Introduction to Evolution and Natural Selection

Evolution is the dominant theme in biology today
→ it provides a framework (=unifying principle)
  for the way that we study and understand the world

→ it’s a way of bringing together many diverse aspects of life’s tremendous complexity

In all fields of science we are constantly looking to disprove theories
theories that cannot be disproven are tentatively accepted
as more and more experiments and observations are done theory:
  continues to hold,
  is modified, or
  is completely discarded
few theories exist unchanged for more than a few years

with evolution: virtually everything we know about the natural world
  biology
  geology
  chemistry
  physics
  astronomy
support or fit into our current theories of evolution

evolution stresses the relatedness of all life rather than its differences
yet, no one has ever witnessed the origin of a major new animal or plant group

→ takes 10,000’s or millions of years

we do however have an increasing amount of fossil data that actually shows the evolution of one species from another, step by step

the theory itself is scientific fact supported by an abundance of scientific observations and experiments
History of the Idea of Change Through Time

Although Darwin has been associated with the idea of “change through time”,

he didn’t “invent” the general idea of ‘change through time’

such ideas were around long before his work

1. **Aristotle (384 – 322 BC)**
   
saw evidence of “design and purpose” in nature

aranged all organisms into a “Scale of Nature” from simplest to most complex

saw a movement toward a “more perfect state”
   → implied at least some kind of directed change

2. **Leonardo da Vinci (15th century)**
   
interpreted fossils as remains of organisms that had become extinct

→ not just “sports of nature”

he doubted the flood story of the Bible

   
made assumption that the Bible was the only reliable source of chronological information for the time covered in biblical writings

arrived at the calculation that the earth was created on Sunday,
October 24, 4004 BC

Lightfoot, making additional assumptions put the time at 9:00 am

4. Leibnitz, 1690

studies concluded that the earth was originally a hot liquid; then cooled off forming a hard crust

→ by 1700’s most scientists believe that fossils were of organic origin
   but most were explained in terms of the Biblical flood

5. Maupertuis (1698-1759)

studied families with hereditary trait of 6 fingers and arrived at some basic rules of genetics

hinted at the concept of mutations and their ability to produce new species

6. Comte de Buffon (1707-1788)

“Histoire Naturelle”, 1749

had to deal with dominant religious ideas
   much of western history was dominated by Church beliefs

   “this is what one might think if one did not know what genesis says”

believed he could get an estimate of the age of the earth based on the rate of heat loss

then he calculated the age of the earth as 74,832 yrs and the
origin of life at 40,000 yrs
he recognized 6 geological periods

7. Jean Baptiste de Lamark (1809)

most thoroughly studied view of evolution before Darwin

he believed that all organisms were endowed with a “vital force” that drove them to evolve toward greater complexity

→ believed living forms were created in a simple state and improved through time:
   a “drive to perfection”

all biologists believed this much

but Lamark was 1st to offer a “mechanism” for this change

he was the only biologist before Darwin to offer a well developed natural theory of how living forms might evolved

his hypothesis assumed that an environmental change would result in a need for a corresponding alteration of a species

these changes would occur over a lifetime and then be passed on to the offspring
   → inheritance of acquired characteristics

eg. snakes:
   orig had 4 legs
crawled thru narrow openings
made less use of legs
eventually lost them
passed this trait onto their offspring

eg. ducks feet
   were webbed because they were used in swimming
eg. giraffes developed long necks by stretching for leaves on higher branches then bore young with longer necks

also, called evolution by “use and disuse of parts”

Lamark’s “mechanism” for evolution has now been discredited:

eg. would be like a suntain or circumcision to be passed to offspring

use or disuse are not passed on genetically

→ individuals do not evolve

Lamark’s ideas are not substantiated by experiments

eg. Prof August Weismann, 1890

mice had tails removed for 20 generations

and still mice were born with tail of original proportions

when scientists discovered the mechanisms of heredity his theories were discredited

but he did suggest that:

all species are interrelated
they change through time
the environment is a factor in that change

8. Chambers, 1844

concluded that life could originate from inorganic substances and electricity

→ Andrew Crosse claimed that mites could be produced from a poisonous solution after weeks of passing a weak electrical current through it
spontaneous generation
Charles Darwin and Evolution by Natural Selection

Historical Development of the Idea

the stimulus for Darwin’s contribution to the idea was his employment as a naturalist on the Beagle

Beagle set sail in 1831

over the next few years of the cruise he collected and catalogued 1000’x of plants and animals and made numerous observations

esp. in Galapagos Islands noted the similarities and differences between mainland and island species

during this same time period:

1. geologists such as Lyell were beginning to realize that the earth was much older than previously thought

2. also, they found that the earth had changed dramatically over time: mountains, oceans, valleys, etc

3. Thomas Malthus noted that populations increase in size until checked by environmental factors
4. In addition to his ocean voyage, Darwin also studied breeds of domesticated animals and plants and pondered their similarities and differences.

Darwin spent 20 years accumulating a massive amount of evidence to demonstrate the process of evolution.

As Darwin pondered his ideas, Alfred Russel Wallace was making similar observations about plants and animals in Malaysia and Indonesia. He arrived at the same conclusions as Darwin independently.

He sent a letter to Darwin asking him to review his work.

Both papers were presented to public in 1858.
The Theory of Evolution

1. Darwin assumed (from Malthus) that:
   - populations increase geometrically
   - yet the population size of any given species remains fairly constant in an area

   each species produces more offspring than will survive into maturity (their reproductive potential is never met)

   eg. if not 1 bacterial cell → 36 hours would cover earth 3-4 ft deep

   eg. fruit fly → in 7 months would produce enough offspring to equal the mass of the earth

2. Darwin also showed that variations occur in all species

   all living things consist of a unique combination of chemicals organized in unique ways

   → variations occur in every species

   no two individuals of a species are alike

3. We also know that species are “adaptable” to their environment

   → life is able to adjust to gradually changing environments
the same species in different parts of the world have different **tolerances** and slightly different characteristics that adapt it better to the local conditions in which it lives

e.g. live oak in Austin, vs live oak in Baton Rouge

e.g. flower and gardening catalogues vs local growers

still they are the same **species**: they interbreed naturally where they come into contact

4. Many (most?) of these variations have a genetic basis

→ they could be passed on to offspring

Darwin was not aware of Mendel’s work, He didn’t know HOW traits were passed on, just observed that some were

took another 50-60 yrs before hereditary information was added to Darwin’s original theory

→ made it even more powerful

those individuals whose variations best fit that environment will be more likely to survive and reproduce

organisms with less favorable variations will die

→ **There is a “struggle for existence”**

→ **with “survival of the fittest”**
**fitness** = ability to reproduce

by a process of **natural selection** evolution sorts through these numerous variations within a population of individuals and “chooses” the **most fit** combination

as the environment slowly changes and certain variations are selected for over 100’s or 1000’s of generations new forms will arise

But unlike what Lamark thought:
the **genotype** of an individual does not change during its lifetime
→ individuals cannot evolve
→ evolution occurs at the population level

5. Darwin also studied breeds of domesticated animals

eg. Dogs today consist of >300 breeds
   → all were created by humans within the last 200 years
eg. cats, cattle, sheep
eg. corn, brassicas

= human directed evolution:
humans did the selecting instead of nature

if humans can do it in 100’x or 1000’s of years surely nature can do it given Billions of years
More Evidence supporting Darwin’s ideas

after Darwin, other biologists continued to collect data that supported the idea of evolution by natural selection

Additional Support for the theory of evolution comes from a diversity of specialized areas:

some of the most direct evidence of evolution continues to come from fossils

6. New geologic data was beginning to indicate that the earth was much older than originally though and that many species that once existed on earth no longer existed.

today the layers of rock can be accurately dated by strata and by radioactive decay methods

Species have been altered:

some have become extinct

~99% of all life that exists and ever existed on earth is now extinct
→ many of these have left a fossil record

the fossil record shows clearly that all organisms did not appear at the same time

the fossil record also shows a progression of species change and replacement over billions of years
→ simpler organisms appeared 1\textsuperscript{st} billion years ago
  - 3.5 BY bacteria
  - 1.5 BY eucaryotes
  - 500 MY animals
  - 400 MY plants
  - 190 MY 1\textsuperscript{st} flowering plants
  - 65 MY modern plants

Evolution involves biological change in an orderly sequence over long periods of time

7. Intermediate Forms

we find more and more “intermediate forms”

eg. between fish and amphibians

eg. between dinosaurs and birds

eg. evolution of the horse, elephant, etc

eg. human ancestors

in a few cases we have essentially every step in the evolutionary process from one species to another

eg. 1 snail species into 2 in So American Lake sediment (year by year evolution)

8. also, we have inadvertently caused population characteristics to shift in many species

eg. peppered moth

eg. antibiotic and pesticide resistance (later)
evolution results from chemical changes in DNA of the chromosomes
by natural mutations
by sexual reproduction

all the varieties of organisms that exist today are the result of slow random mutations that proved to be beneficial in some way

in general, evolution has led to ever increasing structural complexity and specialization
Robustness of the Theory of Evolution

The theory of evolution provides logical explanations for seeming contradictions and puzzles:

1. **Taxonomic Categories**

   taxonomic categories of KPCOFGS are designed to show similarities in different organisms

   the system was set up long before Darwin’s views on evolution were developed (Linneus, 1750’s)

   yet once Darwin proposed his theory it meshed very well with the general classification scheme then in use

   ➔ evolution progresses from simple to complex from generalized to specialized

2. **Genetics, Laws of Inheritance**

   Darwin was not aware of Mendel’s work

   he didn’t know, could not explain, how traits were passed on or why individuals varied

   it took another 50-60 years before hereditary information was combined with Darwin’s ideas ➔ they meshed very well
= neo-Darwinism (revised theory of evolution)

3. Comparative Embryology

the developing embryo often passes through a series of orderly changes or stages from egg → adult

some of these changes seem to repeat traits or levels of complexity found in “ancestral” stock even though the mature individual are quite different

= recapitulation

eg. pharyngeal pouches (gill slits)
   fish → gills
   amphibians → gills in larvae, lost in adult
   reptiles, birds, mammals → in embryo,
   disappear or become modified into parts of ear, throat, tongue, etc in adult

eg. tail

eg heart
   2 chambered → 4 chambered

4. Comparative Morphology (Anatomy)

morphology is the study of structure

principles of classification (taxonomy) is based mainly on morphology

assumes that the greater the structural similarity
the more closely related two organisms are

eg. dendrograms

homologous vs analogous structures

homologous: spines, tendrils, leaves, etc
analogous: spines vs thorns

analogous structures
show how unrelated groups may adapt in similar ways to common environments = convergent evolution
eg. cactus vs euphorbs
eg. fish vs whales and porpoises

→ explains vestigial organs

Darwin: how organisms that were the product of “perfect creation” could have useless parts

→ explains mimicry

resemblances of one organism to another organism or inanimate object
eg. yellow bee orchid
eg. geometrid caterpillar

5. Biogeography

many plants are widely distributed
others are very restricted

also some plants are found in widely separate but similar habitats

in other areas species that “should be there” are missing

the environment alone cannot explain distributions

but centers of origin
many forms were once widespread then got cut off from one another

6. Comparative Biochemistry

similarities and differences in biochemistry correlates with assumed evolutionary relationships

genetic code is universal

all life is based on broadly similar chemicals and metabolic pathways

the more closely related an animal is the more similar its biochemistry:
  eg. DNA
  eg antibodies
  eg. protein structure
eg. nematode worm shares 40% of its DNA with us
chimpanzees and humans share 98% of their DNA
humans with humans share 99%
relatives 99.5%

**Conclusion:**

all forms of comparisons of similarities and differences
point to the same evolutionary relationships
between different organisms:

- embryology
- biochemistry
- DNA analysis
- protein analysis
- fossils, geologic dating
- genetics and heredity

when so many independent techniques fit so neatly
into a single general theory it indicates that the
theory is “robust” and powerful
Natural Selection

almost all biologists accept the basic principles of this theory

many disagree over the finer points
eg. role of chance
eg. speed of evolution

the theory of evolution is continuously being refined

this is the mechanism of evolution 1st proposed by Darwin and Wallace

he didn’t know about other processes that might contribute

natural selection tends to:
-> preserve favorable phenotypes (and genotypes)
-> and eliminate individuals with unfavorable genotypes

natural selection explains why organisms are well adapted to their environments

natural selection DOES NOT lead to a “perfectly adapted organism

-> it “weeds out” organisms that are LESS well adapted

natural selection changes the composition of a gene
pool in a direction that favors the populations survival

we cannot “see” evolution of new species occurring this takes many generations and millions of years

but we can see changes in gene frequencies over time within a population

**What Drives Evolution?**

genetic variation acted on by natural selection

the diversity of life on the earth today is a response to the dynamics of nature over the past several billion years selecting for the most effective combinations of genetic traits

evolution does not proceed at the same rate year after year or from place to place

anything that promotes genetic diversity and intense competition favors the evolution of new traits and sometimes new species

eg. mass extinction events “shuffle the cards” and trigger rapid evolutionary diversification

  eg. cretaceous extinction → rise of mammals and birds

also, more favorable environmental conditions (eg
tropical areas) trigger more intense competition for space and resources

→ tends to promote more rapid evolution of adaptations to outcompete neighbors

eg. search for unusual chemicals esp in tropical forests and coral reefs where intense competition favors poisons, toxins, etc

also, the “discovery” of SEX led to the more rapid development of species since it greatly increased the chances of new variations and mutations, some of which might be beneficial
Punctuated Equilibrium

we know the fossil record is incomplete

in spite of that we have fossils of many transition forms

but often in the fossil record we see little change for millions of years then suddenly (in geologic time) a new form appears “in place of” the old form.

in these cases the transition form is absent

this lack of information was traditionally blamed on incompleteness of the fossil record

in 70’s some biologists began to question whether the fossil record was as incomplete as we had thought

600 MY ago we have identified ~250,000 species of fossils

today, there are several million species

comparing habitat diversity today with the past they show pretty much the same structure → indicates our fossil record is pretty good

SJ Gould and ? developed the idea of “punctuated equilibrium”
a further refinement of evolutionary theory

it stated: long periods of little or no change followed by short periods of rapid evolution (eg 1000’s, not millions of years)

ie. the rate of evolution was not constant through time

evolution occurs in “spurts”

a typical species exists for 5 – 10 MY then goes extinct
humans are new kids on the block