SEMESTER V

17BTU513B EVOLUTIONARY BIOLOGY PRACTICAL 4H - 2C

Total hours/week: : L:0 T:0 P:4 Marks: Internal: 40 External: 60 Total: 100

Practical

(A) Evidence of fossils

1. Study of types of fossils (e.g. trails, casts and moulds and others) and Index fossils of Palaeozoic era
2. Connecting links/transitional forms - Eg. Euglena, Neopilina, Balanoglossus, Chimaera, Tiktaalik, Archaeopteryx, Ornithorhynchus
3. Living fossils - Eg. Limulus, Peripatus ,Latimeria, Sphaenodon
4. Vestigial, Analogous and Homologous organs using photographs, models or specimen.

(B) Variations

1. Sampling of human height, weight and BMI for continuous variation.
2. Sampling for discrete characteristics (dominant *vs* recessive) for discontinuous variations e.g hitch-hiker's thumb, dexterity, tongue rolling, ear lobe (data categorization into 16 groups based on the combination of 4 traits; assigning each subject to the respective group).

(C) Selection Exemplifying Adaptive strategies (Colouration, Mimetic form, Co-adaptation and co-evolution; Adaptations to aquatic, fossorial and arboreal modes of life) using Specimens.

(D) Neo-Darwinian Studies

1. Calculations of genotypic, phenotypic and allelic frequencies from the data provided
2. Simulation experiments using coloured beads/playing cards to understand the effects of Selection and Genetic drift on gene frequencies (E) Phylogeny.

References

1. Ridley, M. (2004). *Evolution* (3rd ed.). Blackwell.
2. Hall, B. K., & Hallgrimson, B. (2008). *Strickberger's Evolution* (4th ed.). Jones and Barlett
3. Zimmer, C., & Emlen, D. J. (2013). *Evolution: Making Sense of Life.* Roberts & Co.
4. Barton, Briggs, Eisen, Goldstein, & Patel, (2007). *Evolution.* Cold Spring Harbor Laboratory Press.

EVOLUTIONARY BIOLOGY PRACTICAL

(Course code: 17BTU513B)

Practical Manual

EVIDENCE OF FOSSILS

1. STUDY OF TYPES OF FOSSILS (E.G. TRAILS, CASTS AND MOULDS AND OTHERS) AND INDEX FOSSILS OF PALAEOZOIC ERA

Remains or vestiges or traces of plants and animals of the past are called fossils. These remains of organisms from past geological ages remain preserved in sedimentary rocks either as actual structures or as impressions, casts or molds. The word ‘fossil’ is derived from the Latin word **“fossilis”** which means **“to dig up”.** In the earlier studies, therefore, a large number of things dug out of earth’s crust were called fossils. These things also included minerals and rocks besides remains of plants and animals. Later on, however, study of fossils were made restricted to only animals and plants.

Study of fossils is of great importance because:

(i) They furnish evidence of the prehistoric life, and

(ii) They also provide missing links in the evolutionary chain.

Plant fossils are rarely as well preserved as animal fossils because their tissues normally do not contain calcified structures. They are usually, therefore, completely decomposed before the process of fossilization. The fossils or remains of large or macroscopic structures, such as leaves, branches, fruits and seeds, are called mega fossils while those of very small or microscopic structures (e.g. spores, pollen grains, etc.) are termed as microfossils. The species of plants or animals which no longer exists is called extinct. On the other hand the species which exists at present is called extant. If a fossil cannot be assigned to any genera containing extant species then its genus is termed as an organ genus. Similarly, if it cannot be assigned to a family, it is placed in a form genus.

Study of fossils is now an established science. It has helped in the construction of phylogenetic classification schemes. It has also thrown light on how some of the complex structures of extant plants and animals have evolved. A full-fledged research institute, devoted fully to the study of fossil plants, now exists in our country. Its name is Birbal Sahni Institute of Palaeobotany, Lucknow.

Formation of Fossils:

In the basic process of fossilization, the physical part of any plant or animal must be buried within a well-protective matrix in the crust of the earth. This matrix in the earth's crust is usually sedimentary. The sedimentary environment of this kind can be of several types such as lake, stream, inland sea or estuarine, etc. In several cases it has also been observed that diatom frustules also get incorporated in deposits of deep sea basins. In rare cases, the sedimentary environment is in the form of volcanic deposits or other subaqueous conditions. The portions of the organisms (plant or animal) preserved in sediment become stony or lithified during course of time.

How Are Sedimentary Rocks Formed?

Accumulation of rock particles results in the formation of sedimentary rocks. Weathering and mechanical abrasion of existing rocks take place and give rise to the rock particles. Chemical weathering and flooding also help in the formation of these particles. These rock particles or sediments accumulate and water is squeezed out of them. During course of time, this makes them much more compact or rocky structure. Such a rocky structure is called sedimentary rock.

Some other conditions which favor fossilization include:

(i) Anaerobic conditions,

(ii) Low pH,

(iii) Forest fires in the form of fossil charcoal, and

(iv) Presence of sedimentary materials such as carbonates, silicates, salts of iron, etc.

Types of Fossils:

Type # 1. Petrified Fossils:

The word petrifaction means turning into stones. The fossils form when minerals replace all or the parts of the organisms. Water is full of dissolved minerals. It seeps through the layer of sediments to reach the dead organism. When water evaporates only the hardened, materials are left behind. There is molecule by molecule replacement of plant parts by minerals such as iron, pyrites, silicates, carbonates, sulphates etc. These minerals get deposited and impregnated inside the cells and the tissues of the plant.

This type of fossil can be studied by preparing the sections and are most suitable for the study of structural details (Fig. 1D). Petrified plant organs roughly spherical in shape are known as coal balls.

Type # 2. Molds and Casts:

A mold forms when hard parts of an organism are buried in the sediment such as sand, silt or clay. The hard part completely dissolves overtime, leaving behind a hollow area of organism shape. A cast forms as a result of the mold. Water with dissolved minerals and sediments fills the mold's empty space or cavity. The cavity is known as incrustation and the mineral sediments that are left in the mold make a cast (Fig. 1C). A cast is opposite to its mold. These fossils are suitable for the study of the morphology of fossil plants.

Type # 3. Carbon Films:

All living things contain an element carbon. When an organism dies and is buried in sediment, the materials that make the organism break down and eventually only the carbon remains. The thin layer of carbon left behind can show an organism's delicate parts like leaves or plant e.g. fern fossil 300 million years old.

Type # 4. Trace Fossils:

These fossils show the activities of the organisms. An animal makes a foot print when it steps in sand. Overtime the foot print is buried in layers of sediment. Then the sediment becomes solid rock.

Type # 5. Preserved Remains:

Some organisms are preserved in or close to their original states. These fossils are called preserved remains e.g., an organism such as an insect is trapped in a tree's sticky resin and dies. More resin covers it sealing the insect inside. It hardens into amber. Some organisms such as a wooly mammoth dies in a very cold region. Its body is frozen in ice which preserves organism even its hair.

Type # 6. Compression:

This type of fossil is common in the sedimentary deposits of rocks. It is a sort of impression where most of the organic remains of the plant remain in the fossil state. The plant or plant part gets buried and the sediments go on accumulating over the plant. The growing pressure of the sedimentary rocks removes the air and the watery contents of the fragment out and causes the plant tissue to compress. The compression shows the original outline of the plant or plant parts but the original thickness of the plant material cannot be determined. The buried part becomes flat due to compression or overlying pressure of the sediments (Fig. 1 A).

Type # 7. Impression:

These fossils are just impression of plants or plant parts on sediments. These fossils are useful in studying the external features of various plant parts and venation pattern of leaves (Fig. 1B).

Type # 8. Pseudofossils:

Sometimes watery solutions of various minerals speed through the sediments and it takes the shape of some plant part or animal. Their study shows that they are neither plants nor animals. Such fossils are called pseudofossils (Fig. 1E).

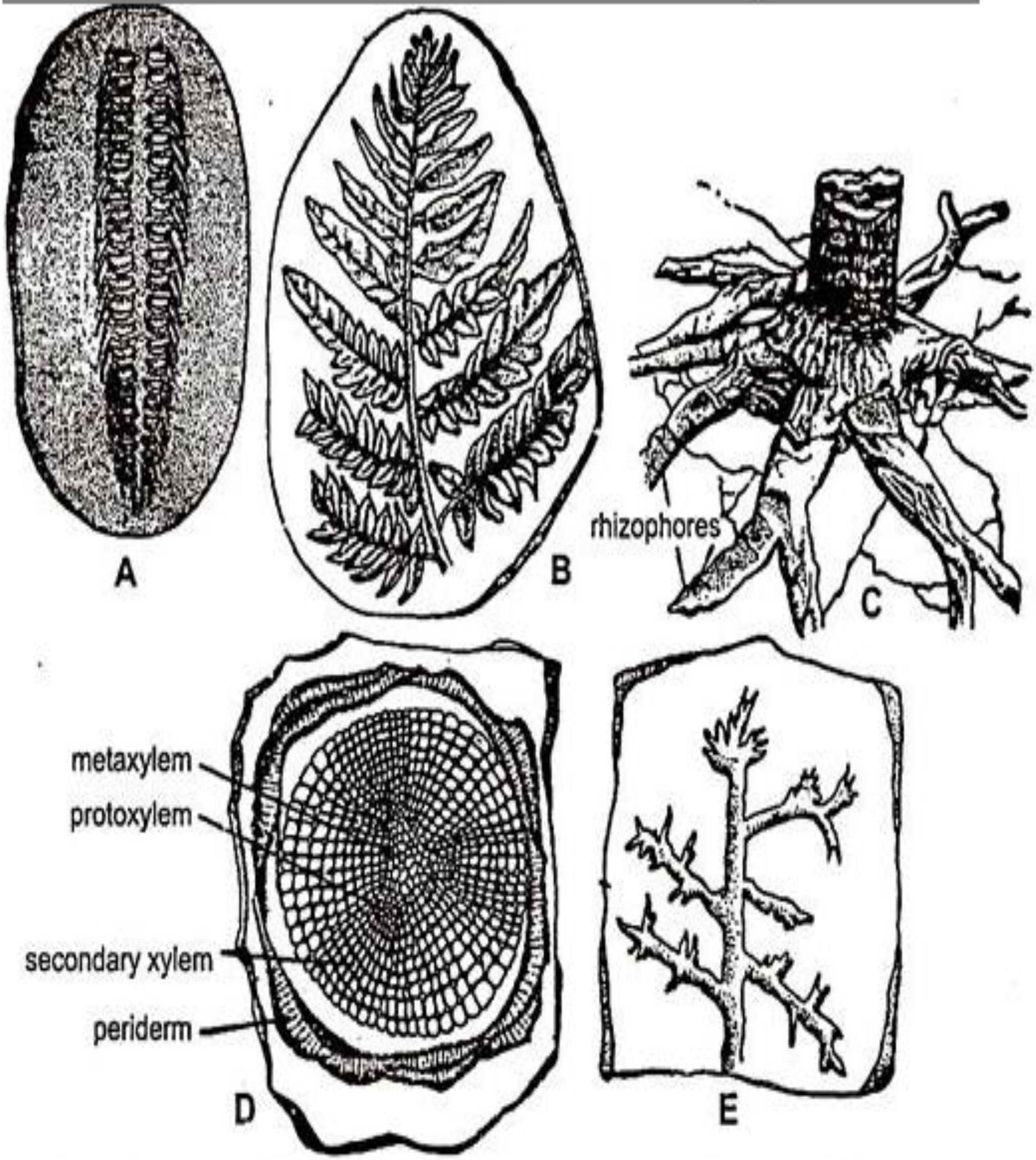
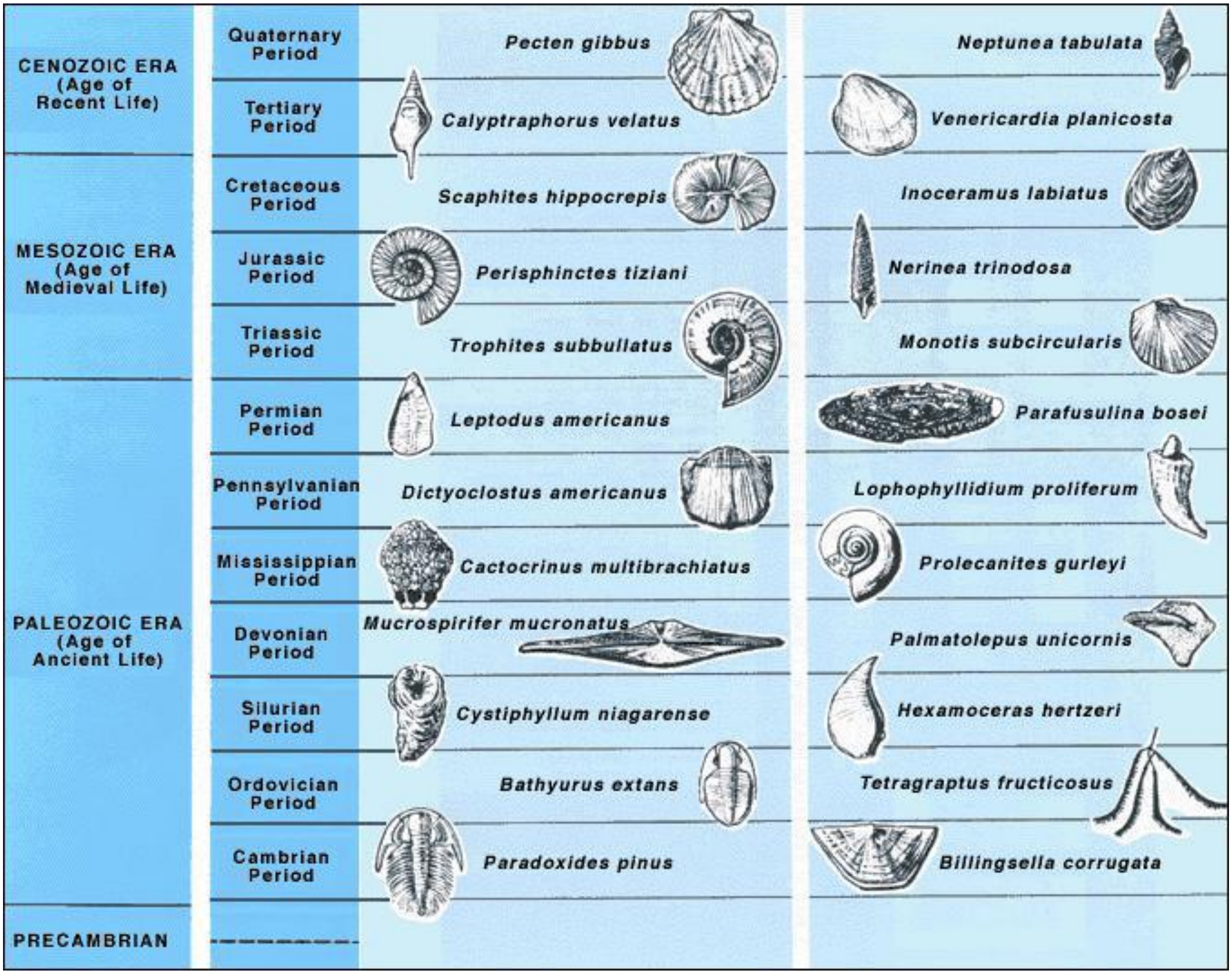


Fig. 1 (A – E) various types of fossils (A) Compression; (B) Impression; (c) Cast; (D) Petrification (E) Pseudofossil.

Index Fossils

Keyed to the relative time scale are examples of index fossils, the forms of life which existed during limited periods of geologic time and thus are used as guides to the age of the rocks in which they are preserved.



Index fossils (also known as guide fossils or indicator fossils) are fossils used to define and identify geologic periods (or faunal stages). Index fossils must have a short vertical range, wide geographic distribution and rapid evolutionary trends. Another term, Zone fossil is used when the fossil have all the characters stated above except wide geographical distribution, they are limited to a zone and can't be used for correlations of stratas.

Fossil	Scientific Name	Time Period	Million Years Ago
Calico Scallop	*Pecten gibbus* *Argopecten gibbus*	Quaternary Period	1.8 million years ago
	Neptunea tabulata	Quaternary Period	1.8 million years ago
	Viviparus glacialis	Tiglian (Early Pleistocene)	0.5 million years ago
	Calyptraphorus velatus	Tertiary Period	
	Venericardia planicosta	Eocene	
Scaphites	*Scaphites hippocrepis*	Cretaceous Period	145 to 66 million years ago
Inoceramus	*Inoceramus labiatus*	Cretaceous Period	
Perisphinctes	*Perisphinctes tiziani*	Jurassic Period	201.3 to 145 million years ago
	Nerinea trinodosa	Jurassic Period	

	Tropites subbullatus	Triassic Period	145 to xxx million years ago
	Monotis subcircularis	Triassic Period	
Leptodus	*Leptodus americanus*	Permian Period	xxx to xxx million years ago
Parafusulina	*Parafusulina bosei*	Permian Period	
	Dictyoclostus americanus	Pennsylvanian Period	xxx to xxx million years ago
	Lophophyllidium proliferum	Pennsylvanian Period	
	Cactocrinus multibrachiatus	Mississippian Period	xxx to 416 million years ago
	Prolecanites gurleyi	Mississippian Period	
Mucrospirifer	*Mucrospirifer mucronatus*	Devonian Period	416 to 359 million years ago
	Palmatolepis unicornis	Devonian Period	
		Silurian Period	359 to xxx million years ago
	Tetragraptus fructicosus	Ordovician Period	xxx to 509 million years ago
	Paradoxides	Cambrian Period	509 to 500 million years ago
	Billingselia corrugata	Cambrian Period	
	Archaocyathids	Lower Cambrian	529 to 509 million years ago

2. CONNECTING LINKS/TRANSITIONAL FORMS

Transitional forms

Fossils or organisms that show the intermediate states between an ancestral form and that of its descendants are referred to as transitional forms. There are numerous examples of transitional forms in the fossil record, providing an abundance of evidence for change over time. A transitional fossil is any fossilized remains of a life form that exhibits traits common to both an ancestral group and its derived descendant group. This is especially important where the descendant group is sharply differentiated by gross anatomy and mode of living from the ancestral group. These fossils serve as a reminder that taxonomic divisions are human constructs that have been imposed in hindsight on a continuum of variation. Because of the incompleteness of the fossil record, there is usually no way to know exactly how close a transitional fossil is to the point of divergence. Therefore, it cannot be assumed that transitional fossils are direct ancestors of more recent groups, though they are frequently used as models for such ancestors.

In 1859, when Charles Darwin's *On the Origin of Species* was first published, the fossil record was poorly known. Darwin described the perceived lack of transitional fossils as, "...the most obvious and gravest objection which can be urged against my theory," but explained it by relating it to the extreme imperfection of the geological record. He noted the limited collections available at that time, but described the available information as showing patterns that followed from his theory of descent with modification through natural selection. Indeed, *Archaeopteryx* was discovered just two years later, in 1861, and represents a classic transitional form between earlier, non-avian dinosaurs and birds. Many more transitional fossils have been discovered since then, and there is now abundant evidence of how all classes of vertebrates are related, including many transitional fossils. Specific examples of class-level transitions are: tetrapods and fish, birds and dinosaurs, and mammals and "mammal-like reptiles". The term "missing link" has been used extensively in popular writings on human evolution to refer to a perceived gap in the hominid evolutionary record. It is most commonly used to refer to any new transitional fossil finds.

Transitional versus ancestral

A source of confusion is the notion that a transitional form between two different taxonomic groups must be a direct ancestor of one or both groups. The difficulty is exacerbated by the fact that one of the goals of evolutionary taxonomy is to identify taxa that were ancestors of other taxa. However, it is almost impossible to be sure that any form represented in the fossil record is a direct ancestor of any other. In fact, because evolution is a branching process that produces a complex bush pattern of related species rather than a linear process producing a ladder-like progression, and because of the incompleteness of the fossil record, it is unlikely that any particular form represented in the fossil record is a direct ancestor of any other. Cladistics deemphasizes the concept of one taxonomic group being an ancestor of another, and instead emphasizes the identification of sister taxa that share a more recent common ancestor with one another than they do with other groups. There are a few exceptional cases, such as some marine plankton microfossils, where the fossil record is complete enough to suggest with confidence that certain fossils represent a population that was actually ancestral to a later population of a different species. But, in general, transitional fossils are considered to have features that illustrate the transitional anatomical features of actual common ancestors of different taxa, rather than to *be* actual ancestors.

Archaeopteryx

Archaeopteryx is a genus of theropod dinosaur closely related to the birds. Since the late 19th century, it has been accepted by palaeontologists, and celebrated in lay reference works, as being the oldest known bird, though a study in 2011 has cast doubt on this assessment, suggesting instead that it is a non-avialan dinosaur closely related to the origin of birds. It lived in what is now southern Germany in the Late Jurassic period around 150 million years ago, when Europe was an archipelago in a shallow warm tropical sea, much closer to the equator than it is now. Similar in shape to a European magpie, with the largest individuals possibly attaining the size of a raven, *Archaeopteryx* could grow to about 0.5metres (1.6 ft) in length. Despite its small size, broad wings, and inferred ability to fly or glide, *Archaeopteryx* has more in common with other small Mesozoic dinosaurs than it does with modern birds. In particular, it shares the following features with the deinonychosaurs(dromaeosaurs and troodontids): jaws with sharp teeth, three fingers with claws, a long bony tail, hyperextensible second toes ("killing claw"), feathers (which suggest homeothermy), and various skeletal features. These features make *Archaeopteryx* a clear candidate for a transitional fossil between dinosaurs and birds, making it important in the study both of dinosaurs and of the origin of birds.

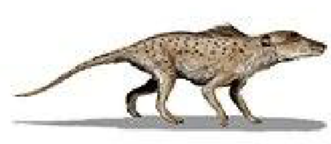
The first complete specimen was announced in 1861, and ten more *Archaeopteryx* fossils have been found since then. Most of the eleven known fossils include impressions of feathers—among the oldest direct evidence of such structures. Moreover, because these feathers take the advanced form of flight feathers, *Archaeopteryx* fossils are evidence that feathers began to evolve before the Late Jurassic.

Australopithecus afarensis - *A. afarensis* - walking posture.

The hominid *Australopithecus afarensis* represents an evolutionary transition between modern bipedal humans and their quadrupedal apeancestors. A number of traits of the *A. afarensis* skeleton strongly reflect bipedalism, to the extent that some researchers have suggested that bipedality evolved long before *A. afarensis*. In overall anatomy, the pelvis is far more human-like than ape-like. The iliac blades are short and wide, the sacrum is wide and positioned directly behind the hip joint, and there is clear evidence of a strong attachment for the knee extensors, implying an upright posture.

While the pelvis is not entirely like that of a human (being markedly wide, or flared, with laterally orientated iliac blades), these features point to a structure radically remodelled to accommodate a significant degree of bipedalism. The femur angles in toward the knee from the hip. This trait allows the foot to fall closer to the midline of the body, and strongly indicates habitual bipedal locomotion. Present-day humans, orangutans and spider monkeys possess this same feature. The feet feature adducted big toes, making it difficult if not impossible to grasp branches with the hindlimbs. Besides locomotion, *A. afarensis* also had a slightly larger brain than a modern chimpanzee (the closest living relative of humans) and had teeth that were more human than ape-like.

Pakicetids,*Ambulocetus*



Reconstruction of *Pakicetus*

Skeleton of *Ambulocetus natans*

The cetaceans (whales, dolphins and porpoises) are marine mammal descendants of land mammals. The pakicetids are an extinct family of hoofed mammals that are the earliest whales, whose closest sister group is *Indohyus* from family Raoellidae. They lived in the Early Eocene, around 53 million years ago. Their fossils were first discovered in North Pakistan in 1979, at a river not far from the shores of the former Tethys Sea. Pakicetids could hear under water, using enhanced bone conduction, rather than depending on tympanic membranes like most land mammals. This arrangement does not give directional hearing under water.

Ambulocetus natans, *which* lived about 49 million years ago, was discovered in Pakistan in 1994. It was probably amphibious, and looked like a crocodile. In the Eocene, ambulocetids inhabited the bays and estuaries of the Tethys Ocean in northern Pakistan. The fossils of ambulocetids are always found in near-shore shallow marine deposits associated with abundant marine plant fossils and littoral molluscs. Although they are found only in marine deposits, their oxygen isotope values indicate that they consumed water with a range of degrees of salinity, some specimens showing no evidence of sea water consumption and others none of fresh water consumption at the time when their teeth were fossilized. It is clear that ambulocetids tolerated a wide range of salt concentrations. Their diet probably included land animals that approached water for drinking, or freshwater aquatic organisms that lived in the river. Hence, ambulocetids represent the transition phase of cetacean ancestors between freshwater and marine habitat.

Tiktaalik

Tiktaalik roseae had spiracles *(air* holes) above the eyes.

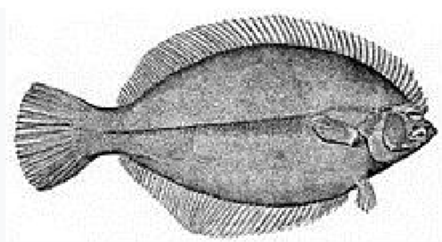
Life restoration of *Tiktaalik roseae*

Tiktaalik is a genus of extinct sarcopterygian (lobe-finned fish) from the Late Devonian period, with many features akin to those of tetrapods (four-legged animals). It is one of several lines of ancient sarcopterygians to develop adaptations to the oxygen-poor shallow water habitats of its time—adaptations that led to the evolution of tetrapods. Well-preserved fossils were found in 2004 on Ellesmere Island in Nunavut, Canada.

Tiktaalik lived approximately 375 million years ago. Paleontologists suggest that it is representative of the transition between non-tetrapod vertebrates such as *Panderichthys*, known from fossils 380 million years old, and early tetrapods such as *Acanthostega* and *Ichthyostega*, known from fossils about 365 million years old. Its mixture of primitive fish and derived tetrapod characteristics led one of its discoverers, Neil Shubin, to characterize *Tiktaalik* as a "fishapod." Unlike many previous, more fish-like transitional fossils, the "fins" of *Tiktaalik* have basic wrist bones and simple rays reminiscent of fingers. They may have been weight-bearing. Like all modern tetrapods, it had rib bones, a mobile neck with a separate pectoral girdle, and lungs, though it had the gills, scales, and fins of a fish.

Tetrapod footprints found in Poland and reported in *Nature* in January 2010 were "securely dated" at 10 million years older than the oldest known elpistostegids (of which *Tiktaalik* is an example), implying that animals like *Tiktaalik*, possessing features that evolved around 400 million years ago, were "late-surviving relics rather than direct transitional forms, and they highlight just how little we know of the earliest history of land vertebrates."

Amphistium



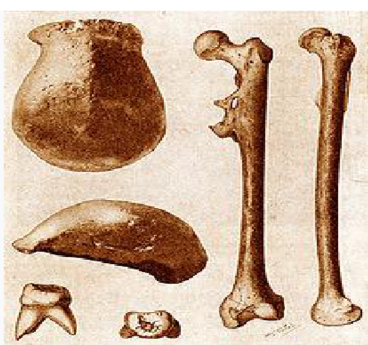
Modern flatfish are asymmetrical, with both eyes on the same side of the head.

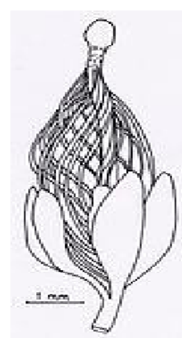
Fossil of *Amphistium* with one eye at the top-center of the head.

Pleuronectiformes (flatfish) are an order of ray-finned fish. The most obvious characteristic of the modern flatfish is their asymmetry, with both eyes on the same side of the head in the adult fish. In some families the eyes are always on the right side of the body (dextral or right-eyed flatfish) and in others they are always on the left (sinistral or left-eyed flatfish). The primitive spiny turbotsinclude equal numbers of right- and left-eyed individuals, and are generally less asymmetrical than the other families. Other distinguishing features of the order are the presence of protrusible eyes, another adaptation to living on the seabed(benthos), and the extension of the dorsal fin onto the head.

Amphistium is a 50-million-year-old fossil fish identified as an early relative of the flatfish, and as a transitional fossil. In *Amphistium*, the transition from the typical symmetric head of a vertebrate is incomplete, with one eye placed near the top-center of the head. Paleontologists concluded that "the change happened gradually, in a way consistent with evolution via natural selection—not suddenly, as researchers once had little choice but to believe." *Amphistium* is among the many fossil fish species known from the Monte Bolca *Lagerstätte* of Lutetian Italy. *Heteronectes* is a related, and very similar fossil from slightly earlier strata of France.

Runcaria a Middle Devonian precursor to seed plants has been identified from Belgium, predating the earliest seed plants by about 20 million years. *Runcaria*, small and radially symmetrical, is an integumented megasporangium surrounded by a cupule. The megasporangium bears an unopened distal extension protruding above the multilobed integument. It is suspected that the extension was involved in anemophilous pollination. *Runcaria* sheds new light on the sequence of character acquisition leading to the seed, having all the qualities of seed plants except for a solid seed coat and a system to guide the pollen to the seed.





"Java Man" or *Pithecanthropus erectus* (now *Homo erectus*), the original "missing link" found in Java in 1891–92.

The term "missing link" refers back to the originally static pre-evolutionary concept of the great chain of being, a deist idea that all existence is linked, from the lowest dirt, through the living kingdoms to angels and finally to God. The idea of all living things being linked through some sort of transmutation process predates Darwin's theory of evolution. Jean-Baptiste Lamarck envisioned that life is generated in the form of the simplest creatures constantly, and then strive towards complexity and perfection (i.e. humans) through a series of lower forms. In his view, lower animals were simply newcomers on the evolutionary scene.

After *On the Origin of Species*, the idea of "lower animals" representing earlier stages in evolution lingered, as demonstrated in Ernst Haeckel's figure of the human pedigree. While the vertebrates were then seen as forming a sort of evolutionary sequence, the various classes were distinct, the undiscovered intermediate forms being called "missing links." The term was first used in a scientific context by Charles Lyell in the third edition (1851) of his book *Elements of Geology* in relation to missing parts of the geological column, but it was popularized in its present meaning by its appearance on page xi of his book *Geological Evidences of the Antiquity of Man* of 1863. By that time it was generally thought that the end of the last glacial period marked the first appearance of humanity, but Lyell drew on new findings in his *Antiquity of Man* to put the origin of human beings much further back in the deep geological past. Lyell wrote that it remained a profound mystery how the huge gulf between man and beast could be bridged. Lyell's vivid writing fired the public imagination, inspiring Jules Verne's *Journey to the Center of the Earth* (1864) and Louis Figuier's 1867 second edition of *La Terre avant le déluge* ("Earth before the Flood"), which included dramatic illustrations of savage men and women wearing animal skins and wielding stone axes, in place of the Garden of Eden shown in the 1863 edition. The idea of a "missing link" between humans and so-called "lower" animals remains lodged in the public imagination. The search for a fossil showing transitional traits between apes and humans, however, was fruitless until the young Dutch geologist Eugène Dubois found a skullcap, a molar and a femur on the banks of Solo River, Java in 1891. The find combined a low, ape-like skull roof with a brain estimated at around 1000 cc, midway between that of a chimpanzee and an adult human. The single molar was larger than any modern human tooth, but the femur was long and straight, with a knee angle showing that "Java Man" had walked upright. Given the name *Pithecanthropus erectus* ("erect ape-man"), it became the first in what is now a long list of human evolution fossils. At the time it was hailed by many as the "missing link," helping set the term as primarily used for human fossils, though it is sometimes used for other intermediates, like the dinosaur-bird intermediary *Archaeopteryx*.

3. LIVING FOSSILS

A **living fossil** is an extant taxon that closely resembles organisms otherwise known only from the fossil record. As a rule, to be considered a living fossil, the fossil species must be old relative to the time of origin of the extant clade. Living fossils commonly are species-poor lineages, but they need not be. The term *living fossil* is not formally defined, but in scientific literature the term usually connotes a bradytelic group. "Bradytely", however, is rarely used in modern scientific literature but the characteristic of a bradytelic group is that its changes fluctuate on a small scale and do not accumulate over time. In modern literature, the term most often used for that distinctive evolutionary tempo is "stasis". Living fossils exhibit stasis over geologically long time scales.

The coelacanths were thought to have gone extinct 66 million years ago, until a living specimen belonging to the order was discovered in 1938.

In popular literature "living fossil" commonly embodies radical misunderstandings such as that the organism somehow has undergone no significant evolution since fossil times, with practically no molecular evolution or morphological, but scientific investigations have repeatedly discredited any such claims about molecular evolution. The minimal superficial changes to living fossils are mistakenly declared the absence of evolution, but they are examples of stabilizing selection, which is an evolutionary process -- and perhaps the dominant process of morphological evolution.

Fossil and living ginkgos

170 million-year-old fossil *Ginkgo* leaves

Living *Ginkgo biloba* plant

Living fossils have two main characteristics, although some have a third. The first two are required for recognition as a living fossil stasis but some authors include the third. They:

1. are members of taxa that exhibit notable longevity in the sense that they have remained recognizable in the fossil record over unusually long periods;
2. show little morphological divergence, whether from early members of the lineage, or among extant species, and
3. tend to have little taxonomic diversity.

Such criteria are neither well-defined nor clearly quantifiable, but modern methods for analyzing evolutionary dynamics can document the distinctive tempo of stasis. Lineages that exhibit stasis over very short time scales are not considered living fossils; what is poorly-defined is the time scale over which the morphology must persist for that lineage to be recognized as a living fossil.

The term "living fossil" is much misunderstood in popular media in particular, in which it often is used meaninglessly. In professional literature the expression seldom appears and must be used with far more caution and it has been used inconsistently.

One example of a concept that could be confused with "living fossil", is that of a "Lazarus taxon", but the two are not equivalent; a Lazarus taxon (whether a single species or a group of related species) is one that suddenly reappears, either in the fossil record or in nature, as if the fossil had "come to life again". In contrast to Lazarus taxa, a living fossil in most senses is a species or lineage that has undergone exceptionally little change throughout a long fossil record, giving the impression that the extant taxon had remained identical through the entire fossil and modern period.

The average species turnover time, meaning the time between when a species first is established and when it finally disappears, varies widely among phyla, but averages about 2–3 million years. So a living taxon that had long been thought to be extinct could be called a Lazarus taxon once it was discovered to be still extant. A dramatic example was the order Coelacanthiformes, of which the genus, *Latimeria* was found to be extant in 1938. About that there is little debate. However, whether *Latimeria* resembles early members of its lineage sufficiently closely to be considered a living fossil as well as a Lazarus taxon, has been denied by some authors in recent years.

Coelacanths disappeared from the fossil record some 80 million years ago (upper Cretaceous) and to the extent that they exhibit low rates of morphological evolution, extant species qualify as living fossils. It must be emphasised that this criterion reflects fossil evidence, and is totally independent of whether the taxons had been subject to selection at all, which all living populations continuously are, whether they remain genetically unchanged or not. This in turn gives rise to a great deal of confusion; for one thing, the fossil record seldom preserves much more than the general morphology of a specimen; to determine much about its physiology is seldom possible. To determine much about its noncoding DNA is hardly ever possible, but even if a species were hypothetically unchanged in its physiology, it is to be expected from the very nature of the reproductive processes, that its non-functional genomic changes would continue at more or less standard rates. It follows that a fossil lineage with apparently constant morphology need not imply equally constant physiology for example, and certainly neither implies any cessation of the basic evolutionary processes such as natural selection, nor reduction in the usual rate of change of the noncoding DNA. In short, not even the most dramatic examples of living fossils can be expected to be without changes, no matter how persistently constant their fossils and their extant specimens might seem. Some living fossils are taxa that were known from palaeontological fossils before living representatives were discovered. The most famous examples of this are:

- Coelacanthiform fishes *Latimeria chalumnae* and *Latimeria menadoensis*
- *Metasequoia*, the dawn redwood discovered in a remote Chinese valley
- glypheoid lobsters
- mymarommatid wasps, eomeropid scorpionflies
- jurodid beetles

All of these were described from fossils before later found alive (2 species, 10 species, one species, and one species respectively).

Other examples of living fossils are single living species that have no close living relatives, but are survivors of large and widespread groups in the fossil record. Consider:

- *Ginkgo biloba*
- *Syntexis libocedrii, the* cedar wood wasp
- Dinoflagellates include taxa that originally were described as fossils (being typified on coccoid, occasionally calcareous cell remnants: dinocysts), but now are known to include still-extant species.

The fact that a living fossil is a surviving representative of an archaic lineage does not imply that it must retain all the "primitive" features (plesiomorphies) of its ancestral lineage. Although it is common to say that living fossils exhibit "morphological stasis", stasis, in the scientific literature, does not mean that any species is strictly identical to its ancestor, much less remote ancestors. Some living fossils are relicts of formerly diverse and morphologically varied lineages, but not all survivors of ancient lineages necessarily are regarded as living fossils. See for example the uniquely and highly autapomorphic oxpeckers, which appear to be the only survivors of an ancient lineage related to starlings and mockingbirds.

Limulus is a genus of horseshoe crab, with one extant species, the Atlantic horseshoe crab (Limulus polyphemus). Many fossil species are known, many of which have since been assigned to other genera.

Scientific classification

Phylum:	Arthropoda
Subphylum:	Chelicerata
Class:	Merostomata
Order:	Xiphosura
Family:	Limulidae
Genus:	***Limulus*** O. F. Müller, 1785
Type species	
Limulus polyphemus (Linnaeus, 1758)	

Currently valid species include:

- *Limulus polyphemus* (Linnaeus, 1758)
- *Limulus coffini*† Reeside & Harris, 1952- Cretaceous, United States
- *Limulus darwini*† Kin & Błażejowsk, 2014- Jurassic, Poland[3]
- *Limulus priscus*† Münster, 1839- Triassic, Germany
- *Limulus woodwardi*† Watson, 1909- Jurassic, England

Doubtful species include:

- *Limulus nathorsti* Jackson, 1906- Jurassic,

Sweden Tentative species:

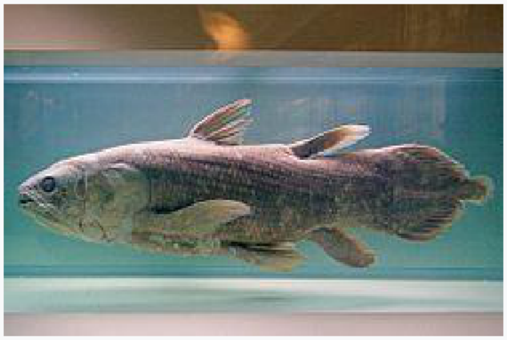
- *"Limulus" decheni*† Zinken, 1862- Paleogene, Germany (considered by some intermediate between *Limulus* and *Tachypleus*)

PERIPATUS

Peripatus is a genus of velvet worms in the Peripatidae family. The name "peripatus" (unitalicized and uncapitalized) is also used to refer to the Onychophora as a whole, although this group comprises many other genera besides *Peripatus*. They are found in Central America and northern South America. They are also found in New Zealand.

Peripatus

Scientific classification	
Kingdom:	Animalia
Phylum:	Onychophora
Class:	Udeonychophora
Order:	Euonychophora
Family:	Peripatidae
Genus:	***Peripatus*** Guilding, 1826

Latimeria	
	
West Indian Ocean coelacanth (*Latimeria chalumnae*), Natural History Museum of Nantes	
Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Sarcopterygii
Order:	Coelacanthiformes
Family:	Latimeriidae
Genus:	***Latimeria*** Smith 1939
Type species	
Latimeria chalumnae	

Latimeria is a rare genus of fish that includes two extant species: West Indian Ocean coelacanth (*Latimeria chalumnae*) and the Indonesian coelacanth (*Latimeria menadoensis*). They follow the oldest known living lineage of Sarcopterygii (lobe-finned fish and tetrapods), which means they are more closely related to lungfish, reptiles and mammals than to the common ray-finned fishes.

They are found along the coastlines of the Indian Ocean and Indonesia. Since there are only two species of coelacanth and both are threatened, it is the most endangered genus of animals in the world. The West Indian Ocean coelacanth is a critically endangered species.

4. VESTIGIAL, ANALOGOUS AND HOMOLOGOUS ORGANS USING PHOTOGRAPHS, MODELS OR SPECIMEN.

Homologous organs:-

The structures that have similar origin, and are similar in their morphology, anatomy, genetics and embryology but perform different functions such types of organs said to be homologous organs.

Homologous structures:-

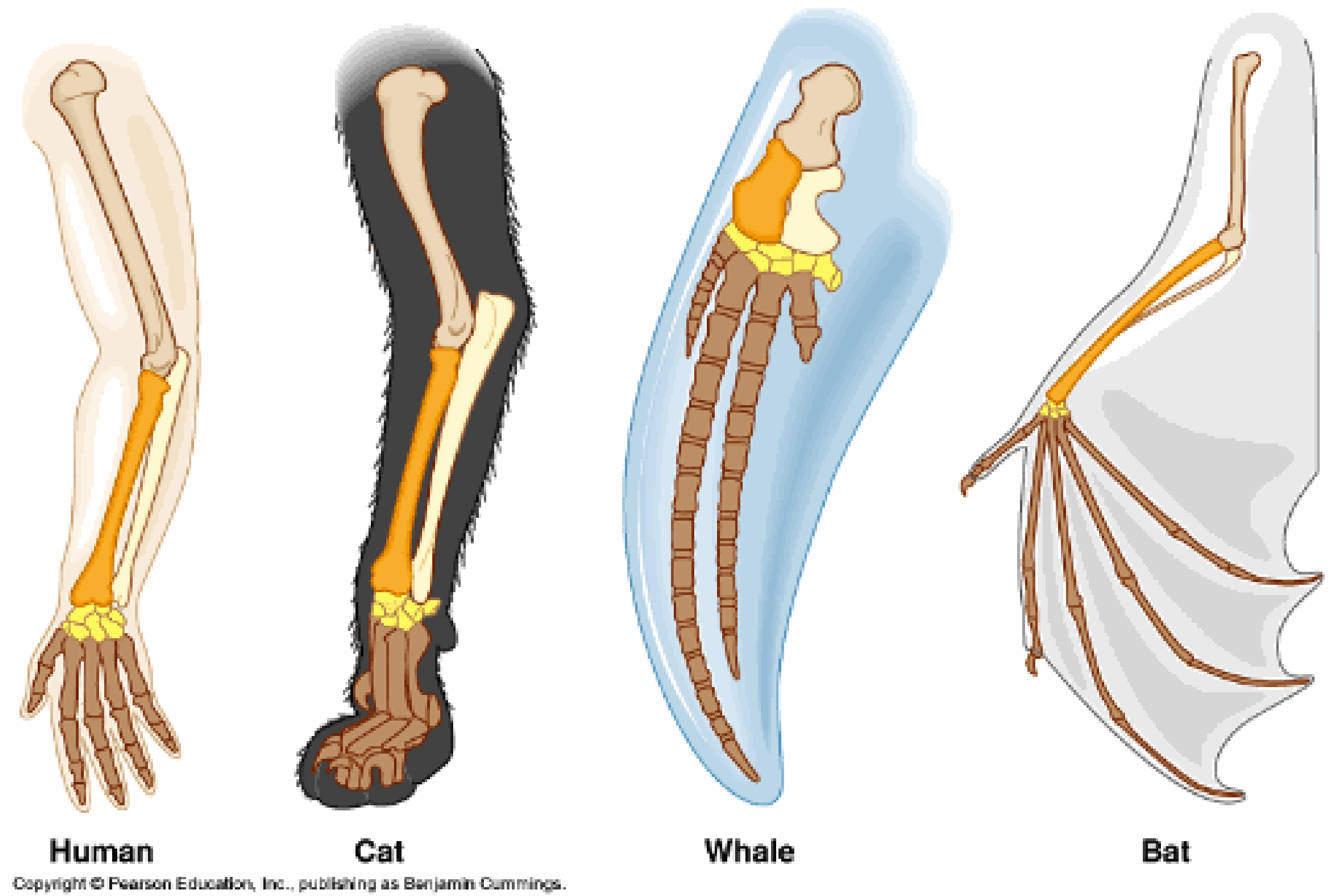
1. Similar in anatomy.

2. Inherited from a common ancestors.

3. Similar development pattern.

4. Result of divergent evolution.

Examples: - ***Bat's wing, wings of birds, seal's flipper, forelimb of a horse, and human arm*** *have a common underlying anatomy but perform different functions.*



Analogous organs:-

The organs which are dissimilar in their origin, structures, anatomy, morphology and embryology but perform similar functions.

Analogous structures:-

1. Disimilar in anatomy.

2. Not inherited from common ancestor.

3. Developmental pattern is not similar.

4. Result of convergent evolution.

*Examples:- **Wings of insects, Pterodactyl, birds and bats** are meant for flying but with different origin.*

Vestigial organs:-

The organs of the body which are smaller and simpler than those in related species. They have lost, or almost lost their original functions are said to be vestigial organs.

Examples:-

vermiform appendix in human, wisdom teeth, male nipple and The Tailbone.

Other mammals find their tails useful for balance, but when humans learned to walk, the tail because useless and evolution converted it to just some fused vertebrae we call a coccyx.

A **homologous**structure is an **organ**, system, or body part that shares a common ancestry in multiple organisms. This **definition** is found in evolutionary biology and uses the **meaning** of having a similar structure or origin.**Organs** such as bat's wing, wings of birds, seal's flipper, forelimb of a horse, and human arm have a common underlying anatomy that was present in their last common ancestors; therefore their forelimbs are**homologous organs**.

Analogous organs are the opposite of homologous **organs**, which have similar functions but different origins. An example of an **analogous** trait**would** be the wings of insects, bats and birds that evolved independently in each lineage separately after diverging from an ancestor without wings.

rudimentary structure in humans corresponding to a functional structure or **organ** in ancestral animals.The **examples** of human vestigiality are numerous, including the anatomical (such as the human tailbone, wisdom teeth, and inside corner of the eye), the behavioral (goose bumps and palmar grasp reflex), and molecular (pseudogenes). Many human characteristics are also **vestigial** in other primates and related animals.

Homologous organs are like arms and legs of human beings and four legs of quadrupeds. They have the same position and more or less the same functions. Analogous organs are arms of man and wings of birds they have the same position but entirely different functions. Vestigial organs had some important functions once, but now they are not required/used eg vermiform appendix in man was required for digesting raw flesh in primitive man (aadi manay) before the discovery of fire, when he used to eat animal flesh. Now when man has started eating cooked food since a few centuries, he doesn't require it and it has become very small and vestigial.

5. SAMPLING OF HUMAN HEIGHT, WEIGHT AND BMI FOR CONTINUOUS

VARIATION. AIM: To sample human height, weight and BMI for continuous variations.

PRINCIPLE:

BMI stands for body mass index. It is a measure of body composition. BMI is calculated by taking a person's weight and dividing by their height squared. For instance, if your height is 1.82 meters, the divisor of the calculation will be (1.82*1.82) = 3.3124. If your weight is 70.5 kilograms, then your BMI is 21.3(70.5/3.3124). BMI is just a guide – it does not accurately apply to elderly populations, pregnant women or muscular athletes such as weight lifters.

MATERIALS REQUIRED:

1. Measuring tape
2. Weighing scale (digital or analog)
3. Pen
4. Clip board
5. Data sheet

PROTOCOL:

1. **INSTRUCTIONS FOR MEASURING WEIGHT** :

a) Set the scale at zero reading.

b) Have the student remove shoes, heavy outer clothing (jacket, vest, sweater, hat), and empty pockets (cell phones, iPods) to extent possible.

c) Have the student step on the scale platform, facing away from the scale read out, with both feet on the platform, and remain still with arms hanging naturally at side and looking forward.

d) Read the weight value to the nearest ¼ pound or 0.1 (1/10) kilogram.

e) Have the student step off the scale and take a second measurement, repeating the steps above (measurements should agree within 0.1 kilogram or ¼ pound; if not, re-measure until this standard is met).

f) For confidentiality and to avoid stigma or harassment, do not call out weight value

g) Record the weight value immediately on the student health record or data log

h) If using a balance beam scale, return the weights to zero position

2. INSTRUCTIONS FOR MEASURING HEIGHT

a) Have the student remove shoes, hat, and hair ornaments / buns / braids to extent possible

b) Have the student stand on the footplate or uncarpeted floor with back against stadiometer rule

c) Have the student bring legs together (in contact at some point, whatever touches first)

d) Assure student's legs are straight, arms are at sides, and shoulders are relaxed

e) Assure the back of the student's body touches/has contact with the stadiometer at some point, preferably with heels, buttocks, upper back and head touching the measuring surface

f) Assure that the student's body is in a straight line (mid-axillary line parallel to the stadiometer),

Figure 1: Mid-axillary Line

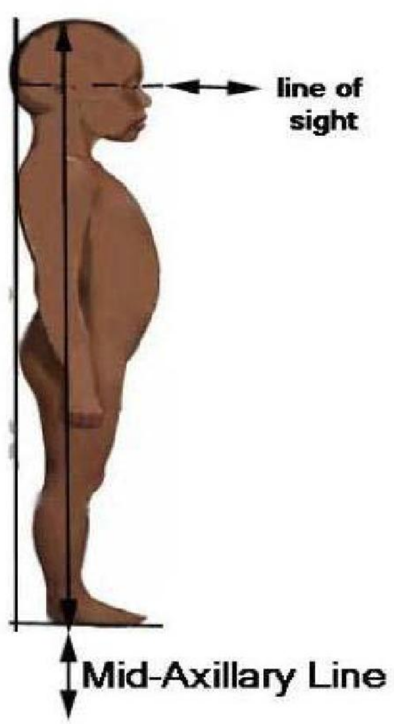


Figure 2: Frankfort Horizontal Plane

After collecting the individual's height and weight, the BMI is calculated

FORMULA AND CALCULATION:

BMI =weight (kg) / [_____] (m) * _____ (m)]

BMI = _______ kg/ ______ m

BMI = _________________

Observations:

RANGE	DESCRIPTION
<18	You are very underweight and possibly malnourished
18.1 - 20	You are under weight and could afford to gain a little weight
20.1 - 26	You are healthy weight range for young and middle - aged adults
26.1 - 30	You are overweight
< 30	You are obese

Results

The measured height of the individual is _____________.

The measured weight of the individual is _____________.

The calculated BMI of the individual is _______________.

6. SAMPLING FOR DISCRETE CHARACTERISTICS (DOMINANT *VS* RECESSIVE) FOR DISCONTINUOUS VARIATIONS

Variation & Inheritance

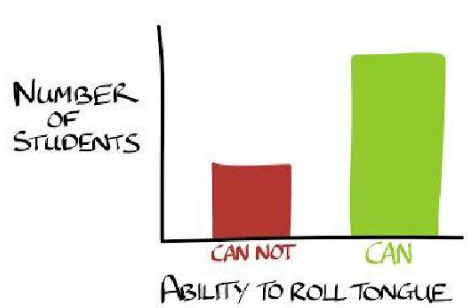
What you need to know...

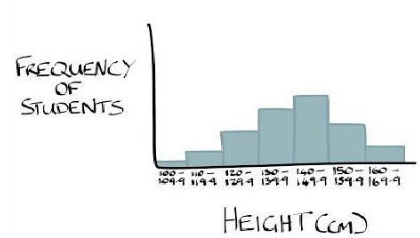
- Comparison of **discrete** and **continuous** variation.
- Most features of an individual **phenotype** are **polygenic** and show **continuous** variation.
- Identification of **phenotype** and **genotype**, **dominant** and **recessive** characteristics and **homozygous** and **heterozygous** individuals.

Something everyone knows but takes for granted is that we're all different. Each individual in a species is different from the others, and species are different from each other. The word we use to describe the differences between living things is **variation**. In this topic we're interested in the causes of variation and the different forms of variation. If you think about it, you already know what makes us different from each other. There are two major causes of variation...your genes and your environment. Apart from identical siblings, we're born with a different combination of genetic information. This is the benefit of **sexual reproduction** to species - it creates variation within the species. But as you know, the environment plays a part in our appearance too. For example, our nutrition can play a major role in our appearance. In this topic we're focusing on inherited variation. How do those genes we inherit bring about the differences between us?

Discrete and Continuous Variation

Variation between individuals of a species can be grouped into two large categories: **discrete** and **continuous**. Discrete variation is either/or and is often caused by the presence or absence of a small number if genes. For example, our ability to "roll" our tongues is determined by just one gene. We can all either roll our tongue or not - there's nothing in between.





If you were to do a survey of all the students in your class to find out what the variation was in terms of their ability to roll their tongues, there would only be two options: can roll or can't. If you were to draw a graph of the results, because of the discrete nature of this variation, you would draw a bar graph which might look a little like this.

In reality however, most examples of the ways in which members of a species vary from each other is more complicated than this. Most of the features of an organism are the result of a complex interaction between a number of different genes, often with the environment playing a part also. The involvement of a variety of genes in the determination of an organism's features is known as **polygenic** inheritance. This more complex cause brings about what is known as **continuous** variation. Height is a good example of continuous variation.

There are a wide range of different heights and if you look around your class it is unlikely that any two individuals are exactly the same height. It wouldn't make sense to draw a graph like the one above for heights as you could have a bar for each individual in the class! So, when we draw a graph of continuous variation we categorise the individuals and draw bars to show the frequency in each of the categories. This type of graph is called a histogram and is likely to look something like this:

If your sample is size is large enough, a graph of continuous variation of an organism will almost always have a shape like the one above. This is known as normal distribution. If you're searching the web for variation resources you might quite often encounter the word discontinuous instead of discrete, such as on **these** BBC pages, the two are equivalent and so these resources are still useful. You just need to make sure you use the word **discrete** in your assessments.

Inheritance

As we've already mentioned, our genes play a crucial role in our features. We've known for some time now that our genes influence our characteristic. The ways in which our genes impact on our appearance is often complicated as mentioned above, but not always. In this course you need to know about the ways genes are inherited and expressed, but only in the most basic form. We're going to focus on single-gene inheritance, but as mentioned above most of our features are as a result of the complex interactions between many genes (polygenic). We'll save that for a future course!

Before we begin we need to revise some terms and introduce some new ones. Firstly, I'm assuming you remember what a gene is...if you're not sure stop reading now and go back and refresh your understanding of **DNA, genes and chromosomes**. We also need to introduce the terms **phenotype** and **genotype**. The phenotype of an organism is its physical appearance. For example, in the examples above this would be can or cannot roll your tongue or height. The genotype is the genetic makeup of the organism. Two organisms with the same phenotype will not necessarily have the same genotype as we'll soon see...

Take our ability to roll our tongues as an example. As mentioned above, this is controlled by just one gene. However, as we each receive two full sets of the 23 different human chromosomes at **fertilization**, we each have two copies of the gene for tongue rolling. Something we've not mentioned yet, is that our genes can come in different forms. So, the gene for tongue rolling for example comes in two different versions: can roll and can't roll. For the sake of easiness we can summarise these two versions of the tongue rolling gene with letters. We'll use the same letter for them both as they're both versions of the same gene, so we'll just use a capital letter and a lowercase letter. For example we can summarise the 'can roll' version of the gene as '**R**' and the 'can't roll' version of the same gene '**r**'. There is a reason why I used the capital letter for the 'can roll' version. The 'can roll' version of the gene is the **dominant** version of the gene and 'can't roll' is **recessive**. What this means is that if you have both copies of the gene, you can roll your tongue. That version of the gene overrides the other, which is why we describe it as dominant.

Now that we have these letters to summarise the two versions of the gene, we can begin to think about the **genotypes** of individuals of different **phenotypes**. *So, if an individual's phenotype is that they can not roll their tongue, what would their genotype be?* That one's easy. It would have to be '**rr**'. Everyone has two copies of the gene, so there has to be two letters. Neither of them can be '**R**' as that is dominant and so that would mean that they would be able to roll their tongue!

What about people who's phenotype is that they can roll their tongue then? *What's their genotype?* That's not so straightforward. Their genotype can either be '**RR**' or '**Rr**'. Remember, because

'**R**' is dominant it only takes one copy of that version of the gene to be able to roll your tongue, but we wouldn't be able to determine which of the two genotypes a tongue roller is without further tests.

We have two more words to introduce here before we can move on: **heterozygous** and **homozygous**. These words are used as a way to describe the different genotypes of individuals. Heterozygous means that they have two different forms of the gene, whereas homozygous means their two versions of the gene are the same. In our tongue rolling example we would describe each of the genotypes as follows:

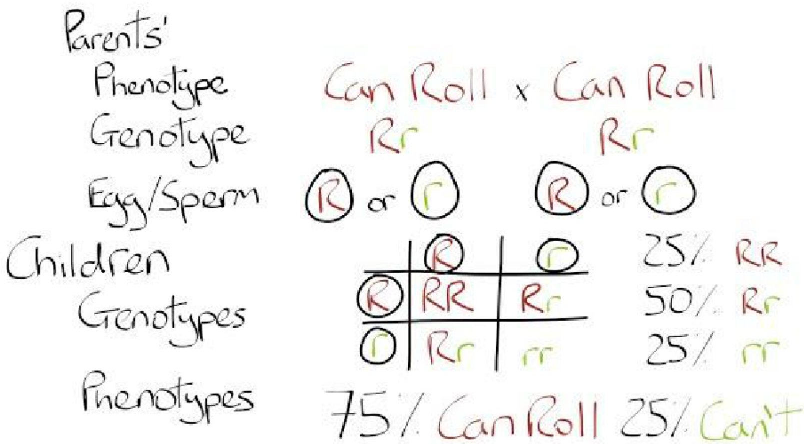
Genotype	**Heterozygous/Homozygous**	**Phenotype**
RR	Homozygous Dominant	Can Roll Tongue
Rr	Heterozygous	Can Roll Tongue
rr	Homozygous Recessive	Can't Roll Tongue

We can use this information to predict what we would expect the phenotypes of offspring from sexual reproduction to be. The diagrams below show what we would expect the phenotypes of the children from parents with different genotypes for tongue rolling.

Would the children of parents who are both homozygous, one dominant and one recessive, be able to roll their tongue?

This example shows that the children of a person who is homozygous dominant and a person who is homozygous recessive would all be heterozygous and so would all be able to roll their tongue. Remember, egg and sperm cells are gametes, which means they only have one set of the species' chromosomes. That's why they only have one letter in each.

Would the children of two heterozygous parents be able to roll their tongues?

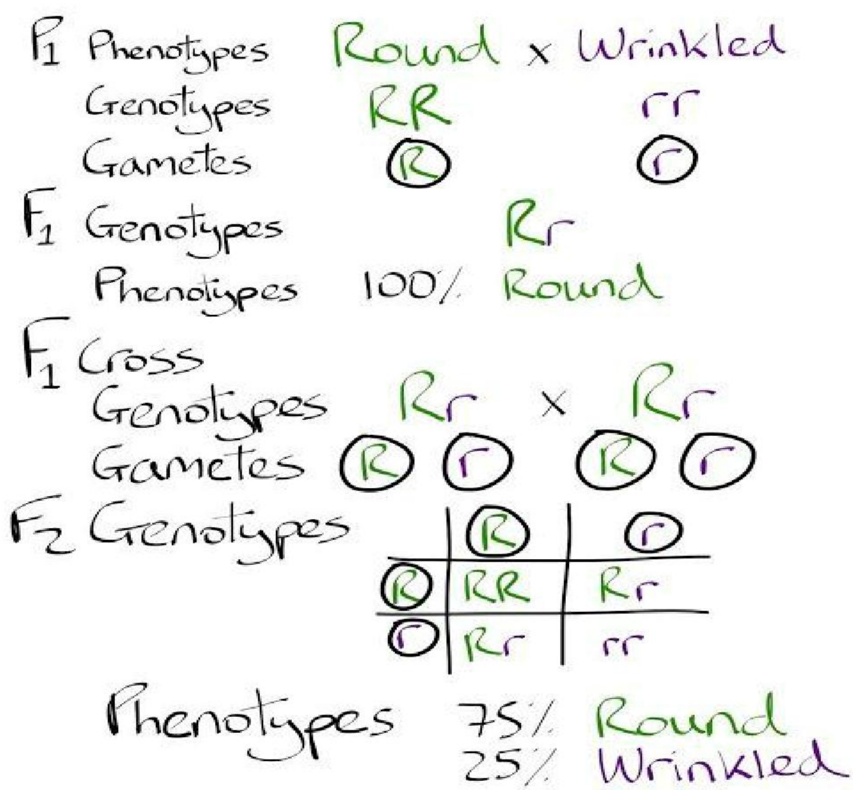


This example is more complicated. Here we have two people who can roll their tongues but are both heterozygous. This means their gametes could get either form of the gene. So, the little table above helps us work out what proportion of genotypes and phenotypes we would expect in their children. In this example we would expect 25% of their children to be homozygous dominant (RR), 50% to be heterozygous (Rr) and 25% to be homozygous recessive (Rr). Because both RR and Rr have the same phenotype, the expected phenotypes would be 75% 'can roll' and 25% 'can't roll'. However, to actually see these expected ratios the couple would have to have a lot of children! So most of our genetic experiments are done with species which produce large numbers of offspring quickly, such as plants, fruit flies and mice.

For example, pea plants have a number of different characteristics which are controlled by one gene and can be easily studied. One such characteristic is the surface of the pea seeds. Again, for the pea surface there are two possible phenotypes: round or wrinkled. Round is dominant and wrinkled is recessive. You don't have to always use the letter 'R' in genetic crosses, but it makes sense to do so again in this example (you normally choose a letter related to the phenotype, and it's best to choose a letter which has a different form in the lower and upper case versions. So, although we could use 'P' for pea or 'W' for wrinkled, both of these only change in size between the upper and lower case versions and so it could be confusing). Therefore then '**R**' in this case means 'round' and '**r**' means wrinkled.

The basic sort of experiment you could do to investigate the inheritance of seed surface would be to cross two homozygous plants with different phenotypes. You could then cross two of the offspring plants together. We use a shorthand to indicate which of the generations we're discussing in such an experiment as you'll see in the following diagram. The parents we can refer to as '**P_1**', the offspring as '**F_1**' and the offspring of the offspring as '**F_2**'.

So what genotypes and phenotypes would we expect from this cross then?



As you can see from the diagram above, 100% of the **F_1** generation would have the genotype **Rr** and would have round seeds. The offspring of two **F_1** plants are shown in the **F_2** generation. We would expect 25% of the **F_2** generation to be **RR**, 50% to be **Rr** and 25% to be **rr**. Therefore, 75% of the **F_2** plants should be round and 25% should be wrinkled. The ratio of the two phenotypes is 'Round 3:1 Wrinkled'.