EVOLUTIONARY COMPUTATION

Lecture Notes_1

EVOLUTION

Evolution is the process by which nature selects, from the genetic diversity of a population, those traits that would make an individual more likely to survive and reproduce in a continuously changing environment

Evolution is the change in the characteristics of a species over several generations and relies on the process of natural selection.

- The theory of evolution is based on the idea that all species? are related and gradually change over time.
- Evolution relies on there being genetic variation? in a population which affects the physical characteristics (phenotype) of an organism.
- Some of these characteristics may give the individual an advantage over other individuals which they can then pass on to their offspring.

Evolution is one of the most fundamental organizing principles of the biological sciences and as such, is the single most dominant theme in biology today evolution stresses the relatedness of all life rather than its differences

- it provides a framework (=unifying principle) for the way that we study and understand the living world
- it’s a way of bringing together many diverse aspects of life’s tremendous complexity

Adaptation vs Evolution

One of the “characteristics of life” is that organisms adapt to their environment as it changes from year to year eg. same species of plant adapts to dryer conditions in one part of its range and wet conditions in another

- eg. same species of plant or insect may have 1 generation in northern part of its range or 2, even 3, generations in the southern part of its range
- eg. virtually every bacterial pathogen has become at least somewhat resistant to antibiotics over the past 60 years over time, these populations may change in their appearance and other visible characteristics and will surely change in their genetic structure
- eg. many unrelated species often adapt in similar was when subjected to the same environmental conditions

Over time, these populations may change in their appearance and other visible characteristics and will surely change in their genetic structure.

- eg. many unrelated species often adapt in similar was when subjected to the same environmental conditions

Over long periods of time, these changes could be significantly different from what you started with 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 shows the evolution of one species from another, step by step and
- today with molecular techniques we can actually observe and measure the rate of evolution in many species today
- there is no controversy surrounding evolution within the scientific community itself;
- the “controversy” is fabricated by those who seek to inject nonscientific beliefs into a very powerful scientific concept

The Theory of Evolution
In science, theories are statements or models that have been tested and confirmed many times. Theories have some important properties:

- They explain a wide variety of data and observations
- They can be used to make predictions
- They are not absolute, they serve as a model of understanding the world and can be changed as the world view changes

In science, the term “Theory” does not express doubt.
In science, the term theory is used to represent ideas and explanations that have been confirmed through tests and observations

The theory of evolution remains one of the most useful theories in biology because it explains many questions and observations.

Some questions that can be answered by evolution.

- Why do so many different animals have the same structures, the arm bones in a human are the same bones as a flipper in a whale?
- Why do organisms have structures they no longer use, like the appendix in a human? Non functioning wings in penguins
- Why are there bones and fossil evidence of creatures that no longer exist? What happened to these creatures?
- Why do so many organisms’ morphology and anatomy follow the same plan?
- Why is the sequence of DNA very similar in some groups of organisms but not in others?
- Why do the embryos of animals look very similar at an early stage?

The Theory of Evolution is considered a Unifying Theory of Biology, because it answers many of these questions and offers and explanation for the data.

The Theory of Evolution by Natural Selection

The theory of evolution was developed by Charles Darwin, in the mid 1800's, after a lifetime of travel, observation, experimentation and discussion.

- in his 3 year voyage on the Beagle, he collected and catalogued 1000's of plants and animals and made numerous observations.
- Darwin collected copious notes on species variations and their relationship to fossil forms
- he also studied breeds of domesticated animals and plants and pondered how we could produce such variations by selective breeding
- 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 Millions of years

Many of Darwin's ideas were stimulated by an explosion of new scientific information eg. in Darwin's time scientists were beginning to realize that the world was much older than previously thought

a. before Darwin the accepted age of the earth was determined by James Ussher (1581-1656) & John Lightfoot (1602-1675)

- 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
- so the earth was believed to be ~6000 years old

b. in the next century, Comte de Buffon (1707-1788;

- "Histoire Naturelle", 1749) believed he could get an estimate of the age of the earth based on its rate of heat loss
- he calculated the age of the earth as 74,832 yrs (and the origin of life at 40,000 yrs)
- he also recognized 6 geological periods
- much of western science at this time was still dominated by Church beliefs and he was heavily pressured by the Church to reconsider his calculations
- his solution: "this is what one might think if one did not know what genesis says"

c. 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

d. species' populations are able to adapt to gradually changing environments

- the same species in different parts of the world have different tolerances and slightly different characteristics to survive the local conditions in which it lives
- eg. live oak in Austin, vs live oak in Baton Rouge
- eg. flower and gardening catalogues vs local growers

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

e. Most of these variations have a genetic basis

- they can be passed on to their 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

f. Each species produces more offspring than will survive into maturity

- 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

g. Those individuals whose variations best fit their environment will be more likely to survive and reproduce

- fittness = ability to reproduce
- organisms with less favorable variations will be less likely to survive
- "There is a "struggle for existence"
- " with "survival of the fittest"

h. by a process of natural selection, evolution sorts through these numerous variations within a population and "chooses" the most fit combination as the environment slowly changes and certain variations are selected over 100's or 1000's of generations new forms will arise

Evidence of Evolution

1. Fossil Evidence

- If today's species came from ancient species, the we should be able to find remains of those species that no longer exist.
- We have tons of fossils of creatures that no longer exist but bear striking resemblance to creatures that do exist today.
- Carbon dating–gives an age of a sample based on the amount of radioactive carbon is in a sample.
- Fossil record-–creates a geologic time scale.

2. Evidence from Living Organism

- Evidence of Common Ancestry –Hawaiian Honeycreeper
- Homologous Structures–structures that are embryologically similar, but have different functions, the wing of a bird and the forearm of a human
- Vestigial Organs–seemingly functionless parts, snakes have tiny pelvic and limb bones, humans have a tail bone
- Biochemistry and DNA

- Embryological development–Embryos of different species develop almost identically
- Observation of species change (wolves/dogs, peppered moths)

3. Additional evidence supporting evolutionary theory

- today the layers of rock can be accurately dated by strata and by radioactive decay methods
- also, we have found fossils of many "intermediate forms" between major groups in the fossil record
- we have learned the science of genetics and can explain how mutations occur and how they are passed on (this process was completely unknown to Darwin)
- In modern times we have added a massive amount of molecular evidence that supports evolutionary theory

Examples of Evolution

1. industrial melanism (Kettlewell's moths)
2. dog breeds
3. viruses & vaccines
4. bacteria & antibiotics
5. elephant tusks

Natural selection

Natural selection is a mechanism by which populations adapt and evolve.
In its essence, it is a simple statement about rates of reproduction and mortality: Those individual organisms that happen to be best suited to an environment survive and reproduce most successfully, producing many similarly well-adapted descendants. After numerous such breeding cycles, the better-adapted dominate. Nature has filtered out poorly suited individuals and the population has evolved.

VISTA

Natural selection is a simple mechanism that causes populations of living things to change over time. In fact, it is so simple that it can be broken down into five basic steps, abbreviated here as **VISTA:** Variation, Inheritance, Selection, Time and Adaptation.

Variation and Inheritance

Members of any given species are seldom exactly the same, either inside or outside. Organisms can vary in size, coloration, ability to fight off diseases, and countless other traits. Such variation is often the result of random mutations, or "copying errors," that arise when cells divide as new organisms develop.

When organisms reproduce, they pass on their DNA--the set of instructions encoded in living cells for building bodies--to their offspring. And since many traits are encoded in DNA, offspring often inherit the variations of their parents. Tall people, for example, tend to have tall children.

Selection: Survival and Reproduction

Environments cannot support unlimited populations. Because resources are limited, more organisms are born than can survive: some individuals will be more successful at finding food, mating or avoiding predators and will have a better chance to thrive, reproduce, and pass on, their DNA. Small variations can influence whether or not an individual lives and reproduces. Differences in color, for instance, aid some individuals in camouflaging themselves from predators. Sharper eyes and claws help an eagle catch its dinner. And brighter coloration improves a male peacock's chances of attracting a mate.

Time and Adaptation

In generation after generation, advantageous traits help some individuals survive and reproduce. And these traits are passed on to greater and greater numbers of offspring. After just a few generations or after thousands, depending on the circumstances, such traits become common in the population. The result is a population that is better suited--better adapted--to some aspect of the environment than it was before. Legs once used for walking are modified for use as wings or flippers. Scales used for protection change colors to serve as camouflage.

Types of Evolution

Evolution over time can follow several different patterns. Factors such as environment and predation pressures can have different effects on the ways in which species exposed to them evolve. Figure 1 shows the three main types of evolution: divergent, convergent, and parallel evolution.

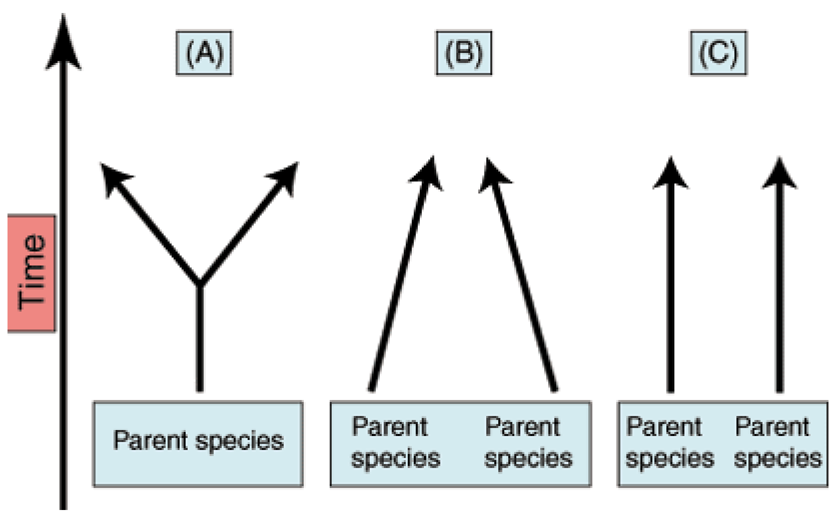

Figure 1

Divergent Evolution

When people hear the word "evolution," they most commonly think of divergent evolution, the evolutionary pattern in which two species gradually become increasingly different. This type of evolution often occurs when closely related species diversify to new habitats. On a large scale, divergent evolution is responsible for the creation of the current diversity of life on earth from the first living cells. On a smaller scale, it is responsible for the evolution of humans and apes from a common primate ancestor.

Convergent Evolution
Convergent evolution causes difficulties in fields of study such as comparative anatomy. Convergent evolution takes place when species of different ancestry begin to share analogous traits because of a shared environment or other selection pressure. For example, whales and fish have some similar characteristics since both had to evolve methods of moving through the same medium: water.

Parallel Evolution
Parallel evolution occurs when two species evolve independently of each other, maintaining the same level of similarity. Parallel evolution usually occurs between unrelated species that do not occupy the same or similar niches in a given habitat.

Evidence for evolution comes from many different areas of biology:
Anatomy. Species may share similar physical features because the feature was present in a common ancestor (**homologous structures**).
Molecular biology. DNA and the genetic code reflect the shared ancestry of life. DNA comparisons can show how related species are.
Biogeography. The global distribution of organisms and the unique features of island species reflect evolution and geological change.
Fossils. Fossils document the existence of now-extinct past species that are related to present-day species.
Direct observation. We can directly observe small-scale evolution in organisms with short lifecycles (e.g., pesticide-resistant insects).

Co-evolution
Just as no man is an island, neither is any bird, insect, plant, or mammal. Many species live in close relationships with others, affecting each others ways of life. It seems logical to think that species that live closely with each other might evolve in adaptation to each other. This logic is extremely difficult to prove, since it requires direct proof of evolution in not one but two species. However, there is ample evidence to suggest that coevolution does take place.

Coadaptation
In order to live in symbiotic or parasitic relationship, species must be adapted to each other. For example, cattle harbor bacteria in their stomachs that help them break down plant material. To live like this, the immune system of the cattle must be adapted to not kill these useful bacteria and the bacteria themselves must be adapted to live in the harsh environment of the cow's stomach. If a population of cattle moved to a new location where radically new plant material was available, they might adapt to eating this new food source. The bacteria, in turn, might then undergo adaption of their own digestive mechanisms to the new plant material. This would be an example of coadaptation. Most biologists accept coevolution on the basis of coadaptation if there is no overwhelming evidence to the contrary.

Coevolutionary Arms Races
In parasitic relationships, the prey species often evolves mechanisms to defend itself against the parasite. However, the parasite may also evolve to evade these new mechanisms. This back-and-

forth evolution of defense and offense, often called a coevolutionary arms race, can often result in a rapid burst of evolutionary change in both species.

Case Study Problems

Problem 1: On his voyage with the *Beagle*, Charles Darwin carefully studied several species of finches. He found that many had come from a single species, but they had adapted to their environment by choosing different food sources and developing radically different beak designs to match their choice of food. What pattern of evolution did the finches show?
The finches showed divergent evolution. As time passed, the different species adapted to their own lifestyles and became more and more different from the other closely related species.

Problem 2: Many species of owls hunt only at night. These winged predators have evolved extremely sensitive hearing to help track insects and other prey. Another night hunting winged predator, the bat also has extremely sensitive hearing to track prey in the dark. What pattern of evolution does this show?
This is an example of convergent evolution. Owls (birds) and bats (mammals) are not closely related, but both have evolved similar traits (flight and good hearing) to help them fill the same role as night hunters.

Problem 3: Imagine two types of ancient forest animals: a goat-like grazing animal and a small ground-dwelling rodent that lives on insect prey. At the same time, these two animals leave the forest and begin living in grassy plains. The rodent evolves large powerful claws for digging burrows to hide in, while the grazer develops long legs for running from predators. What type of evolution does this show?
This is an example of parallel evolution. The two animals were fairly dissimilar to begin with. They filled different roles in the forest environment. When they moved to the plains, both animals evolved to adapt to the new environment, but they did not become any more or less similar to each other.

Problem 4: What difficulty does convergent evolution pose for evolutionary biologists?
The major difficulty involved with convergent evolution is the formation of analogous structures. These structures may appear similar and perform similar functions, making it seem that two species are closely related. However, analogous structures develop from different ancestral structures and do not indicate close relationships.