows under what conditions the genetic makeup of a population DOES change.

2) Allows us to take a "snapshot" of a population and figure out genetic makeup (as above).

Rules for a population to stay in Hardy-Weinberg equilibrium (see p. 474):

1) Large population size (no random effects from really small populations) **[Fig. 23.8, p. 476]**.

2) No movement of genes in or out of population.

3) No net mutations (we haven't really talked about mutations).

4) Random mating.

5) No natural selection.

Obviously, very few of these hold over time (give some examples). But principle is useful for getting snapshots, particularly with organisms having large generation times.

In lab we will see what happens when #5 is violated.

Finally, a word about mutations [details in Genetics]:

Where do "new" alleles come from?

-> Mutations. Most are harmful, many are irrelevant, a few are beneficial (i.e., increased speed, etc.)

Causes - environment. Damage to DNA (again, details in genetics).

Original source of variability in populations (provides raw material for evolution).

Mutations are the driving force behind evolution and the ultimate source for variability (which natural selection can work on).