5 Evolution and biodiversity

Introduction

- theory that diversity of life evolved by natural selection
- ancestry of groups of species can be deduced by comparing base or amino acid sequences

5.1 Evidence for evolution

Evolution in summary

- strong evidence for characteristics of species changing over time: evolution
- difference between acquired (developed during lifetime) and heritable characteristics
- evolution only concerns heritable characteristics passed form parents
- mechanism for evolution is natural selection
- strong disbelief from different groups: important to look at evidence

Evidence from fossils

- fossils found in various rock layers were different
- radioisotope dating revealed ages of rock strata and of fossils in them (paleontology)
- sequence of fossils matches sequence in which they would evolve (bacteria first, etc.)
- sequence fits with ecology of groups (plant fossils before animal fossils)
- many sequences of fossils are known which link existing organisms to likely ancestors

Evidence from selective breeding

- humans deliberately breed animal species for thousands of years
- domesticated breeds have not existed in their current form: artificial selection: changes were achieved by repeatedly selecting and breeding individuals most suited for human uses
- effectiveness of artificial selection is shown by considerable changes in short time
- artificial selection shows that selection can cause evolution but not vice versa

Evidence from homologous structures

- some similarities in structure are superficial (e.g. tail fins in whales and fishes): analogous structure: have different origins and became similar because they perform the same or similar function: convergent evolution
- homologous structure: may look superficially different and perform different function but have “unity of type”: same bones in same relative positions: have same origin
- adaptive radiation: homologous structures became different as they perform different functions
- homologous structures do not prove evolution but are difficult to explain without it
- vestigial organs: reduced structures that serve no function: easily explained by evolution: no longer have a function and so are being gradually lost

Speciation

- if two populations separate they do not interbreed, natural selections acts differently: evolve in different ways: characteristics will gradually diverge
- if they have chance of interbreeding but don’t they evolved into separate species: speciation
- speciation often occurs when species migrates to an island: explains large numbers of endemic species on islands
- endemic species: found only in a certain geographical area

Evidence from patterns of variation

- if populations gradually diverge to become separate species, we would expect to find examples of all stages of divergence at any moment
- species can gradually diverge over long periods of time and there is no sudden switch
- continuous range in variation does not match belief that species were created as distinct types or that they are unchanging
- continuous range in variation provides evidence for evolution of species and origin of new ones

5.2 Natural selection

Variation

- theory of evolution by natural selection is based on variation
- typical populations vary in many respects
- natural selection depends on variation within populations; if all individuals were same there would be no way of some individuals being favored more

Sources of variation

- causes of variation are mutation, meiosis, sexual reproduction
- mutation is the original source of variation, new alleles are produced
- meiosis produces new combinations, every cell produced has different combination due to crossing over and independent orientation of bivalents
- sexual reproduction fuses two gametes from different parents, bring mutations together
- species without sexual reproduction only get variation from mutation; generally assumed that such species will not generate enough variation to evolve quickly enough for survival during times of environmental change

Adaptations

- adaptation: characteristics that make an individual suited to its environment or way of life: close relationship between structure and function
- characteristics develop over time and thus species evolve
- adaptations develop by natural selection, not with the direct purpose of making an individual suited to its environment
- adaptations do not develop during lifetime of an individual (= acquired characteristics); acquired characteristics cannot be inherited

Overproduction of offspring

- living organisms vary in the number of offspring they produce
- overall trend that living organisms produce more offspring than the environment can support
- causes struggle for existence within population

Differential survival and reproduction

- chance plays part in deciding which individual survives and reproduces and which not
- characteristics of an individual also have an influence
- less adapted individuals tend to die or fail to reproduce; best adapted tend to survive and produce many offspring: natural selection

Inheritance

- variation between individuals can be passed on to offspring: it is heritable
- variation in behavior can be heritable
- not all features are passed on to offspring: acquired characteristics are not passed on and are not significant in the evolution of a species

Progressive change

- well adapted individuals survive, reproduce, pass on characteristics to offspring
- less well adapted have lower survival rates and less reproductive success
- increase in proportion of individuals with well adapted characteristics: gradually change
- major evolutionary changes are likely to occur over long periods of time and many generations
- there are examples of smaller but significant changes (e.g. dark wing moths in polluted areas, changes in beaks of finches on Galapagos, antibiotic resistance in bacteria)

5.3 Classification of biodiversity

Development of the binomial system

- congresses are held so that all biologists use same system of names of living organisms
- separate congresses for animals and for plants and fungi

- International Botanical Congress (IBC) proposed that 1753 is starting point for genera and species of plants and fungi (in that year Linnaeus published book that gave consistent binomials for all species known)
- International Zoological congress accepted rules for naming and classifying animal species from 1758 (Linnaeus)

The binomial system

- biologists use binomial nomenclature; it consists of two words (genus, species/specific name)
- genus: group of species that share certain characteristics
- rules: genus name is upper-case, species name is lower-case, binomial is shown in italics, after it was used in a text the genus can be abbreviated to initial letter, earliest published name (plants: 1753; animals: 1758) is the correct one

The hierarchy of taxa

- taxon in Greek is group of something
- species are arranged into taxa
- species classified into genus, genera into families, families into orders, orders into classes, etc. until level of kingdom or domain
- going up hierarchy, taxa include more species which share fewer features

The three domains

- traditional classification systems (based on cell type): eukaryotes and prokaryotes
- prokaryotes are very diverse: esp. after RNA sequence was determined
- prokaryotes have two distinct groups: Eubacteria and Archaea
- all organisms are classified into three domains: Eubacteria, Archaea, Eukaryota
- archaeans live in broad range of habitats
- archaeans are obligate anaerobes and give off methane as waste product
- viruses are not classified into any of the three domains: have genes coding for proteins but have too few characteristics of life to be living organisms

Eukaryote classification

- principal taxa for classifying eukaryotes are divided into kingdoms, then phyla, classes, orders, families, genera, species
- biologists recognizes four kingdom of eukaryote: plants, animals, fungi, protoctista
- protoctista are most controversial as they are very diverse and should be divided further

Natural classification

- goal to classify spices so they follow the way a species evolved
- natural classification: all members of a genus or higher taxon should have a common ancestor
- natural classification is problematic as it is not always clear which groups of species share a common ancestor: causes unnatural or artificial classification
- convergent evolution can make distantly related organisms appear superficially similar
- adaptive radiation can make closely related organisms appear different
- molecular methods have been introduced: significant changes to classification

Reviewing classification

- new evidence may show that members of a group do not share common ancestor: group is split into two or more taxa
- species in different taxa are found to be closely related, two or more taxa are united or species moved from one genus to another
- classification of humans caused most controversy: humans are in order Primates and family Hominidae: debate to include great apes
- research shows that chimpanzees and gorillas are closer to humans than orang-utans and so should be in the same family

Advantages of natural classification

- natural classification of species is helpful in research into biodiversity

- identification of species is easier: species can be identified by assigning to kingdom, phylum, until species level: dichotomous keys are helpful for the process
- members of group in natural classification have evolved from common ancestor: inherit similar characteristics: allows predictions of characteristics of species found in that group

5.4 Cladistics

Clades

- species can evolve and split to form new species; happened repeatedly so now there is a large groups of species all derived from a common ancestor
- clade: group of organisms evolved from common ancestor
- clade includes: all species alive today, common ancestral species, species that evolved from it and then became extinct
- clades can include thousands of species or only a few

Identifying members of a clade

- not always obvious which species evolved from common ancestor, should be included in clade
- most objective evidence from base sequence of genes and amino acid sequences of proteins
- species with recent common ancestor are expected to have few differences in these sequences
- species diverging form common ancestor long ago will have many differences in sequences

Molecular clocks

- differences in base sequence of DNA and amino acid sequence of proteins are result of mutations: accumulate over time at roughly constant rate
- mutations can be used as a molecular clock

Analogous and homologous traits

- similarities between organisms can be either homologous or analogous
- homologous: similar ancestry
- analogous: convergent evolution, evolved independently
- problems between distinguishing led to mistakes in classification
- morphology (form and structure) of organisms is rarely used for identifying; base and amino acid sequences are trusted more

Cladograms

- tree diagram based on similarities and differences between the species in a clade
- principle of parsimony: how species in a clade could have evolved with the smaller number of changes of base or amino acid sequence: most probable sequence of divergence
- node: branching point: usually two clades branch off but it can be three or more
- node represents a hypothetical ancestral species that split to form two or more species

Cladograms and reclassification

- construction of cladograms based on base and amino acid sequences only became possible towards end of 20th century
- cladistics: construction of cladograms and identification of clades
- traditional classification based on morphology does not always match evolutionary origins: some groups have been classified, merged, split, or species transferred
- reclassification is time-consuming but worthwhile: new classification based on cladistics are likely to be much closer to truly natural classification, predictive value will be higher