MICROEVOLUTION AND MACROEVOLUTION

Microevolution is simply a change in gene frequency within a population. Evolution at this scale can be observed over short periods of time- for example, between one generation and the next, the frequency of a gene for pesticide resistance in pest increases. Such a change might come about because natural selection favoured the gene, or because the population received new immigrants carrying the gene, because some non-resistant version of gene mutated to the resistant version, or because of random genetic drift from one generation to the next.

Microevolution (variation) takes place through genetic drift, natural selection mutations, insertions/deletions, gene transfer, and chromosomal crossover, all of which produce countless observed variations in plant or animal populations throughout history. Examples include variations of the peppered moth, Galpagos finch beaks, new strains of flu viruses, antibiotic-resistant bacteria, and variations in stickleback armour.

Examples of microevolution

-- Size of the sparrow:

House sparrows were introduced to north America in 1852. Since that time, the sparrows have evolved different characteristics in different locations. Sparrow population in the north are larger bodied than sparrow population in the south. This divergence in population is probably at least partly a result of natural selection. Larger bodied birds can survive lower temperature than smaller bodied birds can.

-- Evolving Resistance

Science has documented many examples of evolution of resistance of pests to pesticides, weeds to herbicides and pathogens to medicines- all of which are cases of microevolutionary natural selection.

-- **The wisdom teeth** in man which appears around 16-18 years doesnot appears now till 20s. it means man does not need it any more.

-- **Average age of menarche** in women is decreasing and varies among different population.

Macroevolution, in contrast, is used to refer to changes in organisms which are significant enough that, over time, the newer organisms would be considered an entirely new species. In other words, the new organisms would be unable to mate with their ancestors.

Whereas microevolution explains diversification on an individual level over relatively short periods of time, macroevolution defines changes in large populations that often entail catastrophic environmental changes.

Micro evolution happens on a small-time scale – from one generation to the next, when such small changes build up over millions of years they turn into evolution on a grand scale- in other words, macro evolution.

Macroevolution encompasses grandest trends and transformation in evolution such as origin of mammals and radiation of flowering plants.

GRADUALISM AND PUNCTUATED EQUILIBRIUM

Gradualism and punctuated equilibrium are two ways in which the evolution of a species can occur. A species can evolve by only one of these, or by both. Scientists think that **species with a shorter evolution evolved mostly by punctuated equilibrium, and those with a longer evolution evolved mostly by gradualism.**

Gradualism **is selection and variation that happens more gradually**. Over a short period of time, it is hard to notice. Small variations that fit an organism slightly better to its environment are selected for: a few more individuals with more of the helpful trait survive, and a few more with less of the helpful trait die. Very gradually, **over a long time**, the population changes**. Change is slow, constant, and consistent.**

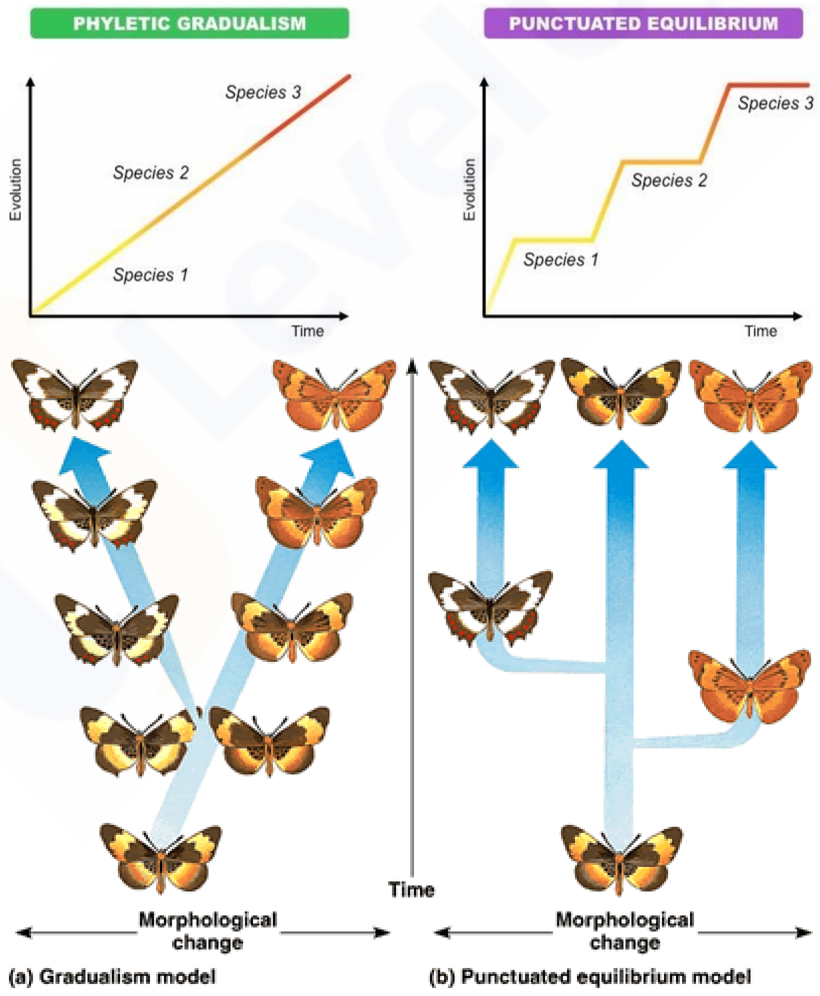
In punctuated equilibrium, change comes in spurts. There is a period of very little change, and then one or a few huge changes occur, often through mutations in the genes of a few individuals. Mutations are random changes in the DNA that are not inherited from the previous generation but are passed on to generations that follow. Though mutations are often harmful, the mutations that result in punctuated equilibrium are very helpful to the individuals in their environments. Because these mutations are so different and so helpful to the survival of those that have them**, the proportion of individuals in the population who have the mutation/trait and those who don't changes a lot over a very short period of time.** The species changes very rapidly over a few generations, then settles down again to a period of little change.

This explanation talks about punctuated equilibrium as the result of one or a few mutations that cause large change. However**, punctuated equilibrium** is any sudden, rapid change in a species and **can also be the result of other causes, such as huge and sudden changes in the environment that result in more rapid changes in the organisms through harsher selection.** How did the tiger get its stripes: gradualism or punctuated equilibrium? We don't know whether the tiger got its stripes through gradualism or punctuated equilibrium, but in order to explain both concepts, here is how it could have happened through each. Let's assume that stripes are helpful because they help the tiger to camouflage, blend in with the tall grasses where it lives, so that it can sneak up on its prey (what it eats) and not be noticed.

Gradualism: A long time ago, there were a lot of tiger-like animals, but without stripes. Most of them were unmarked, but a few had light markings and color variation in their fur. These few blended in with the tall grasses a little bit better, so they were generally able to catch more food, and fewer of the marked than unmarked ones died of hunger, so more of them were able to reproduce. In the next generation, more animals were marked than in the previous generation. Of those that were marked, some had more, some less, and some the same amount of marks than in the previous generation. Also, the marks were more, less, or the same amount clearly defined. Again, the ones with marks did better than the ones without, and the ones with more, clearly defined marks did better than the ones with fewer or fainter marks. Very gradually, over many, many generations, stripes over the tigers' whole bodies formed and appeared in the whole population, because the tigers that survived in each generation were those whose marks were most clear and contrasted most with the rest of the fur, and those that covered the most area on the bodies of the tigers.

Punctuated equilibrium: A long time ago, there were a lot of tiger-like animals, but without stripes. One time, a mutation occurred in a few of the animals, causing a huge change: they were born with stripes! This was so helpful to survival that out of the whole population, none or almost none of those with stripes died of hunger. They lived to reproduce, and their striped offspring also did very well. Over only a few generations, the whole population was born striped.

A combination: Here is one idea of how tigers could have gotten their stripes by both gradualism and punctuated equilibrium: A mutation had a huge affect, causing distinct, stripe-like markings. These were then gradually "polished up" into stripes.



The idea of punctuated equilibrium originated long after the idea of gradualism. Darwin saw evolution as being "steady, slow, and continuous". Later, scientists were studying fossils and they found that some species have their evolution almost "mapped out" in fossils. For others they found a few, very different species along the evolutionary course, but very few or no fossils of "in between" organisms. Also, when dating the fossils, scientists saw that in some species change was very slow, but in others, it must have occurred rapidly to be able to produce such change over such a short amount of time. The scientists reasoned that there had to be another way that evolution could have happened that was quicker and had fewer intermediate species, so the idea of punctuated equilibrium was formed.

PROGRESSIVE EVOLUTION OF MAN

- About 15 million years ago**, primates called Dryopithecus and Ramapithecus** were existing on the earth. They were hairy and walked like gorillas and chimpanzees. Ramapithecus was more like while Dryopithecus was more ape like. So, they were the forerunners of hominids.
- Progress was made further when a skull was discovered about 4-**5 million years ago**. It had a brain size of about **500 cm3** within the range of ape brain but its jaw and teeth were human like. It was probably not taller than 4 feet but walked up right. It was named as **Australopithecus africanus** which lived in East Africa grass lands. Evidence shows that they hunted with stone weapons but essentially ate fruits.
- **From the Australopithecus evolved the Homo Habilis (the Handy man)** which was characterized by having a larger brain than Australopithecus (650 – 800 c.c.), using tools and being bipedal. They probably did not eat meat.
- ***Homo erectus* appeared about 1.5 million years ago.** Its brain capacity increased to about 800 – 1200 c.c. and they migrated to Asia and Europe. Fossils of Java man and Peking man belonged to *Homo erectus.* They probably ate meat.
- ***Homo erectus was* later replaced by *Homo sapiens.*** There were **several sub-species of H. sapiens, a wide spread one of which was *Homo sapiens Neanderthals*** (Neanderthal man), a large brained game hunter. The Neanderthal man with a brain size of 1400 c.c. lived in near east and central Asia between 10000 – 40000 years back. They used hides to protect their body and buried their dead bodies.
- The oldest remains of **H. Sapiens sapiens (cro-magnon) appeared around 35000 years ago, probably having evolved from Neanderthal man**. They had large-brain size and existed as hunter gatherers in co-operative bands. They were stout, short and used hides for clothing. They built their huts for shelter and buried their dead bodies.

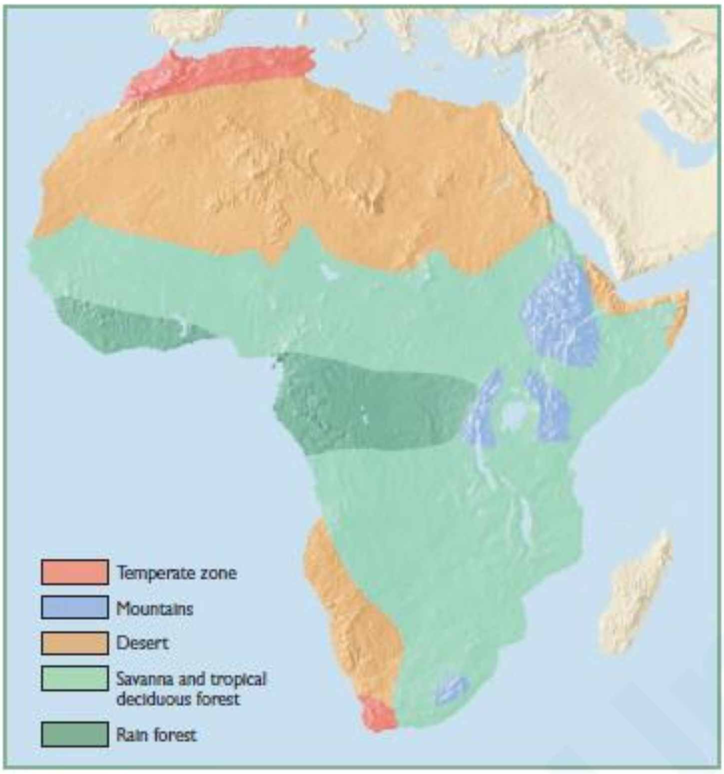
THE BENEFITS OF BIPEDALISM

Not many creatures use full bipedal locomotion. Birds do — and many dinosaurs did — but they also use their tails for balance and support. Human bipedalism involves a large number of individual physical features and evolutionary changes and remarkable acts of coordination.

When we stand and walk, with our trunk erect and knees straight, we have to balance our bodies vertically on two relatively small points of contact with the ground. We can 't run particularly fast, and we aren't very stable on rough or slippery surfaces. So what could be the benefit of such a mode of locomotion, and under what environmental circumstances was it adaptive enough to confer a reproductive advantage and so become established in our evolutionary line?

Compare the map of early hominid sites with the map of Africa's climatic and vegetation zones. Note that the sites are now located in savannas or tropical deciduous forests (open grasslands or woodlands more open than the rain forest and with trees that undergo seasonal cycles of growth). Where these zones grade into one another, an area called an ecotone, there is a mix of forest and open areas, as one zone grades into another. As we will see, our earliest ancestors exhibited traits associated with both bipedalism and an arboreal adaptation: relatively long arms; heavy shoulder girdles, arm bones, and arm muscles; and curved finger and toe bones. Perhaps in the earliest stages of our lineage, our ancestors were adapted to both a tree-climbing and a terrestrial, open-area way of life. So, we may ask how bipedalism could have been a benefit in such a mix of environments, where open space intermingled with the typically arboreal environment of the primates. Several different models have been proposed.

Map of major early fossil hominid sites.

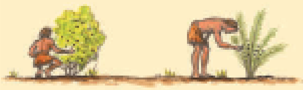


General climatic and vegetation zones of Africa today. Except for the large deserts in the north and south, the zones are much the same as when our evolutionary story began some 5 mya, although specific local conditions may have differed. Moreover, where zones meet, the conditions grade into one another, producing an area of mixed vegetation and other conditions.

1. **Carrying model**. Freeing the arms and hands from a role in locomotion would have meant that our ancestors could transport food from open areas to safer locations, such as a grove of trees or perhaps the foot of a steep hill. This would have been especially important if the food were part of an animal carcass, since other meat eaters would also have found it attractive. Moreover, bipedalism would have allowed mothers to carry children in their arms while walking in search of food. Perhaps our ancestors carried sticks and rocks to throw in defense against predators or to scare scavengers away from a kill. (Chimps will occasionally hurl rocks and sticks, though not particularly accurately.) Under experimental conditions (Videan and McGrew 2000), it has been shown that having something to carry is a major stimulus for bipedal locomotion in chimpanzees and bonobos.
2. **Vigilance model**. Bipedalism, by elevating the head, helped our ancestors locate potential sources of food and danger. Videan and McGrew's (2000) experiment, just noted, showed this to be an important factor in the use of bipedalism; in fact, it was the most frequent context of upright posture. It should be noted here, however, that this model only addresses upright posture, not necessarily upright locomotion.
3. **Heat dissipation model**. The vertical orientation of bipedalism helps cool the body by presenting a smaller target to the intense equatorial rays of the sun and by placing more of the body above the ground to catch any cooling air currents. Open spaces in Africa can be hot, and the heat built up by long periods of walking in search of food needs to be dissipated. (This factor may also explain the adaptive significance of the relatively hairless bodies of modern hominids. Having no hair allows sweat to evaporate more quickly and cool the body more efficiently.)

4. **Energy efficiency model**. Numerical data indicate that although bipedalism is an energy-inefficient way of running fast, compared to quadrupedalism, it is more efficient for walking. Bipedal walking is a more efficient way of traveling than walking on all fours, at least if we compare human and chimpanzee walking. Peter Rodman and Henry McHenry (1980) pointed out that although humans do not necessarily walk more efficiently than all quadrupeds, they certainly walk more efficiently than knuckle walking apes. In other words, if hominins evolved from a knuckle walking ancestor, then the shift to upright posture would have made perfect energetic sense. Although there is still some argument about the relative efficiency of early hominin walking, most studies suggest that bipedal walking (but not running) is a more efficient means of locomotion than knuckle walking (Leonard & Robertson, 1997). Recent experiments suggest that oxygen consumption is greater in chimpanzees than in humans when walking bipedally, and models for early Australopithecus suggest even they would be substantially more efficient than were chimpanzees (Pontzer et al., 2009). This greater efficiency in getting between food patches may have had other advantages as well. Greater efficiency in moving between patches of food would have allowed hominins to maintain group size even as the Miocene forests dried (Isbell and Young, 1996).
5. **Foraging/bipedal harvesting model**. This idea refers to the benefits of standing upright to reach sources of food on bushes and trees, particularly those difficult or impossible to climb.
6. **Display model**. Jablonski and Chaplin (2000) propose that the important factor of bipedalism was an upright display posture like that seen in chimps and bonobos during dominance confrontations. An upright display posture conveys meaning because it makes the individual seem larger; it is also directly related to mating success.
7. **Walking in the trees**. Apes use hand-assisted bipedalism when walking along branches too flexible to support their weight. They reach up and grab onto branches overhead, with their lower limbs extended. If this was true of earlier apes, it could extend bipedalism well before the hominids and redefine hominid bipedalism as “less an innovation than an exploitation of a locomotor behaviour retained from the common great ape ancestor” (Thorpe et al. 2007:1328).

Each of these models has logic and evidence in its support. It seems reasonable, at the moment, to provisionally suppose that all these factors, acting together, could have played an adaptive role in the emergence of the hominid lineage and its characteristic mode of locomotion.

Factor	Speculated Influence	Comments
Carrying (objects, tools, weapons, infants) 	Upright posture freed the arms to carry various objects (including offspring).	Charles Darwin emphasized this view, particularly relating to tools and weapons; however, evidence of stone tools is found much later in the record than first evidence of bipedalism.
Hunting 	Bipedalism allowed carrying of weapons, more accurate throwing of certain weapons, and improved long-distance walking.	Systematic hunting is now thought not to have been practiced until after the origin of bipedal hominins.
Seed and nut gathering 	Feeding on seeds and nuts occurred while standing upright.	Model initially drawn from analogy with gelada baboons (see text).
Feeding from bushes 	Upright posture provided access to seeds, berries, etc., in lower branches; analogous to adaptation seen in some specialized antelope.	Climbing adaptation already existed as prior ancestral trait in earliest hominins (i.e., bush and tree feeding already was established prior to bipedal adaptation).
Thermoregulation (cooling) 	Vertical posture exposes less of the body to direct sun; increased distance from ground facilitates cooling by increased exposure to breezes.	Works best for animals active midday on savanna; moreover, adaptation to bipedalism may have initially occurred in woodlands, not on savanna.
Visual surveillance 	Standing up provided better view of surrounding countryside (view of potential predators as well as other group members).	Behavior seen occasionally in terrestrial primates (e.g., baboons); probably a contributing factor, but unlikely as "prime mover."
Long-distance walking 	Covering long distances was more efficient for a biped than for a quadruped (during hunting or foraging); mechanical reconstructions show that bipedal walking is less energetically costly than quadrupedalism (this is not the case for bipedal running).	Same difficulties as with hunting explanation; long-distance foraging on ground also appears unlikely adaptation in earliest hominins.
Male provisioning 	Males carried back resources to dependent females and young.	Monogamous bond suggested; however, most skeletal data appear to falsify this part of the hypothesis (see text).

BIPEDALITY HAD ITS BENEFITS AND COSTS: AN EVOLUTIONARY TRADE-OFF

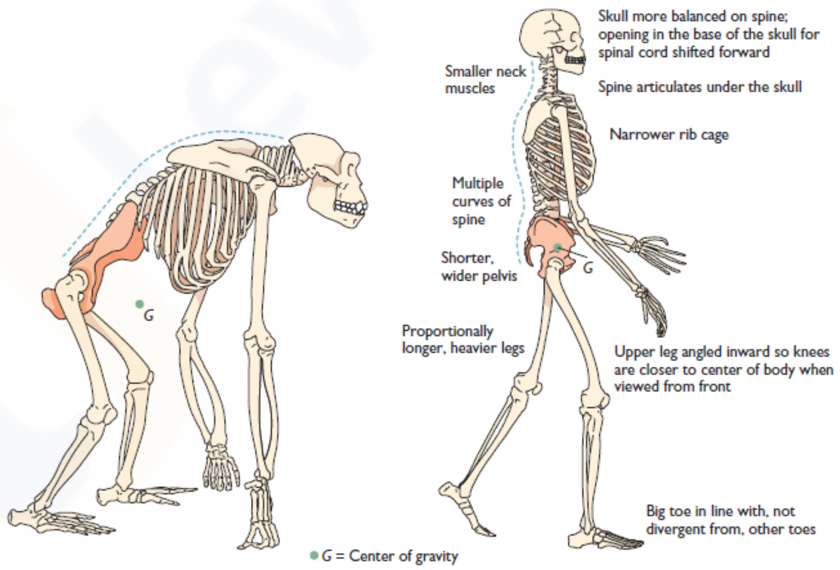
All the hypotheses about human origins have suggested that an apelike primate evolved into an early hominid through completely positive adaptation. Bipedalism's advantages over quadrupedalism included an increased ability to see greater distances (thanks to an upright posture), greater ease of transporting both food and children, ability to run long distances, and the freeing of the hands for, eventually, such remarkable skills and activities as tool manufacture and tool use. However, the profound adaptive shift to bipedalism had its costs. Standing upright yields a better view across the landscape, but it also brings exposure to predators. Standing or walking on two feet while simultaneously lifting or carrying heavy objects over long periods of time causes back injury, such as that associated with arthritis and with slipped intervertebral disks. Bipedality also places an enormous burden on the circulatory system as it moves blood from the legs to the heart. The result of this burden is the development of varicose veins, a condition in which overwork causes the veins to bulge. Lastly, if one of a biped's two feet is injured, then that biped's ability to walk can be severely reduced. Unable to move about the landscape, an early hominid would have had limited chances of surviving and of reproducing. In short, bipedality is a wonderful example of the trade-offs that occur in evolution. Only rarely do adaptive shifts, including one of the most fundamental human behaviours, come without some cost.

BIOLOGICAL AND CULTURAL FACTORS OF HUMAN EVOLUTION

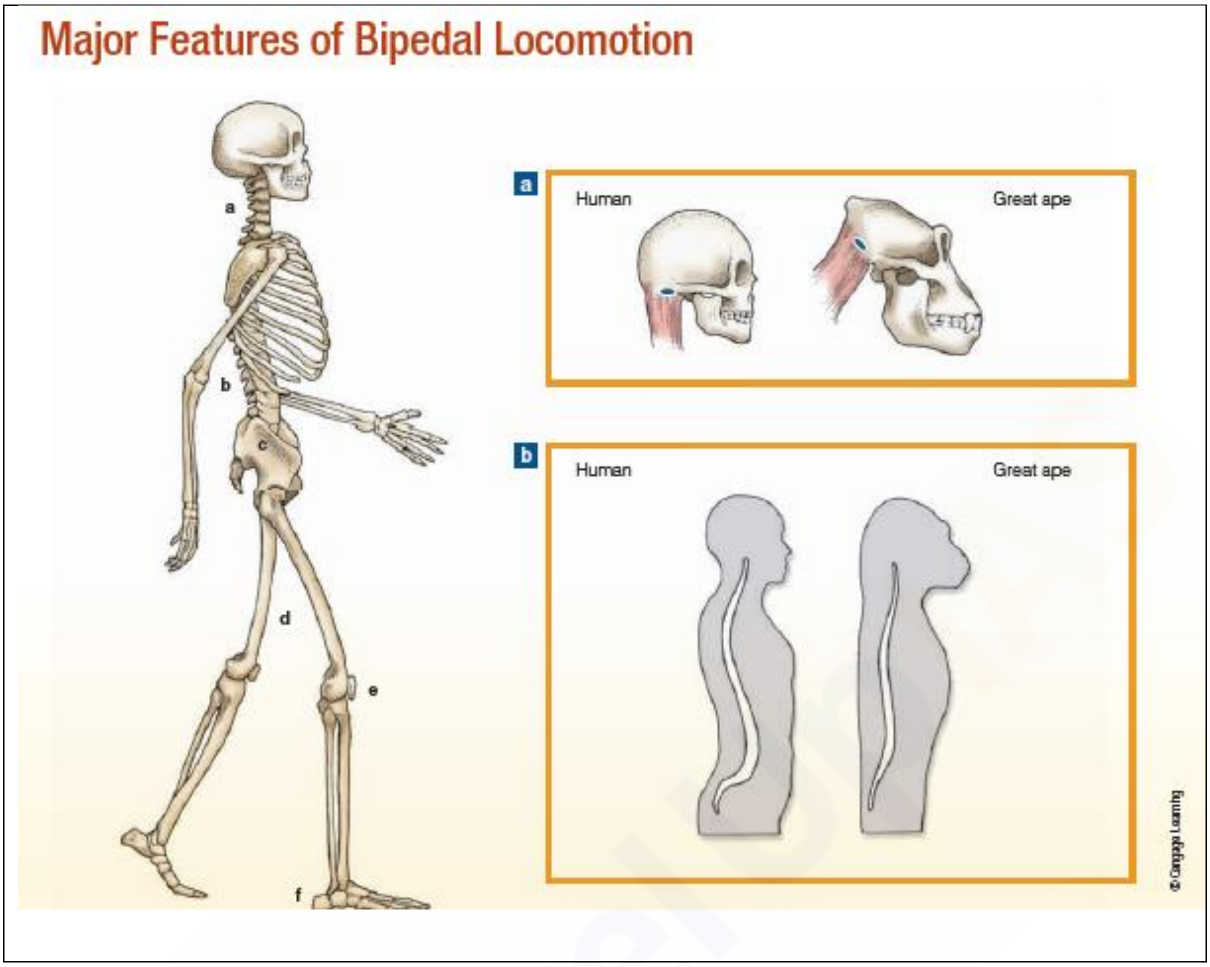
Hominization process is the evolutionary transformation of hominoids into hominids. It is a process that occurred in the hominid line since the divergence of last common hominoid ancestor shared with any living ape. The term is applied to include all those aspects of structural and behaviour changes that occurred in the hominid line finally leading to evolution of man.

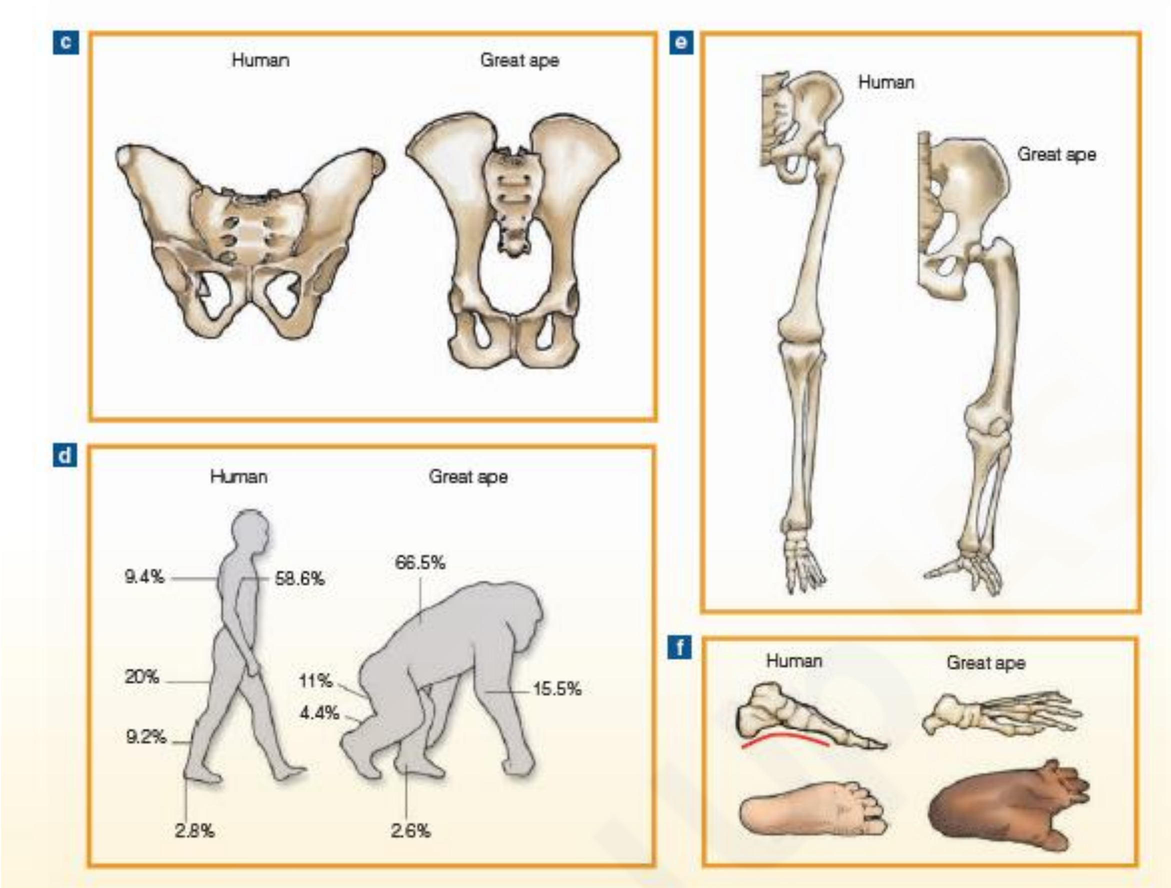
Erect Posture and Bipedal locomotion:

The most obvious thing about the human beings that differentiate them from all other members of the animal kingdom is their upright posture and their associated habit of walking (technically known as bipedal locomotion). Many of the distinctively human morphological traits are directly attributable to these facts of human life. The shape of vertebral column in mammals delicately adjusted to support the animal's centre of gravity.



Note the anatomical changes and, thus, the physical evidence associated with bipedalism in the human primate. Compare human features with corresponding ones in the gorilla. *G* represents the center of gravity when standing bipedally. The ape expends much more energy to keep from falling forward when standing upright.


Major Features of Bipedal Locomotion
a
b
c
d
e
f
a
Human
Great ape
b
Human
Great ape
© Cengage Learning



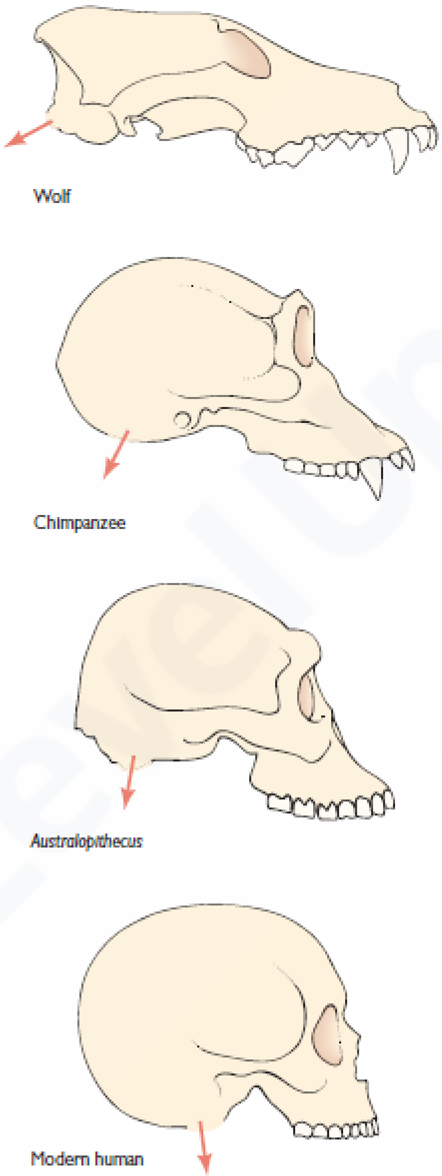
During hominin evolution, several major structural features throughout the body have been reorganized (from those seen in other primates), facilitating efficient bipedal locomotion. These are illustrated here, beginning with the head and progressing to the foot: **(a)** The foramen magnum is repositioned farther underneath the skull, so that the head is more or less balanced on the spine (and thus requiring less robust neck muscles to hold the head upright). **(b**) The spine has two distinctive curves—a backward (thoracic) one and a forward (lumbar) one—that keep the trunk (and weight) centered above the pelvis. **(c)** The pelvis is shaped more in the form of a basin to support internal organs; the ossa coxae (specifically, the iliac blades) are also shorter and broader, thus stabilizing weight transmission. (**d**) The lower limbs are elongated, as shown by the proportional lengths of various body segments (for example, in humans the thigh comprises 20 percent of body height, while in gorillas it comprises only 11 percent). **(e)** The femur is angled inward, keeping the legs more directly under the body; modified knee anatomy also permits full extension of this joint**. (f)** The big toe is enlarged and brought in line with the other toes; a distinctive longitudinal arch also forms, helping to absorb shock and adding propulsive spring.

Characteristics of human vertebral column that are specific to an upright posture include:

- Enlarging of lower vertebrae to absorb the forces of compression,
- Relative constancy in the size of the spines protruding from each vertebra, resulting from a lack of weight bearing stress points along the spine.

- Increase in size and number of spines in sacrum to take up the transmission of weight through the pelvis and legs; and
- Finally a sharp backward curving of the spine in the lumber region (lower back) providing a solid platform to transfer the weight of the body onto the pelvis and giving the human spinal column its distinctive S-shape.
- Even the skull shows adaptation to erect posture, with the shifting forward of the foramen magnum closer to the centre of base of the skull.

Comparison of the placement of the foramen magnum and orientation of the spinal column relative to the skull in a nonprimate quadruped and three primates. The wolf, with equally long fore and hind limbs, has a foramen magnum toward the back of the skull with an almost horizontal orientation of the spine. The chimp, still a quadruped but with longer arms than legs, has a more forward placement with the spine extending at an angle. In the bipedal hominids we see a trend toward a more forward placement and a vertical orientation of the spine.



Remodelling face and Teeth

When an infant is born, it passes out of the mother's womb through the birth canal through the vagina and into the realities of social life. The birth canal is surrounded by skeletal bones that forms lower front of the mother's pelvis. This bone sets the limit on the size that a new born infant can be at the moment of its birth; if it (or any part of it) is too large it will get stuck, with the result that both infant and the mother are quite likely to die – which means they will not contribute their genes to the ongoing evolutionary process. It was noted that a major trend of human evolutionary development was a dramatic increase in brain size since the Australopithecines. Since the size of the head as a whole should not keep getting larger beyond the limits allowed by the process of birth, there was a strong adaptive pressure to shorten the snout and reduce the size of the face to make room for cranial expansion in the course of human evolution.

Specific modifications in face in the evolution of modern man includes:

- The brow ridges diminished.
- The forehead approaches being vertical.
- The chin is prominent.
- The face is flat, with a nose that protrudes.
- The foramen magnum is now exactly at the centre of the skull base, the head balancing nicely on the vertebral column.
- The nasal cavity and palate are shortened and arched.
- The tongue thickened and shortened.
- Teeth became smaller and less thick.
- Jaw became less protruding.

Many factors brought about these changes.
First, the trend toward upright posture resulted in the foramen magnum being moved forward, tilting the head upright into a vertical position and possibly exerting some "squeeze" against the face.

Second, the long, flat mouth, tongue, palate and nasal cavity with a high larynx and the wide angle at which the throat joined the mouth prior to *Homo sapiens,* drastically limited the number of sounds the vocal apparatus could produce and the speed with which it could produce them. If, the evolution of speech was of crucial importance to the overall process of human evolution, then there would have been selective pressures for moulding the face in the form it finally assumed. In fact, there is evidence that the mouth and tongue of Neanderthal are still too flat to produce the modern range of sounds, and also probably lack enough quickness of tongue to produce sounds at a modern rate.
Finally, it appears that human teeth only really were free to become small when people gave up using the mouth as a "tool" – a "fifth hand" used for holding, tearing and even chewing items to soften them. This happened in the last 10,000 years with the development of food production, when the agricultural revolution replaced hunting and foraging as the principal means of subsistence for most of the peoples in the world.

Expansion and Development of Brain

There is a dramatic increase of the brain case as we approach specimens of *Homo sapiens.* This is indeed worth noting, and physical anthropologists have spent a great deal of time studying the rapid increase in brain size in the course of post-australopithecine evolution.
The reasons are complicated. **First**, in general, the overall size of our ancestors increased at each evolutionary stage. We concluded that there were strong selective pressures for this increase in size, probably because a larger body size made it easier to hold and use tools, and also increased the amount of muscle available to hunters and foragers on long treks.

But the brain grew larger, proportionately did the body. The most likely reason is that an increase in brain size tremendously increases the possibility – indeed the probability – of an increase in both the number and kinds of connections between the brain cells. It is an increase in the kinds of connections between brain cells that is apparently responsible for the emergence of new kinds of mental operations such as thinking and using language, operations that are fundamental to human existence.

Culture and Hominization process

Each stage of hominid organic evolution seems to have been accompanied by the major advances in cultural evolution. Paralleling biological evolution of early humans was the development of cultural technologies that allowed them to become increasingly successful at acquiring food and surviving predators.

1) The creation and use of tools.
2) The new subsistence patterns.
3) The occupation of new environmental zones

The creation and use of tools:

The earliest evidences of hand manipulations that are different from apes and similar to Homo can be found in A. afarensis. The hand proportion of the members of this group is approximately similar to human proportions but differ from those of humans suggesting greater power grip. The hand anatomy of afarensis also reveals that the precision grip was greater among them compared to that of the chimpanzee, but lesser than that of the Homo. A. afarensis spent more time on the land than on the trees hence the hand-anatomy had started overshadowing the characteristics of hands of Homo and different from those of apes. Hominids with their manipulative hands, precision grip and contemplating brains, had been able to expand their ecological niche so far beyond the physical capabilities inherent in their makeup, one that no other animal has ever had the potential to achieve.

Recent paleo-anthropological findings reflect the use of tools, antedates the origin of the big, brained Homo sapiens by at least a million and a half year. There is now indisputable evidence of the occurrence of modified stone tools that is 2 million years old found in association with the bones of Homo habilis. In other words, tool-use and tool-making developed before hominid brain capacity had undergone remarkable increase. The old idea that a large brain and associated high intelligence were prerequisites for tool use is no longer tenable. The use of tools by primitive hominids may, in fact, have been a major factor in the evolution of the cerebral cortex and higher intelligence, for once the use and making of tools began to favour survival, there would be high selection pressure for neural mechanism promoting improved crafting and use of tools. The elaborate brain of Homo sapiens may be a consequence of culture as much as its cause. Hominization process, with respect to cultural attainments, had set in much before the modern man appeared on the earth. Oldowan industry of earliest Homo habilis clearly proves the point.

Homo erectus had not only perfected stone tools considerably but had also learned how to control and use fire, as revealed by radio isotope dated hearths in caves. With fire humans could cook their food they could keep themselves warm in cold weather; they could ward off predators and they could light up the dark to see. The hearth no doubt promoted the development of social organization and allowed an opportunity for the beginning of communication through spoken language.

New subsistence patterns

Anthropologists use the term subsistence pattern to refer to source of food and the way it is obtained. A clear measure of success in human evolution gas been the progressive development of new food getting techniques and the inclusion of new food sources. These measures have made it possible for humanity to increase in numbers from a few thousand australopithecines in Africa three million years ago.

Based on analysis of tooth wear pattern and food refuse evidence, it is likely that australopithecines and early transitional humans were primarily wild food collectors and occasional scavengers of meat and eggs. By the time of homo erectus, small game hunting and large animal carcass scavenging were apparently becoming much more common.

Occupation of new environment zones

Homo erectus was the first species in our line of evolution to expand their range beyond tropical and sub-tropical environments into temperate climatic zones of the Old World where they encountered cold winters. This occurred at least a half million years ago in Asia. It was made possible mainly by success of new inventions and new subsistence strategies. The ability to use fire for cooking and heating might also have been significant in successful colonisation of colder regions.

Implications

The cultural development of Homo erectus essentially began a new phase of our evolution-one in which natural selection was altered by cultural inventions. Culture can affect the direction of human evolution by creating non biological solutions to environmental challenges. This potentially reduces the need to evolve genetic responses to the challenges.

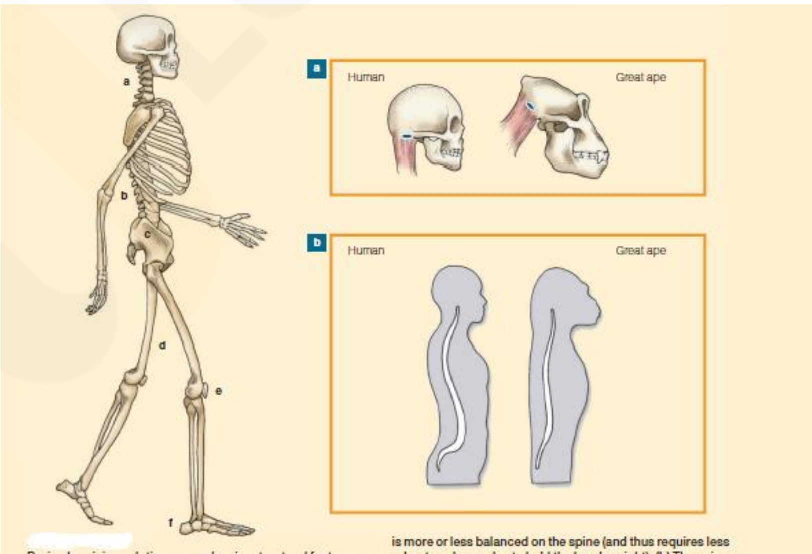
Normally, when animals move into new environmental zones, natural selection, operation on random mutations, causes evolution. In other words, the population's gene pool is altered as a result of adapting to a new environment.
When Homo erectus moved into temperate environments, nature should have selected for biological adaptations that were more suited to cooler climates. Such things as increased amount of insulating body fat and insulating hair covering most of the body would be expected. Homo erectus evidently achieved much of the same adaptation by occupying caves, using fires and becoming more capable at obtaining meat. By using their intelligence and accumulated knowledge, they essentially remained tropical animals despite the fact that they were no longer living in tropics. However, natural selection continued to select for increased brain size and presumably intelligence.

SKELETAL CHANGES DUE TO ERECT POSTURE AND ITS IMPLICATIONS

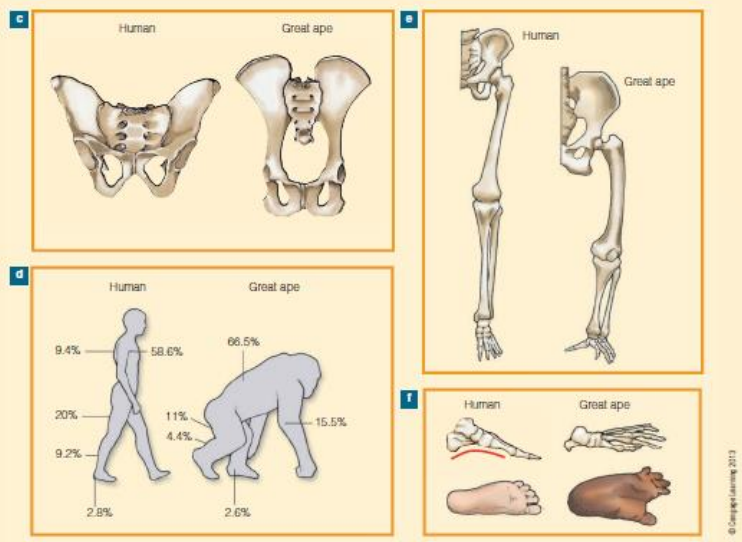
Walking upright is an extremely rare way to move about. In the entire history of life on Earth, truly bipedal posture and walking have appeared in just a few lineages. Of some 4,000 living mammals, only humans are habitual striding bipeds today. Although a number of other primates stand upright occasionally while walking or feeding, only hominins exhibit bipedal behaviour and the extensive morphological adaptations for striding on two legs.

Foot: the human foot has been redesigned to act as a platform to support the entire weight of the body rather than acting as a grasping structure as it did in the early hominids.

- Humans therefore have smaller toes.
- Non-opposable big toe.
- Have a foot arch rather than flat feet.



During hominin evolution, several major structural features throughout the body have been reorganized (from that seen in other primates), facilitating efficient bipedal locomotion. These are illustrated here, beginning with the head and progressing to the foot: (a) The foramen magnum (shown in blue) is repositioned farther underneath the skull, so that the head is more or less balanced on the spine (and thus requires less robust neck muscles to hold the head upright). (b) The spine has two distinctive curves—a backward (thoracic) one and a forward (lumbar) one—that keep the trunk (and weight) centered above the pelvis. (c) The pelvis is shaped more in the form of a basin to support internal organs; the ossa coxae (specifically, iliac blades) are also shorter and broader, thus



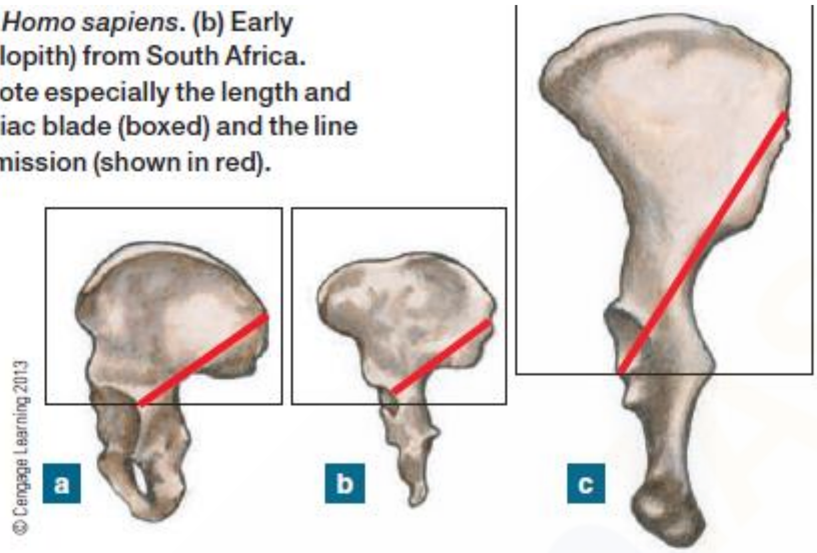
stabilizing weight transmission. (d) Lower limbs are elongated, as shown by the proportional lengths of various body segments (for example, in humans the thigh comprises 20 percent of body height, whereas in gorillas it comprises only 11 percent). (e) The femur is angled inward, keeping the legs more directly under the body; modified knee anatomy also permits full extension of this joint. (f) The big toe is enlarged and brought in line with the other toes; a distinctive longitudinal arch also forms, helping absorb shock and adding propulsive spring.

Knee: Knee joints are enlarged to better support an increased amount of body weight. The degree of knee extension has decreased. Double knee action decreases the energy lost by vertical movement of centre of gravity. Humans walk with knees kept straight and thighs bent inwards so that the knees are almost directly under the body rather than out to the side, as in the case of ancestor hominids.

The Pelvis and Birth Canal: The pelvis of hominins was modified by natural selection to keep the body's centre of gravity over one foot while walking. The bony pelvis consists of two **innominate bones (os coxae)**, each composed of three other bones (the **ischium**, **ilium**, and **pubis**) that fuse during adolescence, and the sacrum, part of the vertebral column. The ischium is the bone you sit on. The ilium is the bone you feel when you put your hands on your hips. And the pubis is the anterior bony portion of the pelvis in the pubic region. The pelvis of a biped is basin-shaped with a short, broad ilium that runs from the posterior to the anterior of the animal. The quadruped ilium is long and flat and situated on the back of the animal. The basin shape supports abdominal organs that tend to be pulled downward by gravity, and it places key locomotor and postural muscles in a better mechanical position. Most important are the anterior **gluteal muscles** (gluteus minimus and medius), which attach to the ilium and are rotated around to the side of the biped.

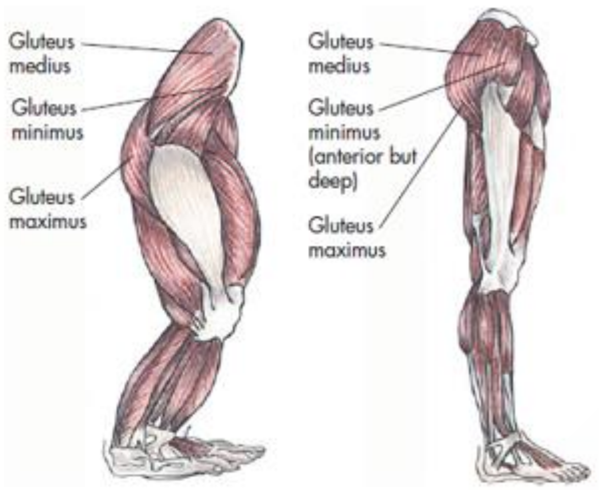
In this position, they connect the ilium to the top of the femur (thigh bone), and when you stand on one limb they contract, pulling the ilium (and the rest of your trunk) toward the support side, so your center of gravity balances over the single foot. The gluteus maximus runs from the back of the ilium to the back of the femur, and when it contracts it keeps your pelvis (and you) from tipping forward in front of your feet. The shortening and broadening of the ilium also moves the hip joint closer to the sacrum. This is good for balance but narrows the birth canal, a problem with which later hominins including ourselves have to contend.

Ossa coxae. (a) *Homo sapiens*. (b) Early hominin (australopith) from South Africa. (c) Great ape. Note especially the length and breadth of the iliac blade (boxed) and the line of weight transmission (shown in red).

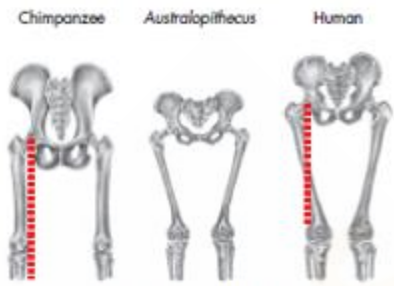


Hip: Hip joints are larger than quadrupedal ancestral species to better support the greater amount of body weight passing through them. Pelvis is shorter in shape. This brought vertebral column closer to the hip joint, providing a stable base for the support of trunk while walking.

The Leg The broad pelvis places the top of the femur far to the side of the biped. However, when you walk your foot must fall directly below your center of gravity. A straight femur, like that of a quadruped, would place the foot far to the side of the center of gravity. Natural selection favoured bipeds with a femur that was angled from the hip into the knee because the angle places the foot below the center of gravity, which saves energy while walking. However, this configuration creates problems at the knee because the musculature attached to the femur must also act at an angle. When the biped flexes its muscles on the front of the femur in an effort to extend the knee, the muscles pull both superiorly (up) and laterally (out). The patella (knee cap) sits in the tendon of this muscle and is likewise displaced outward. To avoid dislocating the patella, the groove on the femur that the patella sits in is deep, and the outside edge or lip is enlarged in a biped. In addition, to help support the excess body weight going through each limb, the bottom of the femur (**femoral condyles**) is enlarged. The top of the tibia or shin bone is similarly enlarged.



The gluteal muscles are repositioned in the biped and aid in support. (After Wolpoff, 1999)



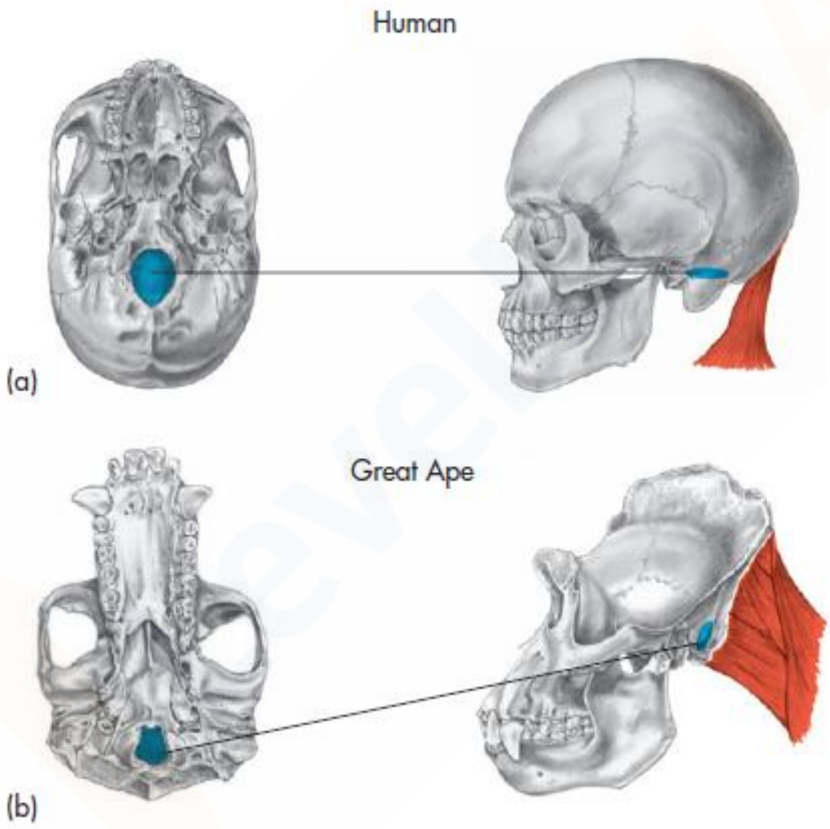
To keep the foot under the center of gravity, the biped's femur is angled from hip to knee. The quadruped femur is not.

The Arm One advantage of walking on two legs is that it frees the arms to do other things. Carrying objects and tool-making are two activities often associated with the hominin lineage (although they are not exclusive associations). Throughout human evolution, the arm and hand skeleton have changed as a result of their release from locomotor activities and their new use, particularly in tool making. Although early hominins have relatively long arms, through hominin evolution the arms shortened relative to trunk length and assumed modern human proportions sometime after the origin of *Homo erectus*. The thumb and phalanges shorten and become less curved.

The Vertebral Column and Skull The spine, or **vertebral column,** is made up of a series of bones in the neck (**cervical vertebrae**), thorax (**thoracic vertebrae**), lower back (**lumbar vertebrae**), and pelvic (**sacrum** and **coccyx**) regions. The quadruped has a gently C-shaped curve that makes the thoracic region of the spine slightly convex. The biped has an S-shaped spine made by adding two secondary and opposing curvatures (in the cervical and lumbar regions) to the C-shaped curvature of the quadruped. If you stand a quadruped up on its back legs, the C-shape of its spine tends to put the center of gravity in front of its feet, causing the animal to fall forward (or dance to avoid falling). The secondary curvatures in the bipedal spine compensate for that C-curve and bring the center of gravity back closer to the hips, ultimately resting over the biped's two feet.

The weight of the biped is borne down the spine to the sacrum, where it passes to the hips, and from there through the two legs. The amount of weight increases as you go down the spine, so the vertebrae of a biped get increasingly large as you approach the lumbar region or lower back. In contrast, weight-bearing doesn't increase along the quadruped's spine, and the vertebral bodies are of nearly equal size in different regions of the spine. These differences can have adverse effects on the biped's body. Lower back problems, especially among pregnant women, are a result of the changes wrought by natural selection on our ancestral skeleton.

The vertebral column attaches to the bottom of the skull of a biped rather than to the back as it does in quadrupeds. So, the junction of the spinal cord and the brain, which occurs through a hole called the **foramen magnum** in the occipital bone, is positioned underneath the skull in bipeds but toward the back of the skull in quadrupeds. Thus, the occipital bone is a clue for paleoanthropologists about the way in which an extinct animal may have stood and walked. Because of this arrangement, the erect position of head is possible without prominent supraorbital ridges and strong muscular attachment as in apes.



(a) The spine meets the skull from below in a biped, so the foramen magnum, in blue, is directly beneath the skull and the neck muscles run down from the skull. (b) In the ape the spine meets the skull from the back so the foramen magnum is positioned posteriorly and the neck muscles also run posteriorly from the skull.

Bipedalism's advantages over quadrupedalism included an increased ability to see greater distances (thanks to an upright posture), greater ease of transporting both food and children, ability to run long distances, and the freeing of the hands for, eventually, such remarkable skills and activities as tool manufacture and tool use.

THEORIES OF ORGANIC EVOLUTION

CONCEPT CHECK

Pre-Darwinian Theory and Ideas: Groundwork for Evolution

Charles Darwin first presented his theory of evolution in his book *On the Origin of Species* (1859). Based on years of personal observation and of study, this unifying biological theory drew on geology, paleontology, taxonomy and systematics, and demography.

SCIENTIST	CONTRIBUTION (AND YEAR OF PUBLICATION)	SIGNIFICANCE
James Hutton	Calculated Earth's age as millions of years (1788)	Provided geologic evidence necessary for calculating time span of evolution
Charles Lyell	Rediscovered and reinforced Hutton's ideas (1830)	Provided more geologic evidence
Robert Hooke	Proved that fossils are organisms' remains (1665)	Revealed that fossils would provide the history of past life
Georges Cuvier	Extensively studied fossils (1796)	Revealed much variation in the fossil record
John Ray	Pioneered taxonomy based on physical appearance (1660)	Created the first scientific classification of plants and animals
Carolus Linnaeus	Wrote *Systems of Nature* (1735)	Presented the binomial nomenclature taxonomy of plants and animals
Thomas Malthus	Founded demography: only some will find enough food to survive (1798)	Provided the concept of characteristics advantageous for survival
Jean-Baptiste de Lamarck	Posited characteristics acquired via inheritance (Lamarckism) (1809)	Provided first serious model of physical traits' passing from parents to offspring
Erasmus Darwin	Also posited characteristics (determined by wants and needs) acquired via inheritance (1794)	Advanced the notion that physical changes occurred in the past

LAMARCKISM (THEORY OF INHERITANCE OF ACQUIRED CHARACTERS):

Lamarck, a French evolutionist, explained organic evolution in the book "Philosophic Zoology". The theory states that modification which the organism acquires in the adaptation to the environment which it meets during its lifetime are automatically handed down to its descendants and so become part of the hereditary. It relied on the **concept of *need and use*.** For example, if an animal that lived by the seashore spent much of its time swimming in the ocean, its offspring, according to Lamarck, would be better swimmers than its parents had been.

In postulating this sort of evolutionary process, Lamarck made one laudable breakthrough and one major error. The breakthrough was seeing the crucial relationship between the organism and its environment. But the fundamental error was thinking that evolutionary change could occur during the lifetime of an individual. This error is easily seen by taking Lamarck's theory to its logical extension: If a mouse loses its tail to a cat, does the mouse later give birth to babies lacking tails? Likewise, no amount of bodybuilding will enable a person to give birth to muscular children.

Lamarckian Theory can be summarised in 4 propositions:

i) Living Organism and their component parts tend to continually increase in size.
ii) Production of new organ results from new need and new need from the new movement.
iii) If an organ is used constantly, it will tend to become highly developed, whereas disuse results in degeneration.
iv) Modifications produced by the above principles during the lifetime of an individual will be inherited by its offspring.

To explain his theory Lamarck used examples like long neck of Giraffe, limblessness in snakes, webbed feet of ducks etc.

Significance:

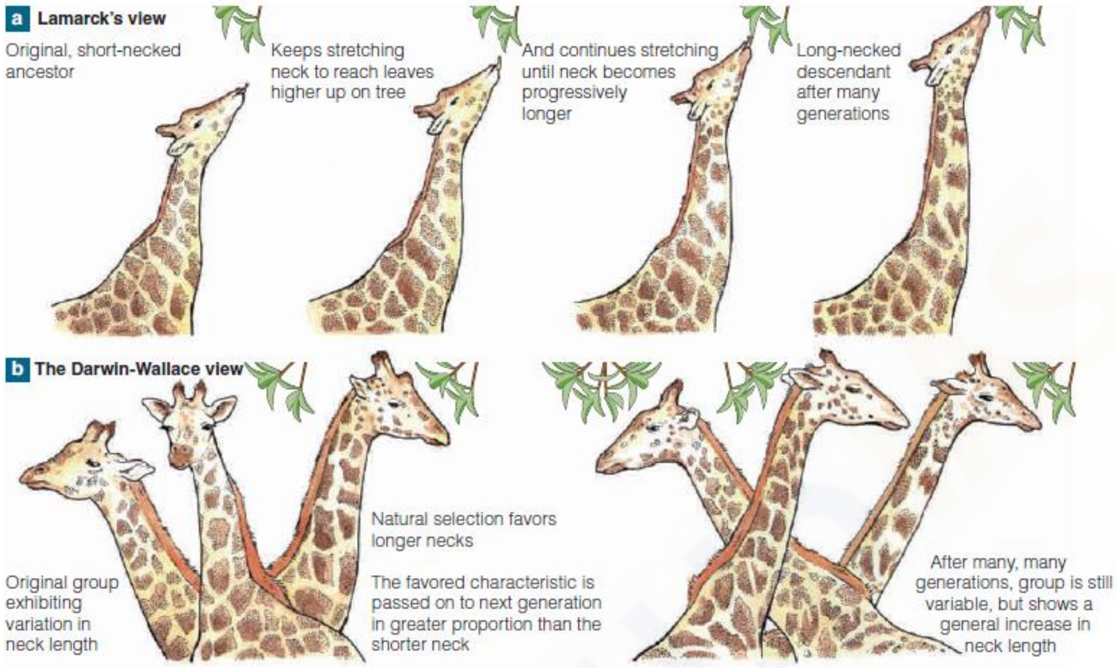
Lamarckian Theory was simple, and it had some appeal as it provided a way in which changes in organisms could come about. It also offered a means of explaining vestigial structures.

Criticism:

i) The first proposition of Lamarck is 'the tendency to increase in size'. But in evolutionary trend a certain group of organism evolved through a reduction in size. For eg: Many ferns and conifers.
ii) The 2nd principle of new organs results from new needs is manifestly false. In case of animals, it meant that desire of animals leads to formation of new structures. In its crudest form this would mean that a man who mused "Birds can fly, why can't I?" should have sprouted wings.
iii) 3rd postulate emphasizes that the organs will develop due to use and degenerate due to disuse. This was met with strong objections. The heart is not increasing in size despite its continuous use.
iv) The fourth and final proposition of Lamarck was that the inheritance of characters acquired during the lifetime of individual. This principle has been tested by many biologists through experiments and has found it incorrect. (**August Weismann** Mice Tail Experiment: He amputated mice Tails's upto 22 generations, but no mice were born without tail in any

generation. Hence, he said there are 2 types of cells- somatic and germinal cells and unless mutation occurs in germinal cells, it cannot be transmitted)

v) Lamarck didn't differentiated between germplasm and somatoplasm.



Contrasting ideas about the mechanism of evolution. (a) Lamarck's theory held that acquired characteristics can be passed to offspring. Short-necked giraffes stretched to reach higher into trees for food; therefore their necks grew longer. According to Lamarck, this acquired trait was then passed on to offspring, who were born with longer necks. (b) The Darwin-Wallace theory of natural selection states that there is variation in neck length among giraffes. If having a longer neck provides an advantage for feeding, the trait will be passed on to a greater number of offspring, leading to an overall increase in the length of giraffe necks over many generations.

DARWINIAN PHASE:

Darwin explained organic evolution in his book 'Origin of Species by Natural Selection' in 1859. The change in species by the survival of an organism type exhibiting a natural variation that gives it an adaptive advantage in an environment, their leading to new environment equilibrium, is evolution by natural selection.

Thus natural selection is a continuous process of trial and error on a gigantic scale, for all of living matter is involved. It includes following elements:

i) **The Universal occurrence of Variation**: Variation is the characteristic of every group of animals and plants and there are many ways in which organism may differ. (Darwin and Wallace didn't understand the cause of variation and assumed it one of the innate cause of living things).

ii) **An excessive natural rate of multiplication**: Every species in the absence of natural check tends to increase in a geometrical manner. Since the number of each species remains fairly constant under natural conditions, it must be assumed that most of the offspring in generation perishes. If all the off spring of any species remained alive and reproduced they would soon crowd all other species on the earth.

iii) **Struggle for existence**: Since more individuals are born than that can possibly obtain food and survive, there is an intra and inter specific or environmental struggle for survival- a competition for food, mates and space.

iv) **Survival of the Fittest:** The consequent elimination of the unfit and the survival of only those that is satisfactorily adapted. The idea is the core of natural selection.

v) **Inheritance of Variation**: Surviving individuals will give to the next generation their characters and in this way, the “successful” variations are transmitted to the succeeding generation. The operation of natural selection over many generations may produce desecndants which are quite different from their ancestors, different enough to be separate species.

Criticisms:

i) The Darwinian theory of natural selection tries to explain the disappearance of non-optimal genetic modifications by lack of adaptation of individuals to the environment, but it doesn’t say anything about origin of modifications.

ii) Increase in geometric progression as inferred by Darwin is not applicable to man. Many countries of the world today have stabilised numbers or even have negative growth rate.

iii) Darwin insisted that natural selection was good enough to explain the whole process of evolution. In other words, he ignored the contribution of mutation, genetic drift, inbreeding and hybridization. At least the contribution of mutations (called ‘’sports” or “chance” in his times was then known but Darwin insisted on small fluctuating variations as the cause of evolution.

iv) To explain the transmission of variations from one generation to the next, Darwin put forth the theory of pangenesis which has been rejected by modern researchers.

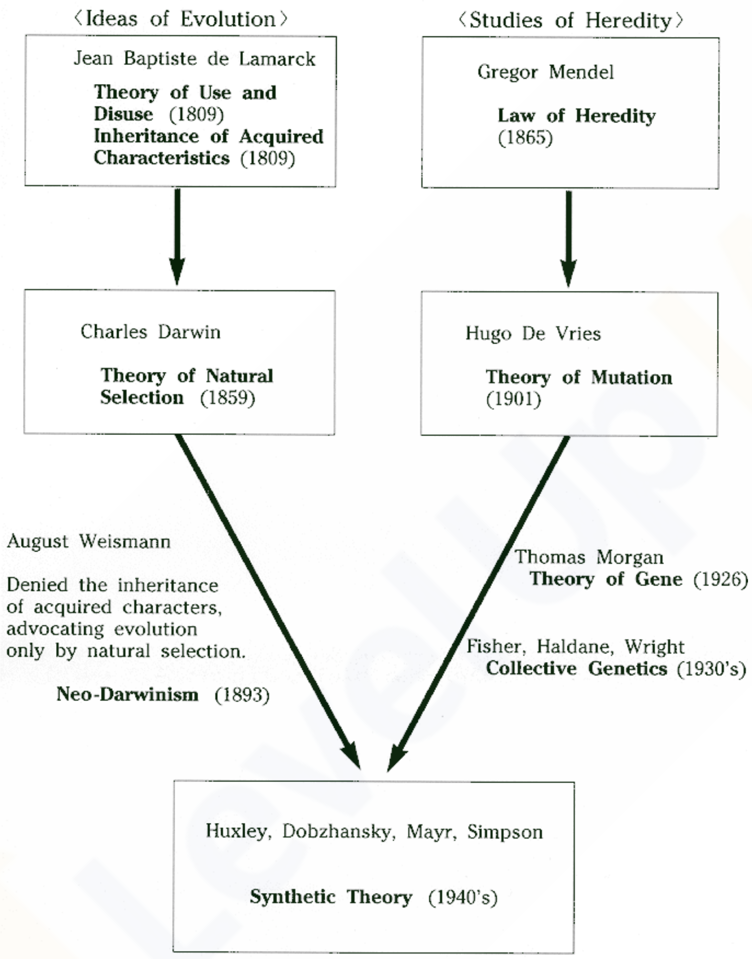
v) Survival of the fittest interpreted by the people as “tooth and claw” or “kill or be Killed” kind of struggle.

Acknowledging the pitfalls in theory of natural selection followers of Darwin (called neo-Darwinians) have modified the theory to the one that has given due importance to other micro evolutionary process. However, natural selection still forms the core of this modified theory.

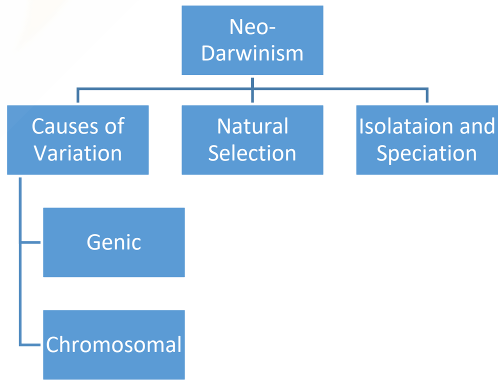
NEO-DARWINISM:

One of the main weaknesses of Darwin was his inability to explain causes of variation. Present Day biologists now know a host of causes. In addition, Darwin considered Natural selection as a force that only favours positive variations and eliminates unfavourable variations. Modern Biologists find many shades of natural selection. All biologists who explain evolution in terms of natural selection are called neo-Darwinians and their theory as Neo-Darwinism.

Neo-Darwinism, also called the modern evolutionary synthesis, generally denotes the integration of Charles Darwin's theory of evolution by natural selection, Gregor Mendel's theory of genetics as the basis for biological inheritance, and mathematical population genetics. Other terminology used synonymously with Neo-Darwinism are modern synthesis, evolutionary synthesis, and neo-Darwinian synthesis.



Essentially, neo-Darwinism introduced the connection between two important discoveries: the units of evolution (genes) with the mechanism of evolution (natural selection). Neo-Darwinism thus fused two very different and formerly divided research traditions, the Darwinian naturalists and the experimental geneticists. Major figures in the development of



the modern synthesis include Thomas Hunt Morgan, Ronald Fisher, T Dobzhansky, J. B. S. Haldane, Sewall Wright, William D. Hamilton, Cyril Darlington, Sergei Chetverikov, E. B. Ford, Julian Huxley, Ernst Mayer, George Gaylord Simpson, and G. Ledyard Stebbins.

At the heart of the modern synthesis is the view that evolution is gradual and can be explained by small genetic changes in populations over time, due to the impact of natural selection on the phenotypic variation among individuals in the populations. According to the modern synthesis as originally established, genetic variation in populations arises by chance through mutation. This genetic variation leads to phenotypic changes among members of a population. Evolution consists primarily of changes in the frequencies of alleles between one generation and another as a result of natural selection. Speciation, the creation of new species, is a gradual process that generally occurs when populations become more and more diversified as a result of having been isolated, such as via geographic barriers, and eventually the populations develop mechanisms of reproductive isolation. Over time, these small changes will lead to major changes in design or the creation of new taxa.

Causes of Variation:
1) Mutation
2) Migration/Gene Flow
3) Genetic Drift
4) Recombination
5) Inbreeding
All the factors have been explained in Hardy Weinberg law.

Natural Selection (explained in **Hardy Weinberg Law**)
Isolation and Speciation:
The emergence of a new species is an important event in evolution. Typically, it's a slow process where two populations gradually become more and more different from each other until they can no longer interbreed. For populations to diverge like this, they have to be genetically isolated -- in other words, they have to mate with each other seldom or never. Without genetic isolation, mating will bring about the exchange of genes between the populations and minimize differences between them so they do not diverge.
Isolation operates through several Pre-zygotic and Post-zygotic Mechanisms.

PRE-ZYGOTIC MECHANISM:
It happens before fertilization occurs between gametes. Basically, pre-zygotic isolation keeps different species from sexually reproducing. If individuals cannot reproduce, they are considered to be different species and diverge on the tree of life.

Mechanical Isolation:

Mechanical isolation is probably the simplest concept that keeps individuals from being able to reproduce offspring with each other. Simply put, mechanical isolation is the incompatibility of sexual organs. They just do not fit together. It may be the shape of the reproductive organs not being compatible, or size differences that prohibit the individuals from coming together.

Temporal Isolation:
Different species tend to have different breeding seasons. The timing of when females are fertile leads to temporal isolation. Similar species may be physically compatible, but may still not reproduce due to mating seasons being different times of the year. If the females of one species are fertile during a given month, but the males are not able to reproduce at that time of the year, then there will be reproductive isolation between the two species.

Behavioural Isolation:
Another type of pre-zygotic isolation between species has to do with the behaviours of the individuals, and, in particular, the behaviours around mating time. Even if two populations of different species are both mechanically compatible and temporally compatible, their actual mating ritual behaviour could be enough to keep the species in reproductive isolation from each other.
Mating rituals, along with other necessary mating behaviours like mating calls, are very necessary for males and females of the same species to indicate it is time to sexually reproduce. If the mating ritual is rejected or not recognized, then not mating will occur and the species are reproductively isolated from each other.

Habitat Isolation:
Even very closely related species have a preference of where they live and where they reproduce. Sometimes, the preferred locations of the reproductive events are not compatible, and this leads to what is known as habitat isolation. Obviously, if individuals of two different species live nowhere near each other, there will be no opportunity to reproduce, and reproductive isolation will lead to even more speciation.

Gametic Isolation:
During sexual reproduction, the female egg is fused with the male sperm and, together, they create a zygote. If the sperm and egg are not compatible, this fertilization cannot occur, and the zygote will not form. The sperm may not even be attracted to the egg due to the chemical signals released by the egg. Other times, the sperm just cannot penetrate the egg because of its own chemical make-up. Either one of these reasons is sufficient enough to keep fusion from happening and the zygote will not form.

This type of reproductive isolation is especially important for species that reproduce externally in the water. For instance, most species of fish have females that will just release her eggs into the water. Male fish of that species will come along and release their sperm all over the eggs. However, since this happens in the water, some of the sperm will get carried away by the water molecules and moved around the area. If there were not gametic isolation mechanisms in place, any sperm would be able to fuse with any egg and there would be hybrids of just about everything floating around.

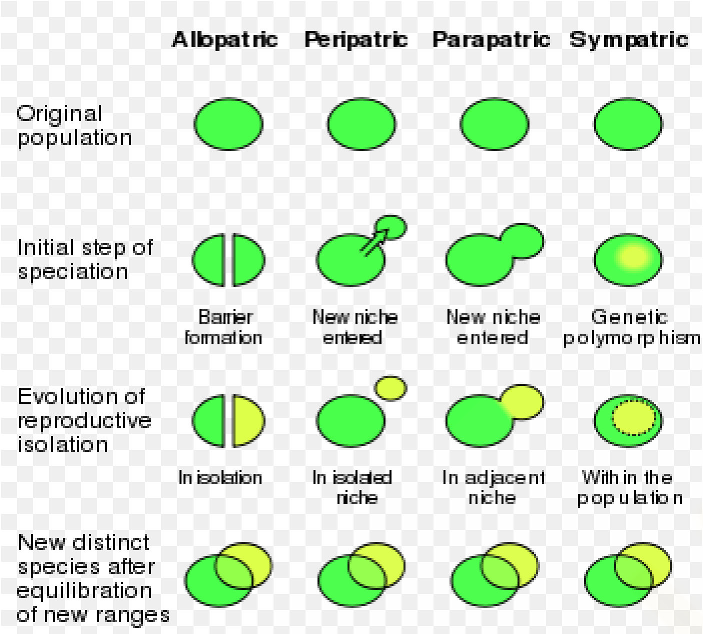
Post-Zygotic Isolation:
Before the postzygotic isolation can happen, there must be an offspring born from a male and female of two different species. This means there were no prezygotic isolations. However, offspring of two different species (known as a "hybrid") are not always viable. Sometimes they will self-abort before being born. Other times, they will be sickly or weak as they develop. Even if they make it to adulthood, a hybrid will most likely be unable to produce its offspring.

POST-ZYGOTIC ISOLATION MECHANISMS:
The Zygote Is Not Viable (Zygote Mortality)
Even if the sperm and the egg from the two separate species can fuse during fertilization, that does not mean the zygote will survive. The incompatibilities of the gametes may be a product of the number of chromosomes each species has or how those gametes are formed during meiosis. A hybrid of two species that do not have compatible chromosomes in either shape, size, or number will often self-abort or not make it to full term.

Hybrid Mortality
If the hybrid can survive through the zygote and early life stages, it will become an adult. However, it does not mean that it will thrive once it reaches adulthood. Hybrids are often not suited for their environment the way a pure species would be. They may have trouble competing for resources such as food and shelter. Without the necessities of sustaining life, the adult would not be viable in its environment.

Hybrid Sterility:
Most animal hybrids are sterile at adulthood. Many of these hybrids have chromosome incompatibilities that make them sterile. So even though they survived development and are strong enough to make it to adulthood, they are not able to reproduce and pass down their genes to the next generation.

Speciation is the changing of individuals within a population, so they are no longer part of the same species. This most often occurs due to geographic isolation or reproductive isolation of individuals within the population. As the species evolve and branch off, they cannot interbreed with members of the original species any longer. There are four types of speciation that can occur based on reproductive or geographic isolation, among other reasons and environmental factors.



Allopatric Speciation:

The prefix allo- means "other". When paired with the suffix -patric, meaning "place", it becomes clear that allopatric is a type of speciation caused by geographic isolation. The individuals that are isolated are literally in an "other place". The most common mechanism for geographic isolation is an actual physical barrier that gets between members of a population.

Peripatric Speciation:

Peripatric speciation is actually a special type of allopatric speciation. There is still some sort of geographic isolation, but there is also some sort of instance that causes very few individuals to survive in the isolated population compared to allopatric speciation.

Parapatric Speciation:

The suffix -patric still means "place" and when the prefix para-, or "beside", is attached, it implies that this time the populations are not isolated by a physical barrier and are instead "beside" each other. Due to disruptive selection a new species is formed.

Sympatric Speciation:

Putting the prefix sym-, meaning "same" with the suffix -patric which means "place" gives the idea behind this type of speciation. In it some type of biological differences appears that divide members into 2 different reproductive groups.

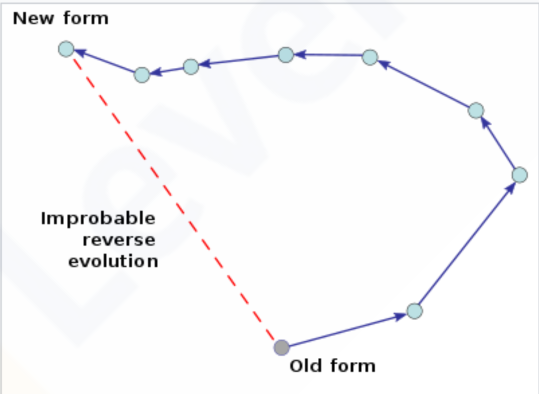
BRIEF OUTLINE OF TERMS AND CONCEPTS OF EVOLUTIONARY BIOLOGY

DOLLO’S RULE

Dollo's law of irreversibility (also known as **Dollo's law** and **Dollo's principle**), proposed in 1893 by French-born Belgian palaeontologist Louis Dollo states that, "an organism never returns exactly to a former state, even if it finds itself placed in conditions of existence identical to those in which it has previously lived ... it always keeps some trace of the intermediate stages through which it has passed.

According to Richard Dawkins, the law is "really just a statement about the statistical improbability of following exactly the same evolutionary trajectory twice (or, indeed, any particular trajectory), in either direction". If an allele has been mutated, a reversal of evolution would require precisely the correct reverse mutation just as the environmental condition reverse in proper order which is impossible. Hence evolution is irreversible.

Dollo’s law has since been refuted by evidence that evolutionary specialization can be undone. For instance, reversible evolution has been observed on a relatively short evolutionary timescale in the peppered moth (Biston betularia). In the 19th century a dark morph of the moth emerged in response to air pollution during the Industrial Revolution and became the dominant colour morph, almost completely replacing the light-coloured form. By the late 20th century, however, the light morph was on the rise again, its increase coincident with the decline of air pollution in England.



Once an organism has evolved in a certain way, it will not return exactly to a previous form. This is illustrated here in two dimensions; in reality, both biomolecules and organisms evolve in many different dimensions.

MOSAIC EVOLUTION

According to this principle, the evolution of the species tends to be inconsistent and asymmetrical. That is, it may be rapid at one time and slow at another. In rare cases it may virtually stop altogether.

As evolution is a gradual process, it can’t be expected that all aspects of evolution will be completed at a stretch i.e. evolutionary change may take place in certain body parts or system without simultaneous changes in other body parts or system.

An example can be seen in the patterns of development of the different elephant species. The Indian elephant underwent rapid early molar modification with little foreshortening of the forehead. The African elephant underwent parallel changes but at different rates: the foreshortening of the forehead took place in an early stage of development, molar modification occurring later.

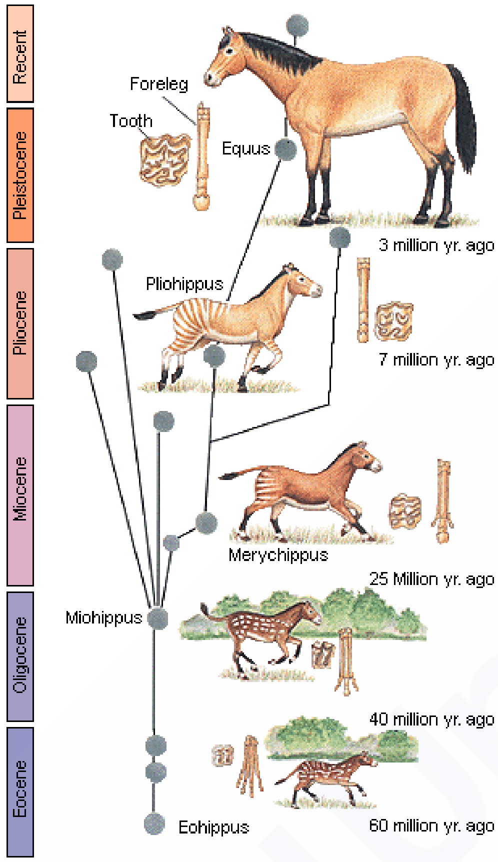
Similarly, in man there was early evolution of structures for bipedal locomotion, but during the same time there was little change in skull form or brain size; later, both skull and brain evolved rapidly into the state of development associated with modern human species.

The phenomenon of mosaic evolution would seem to indicate that the process of natural selection acts differently upon the various structures and functions of evolving species. Thus, in the case of human development, the evolutionary pressures for upright posture took precedence over the need for a complex brain. Furthermore, the elaboration of the brain was probably linked to the freeing of the forelimbs made possible by bipedal locomotion.

COPE'S RULE

Cope's Rule is the observation that animal groups tend to evolve through time towards larger body size. Edward Drinker Cope (1840-1897) never formally stated this rule, but it is implicit in many of his writings. Cope is famous for his work on dinosaurs and fossil mammals. Cope was an evolutionist, and he wrote textbooks that promoted Darwinism. In these, he reconstructed phylogenies of reptiles and mammals, and in doing so, he noted how mean body size increased through time; classic examples include the evolution of the horses from terrier sized Hyracotherium from the Eocene to the modern, which is twenty times the size.

To some extent this principle is similar to Lamarck's proposition that every organisms has a tendency to increase in size.



There has been debate about whether Cope's rule should be termed a law, but that is not possible because of exceptions to his observation, and also because, if it were termed Cope's law, there would be an implication of an innate force that drove animals to become bigger. Exceptions to Cope's observation include many cases of evolution to small size, like rise of herbs and shrubs is a recent thing and they have been derived from trees and other large plants. Example ferns and conifers. A rule is, according to Webster, 'a generally prevailing condition,' which is the true status of Cope's observation.

Why should body size generally increase within animal lineages? Most discussions have focussed on the advantages of being big:
-improved ability to capture prey (lions) or to escape predation (sauropod dinosaurs, elephants);
- greater reproductive success (sexual selection);
- increased intelligence (brain size relates to body size);
- expanded size range of acceptable food (giraffes, elephants);
- decreased annual mortality (as a result of the above);
- extended individual longevity (life span relates broadly to body size);
- Increased heat retention per unit volume (Bergmann's rule: body size of endotherms increases polewards).

But the story is not so simple**: there are disadvantages with large size**, particularly the fact that large animals require a great deal of food, and hence can have problems when food is sparse. Elephants have to migrate huge distances merely to find enough fodder. In addition, large animals are rare, so, during crises, size is clearly exposed as a specialization, like an unusual dietary requirement, and a lineage of large animals is, on the whole, more exposed to extinction, than a related lineage of smaller animals.

So, Cope 's rule is true, and there are indeed genuine advantages to large body size. But there is no driving principle here. We tend to notice large animals and forget that all we are seeing is an increase in variance through time, while mean body size of most clades remains constant.

GAUSE'S RULE/ COMPETITIVE EXCLUSION PRINCIPLE

Evolution is all about a struggle for survival and reproduction. For predators it becomes an arms race. For hundreds of millions of years predatory animals have honed their offensive weapons while prey animals have evolved ever more effective defensive adaptations. Each animal, predator, or prey carved out their particular niche and occupied that niche until they were driven out, to another niche, or went extinct, or still occupy it today.

In the normal course of the evolution if two organisms occupy same trophic level in the ecosystem, these organisms try to reach equilibrium through different strategies. For example, two organisms may adaptively radiate to occupy different niches in the same trophic level, thus minimising extent of competition.

However, in some cases, it so happens that the very presence of a competitor results in domination of other organism which tries to adapt effectively, ultimately resulting in the exclusion of competitor. Such adaptive strategies adopted by the organism to reduce the other to the point of exclusion, called competitive exclusion, is not seen in these organisms in absence of a competitor.

The famous Russian biologist Gause had conducted experiments in this context on different species of paramecium (Paramecium aurelia and Paramecium caudate) and explained how effectively each organism causes or stimulates a selection pressure on the other.

The term **niche differentiation** (synonymous with niche segregation, niche separation and niche partitioning), as it applies to the field of ecology, refers to the process by which competing species use the environment differently in a way that helps them to coexist. The competitive exclusion principle states that if two species with identical niches (i.e., ecological roles) compete, then one will inevitably drive the other to extinction. When two species differentiate their niches, they tend to compete less strongly, and are thus more likely to coexist. Species can differentiate their niches in many ways, such as by consuming different foods, or using different parts of the environment.

As an example of niche partitioning, several anole lizards in the Caribbean islands share common food needs—mainly insects. They avoid competition by occupying different physical

locations. For example, some live on the leaf litter floor while others live on branches. Species who live in different areas compete less for food and other resources, which minimizes competition between species. However, species who live in similar areas compete strongly.
For millions of years nature kept every species in check. Population explosions of any species was soon met by either a corresponding explosion of predatory animals, or in cases where there were not enough predator animals, like rat or mice plagues, starvation would ultimately reduce their numbers to what the territory would support.

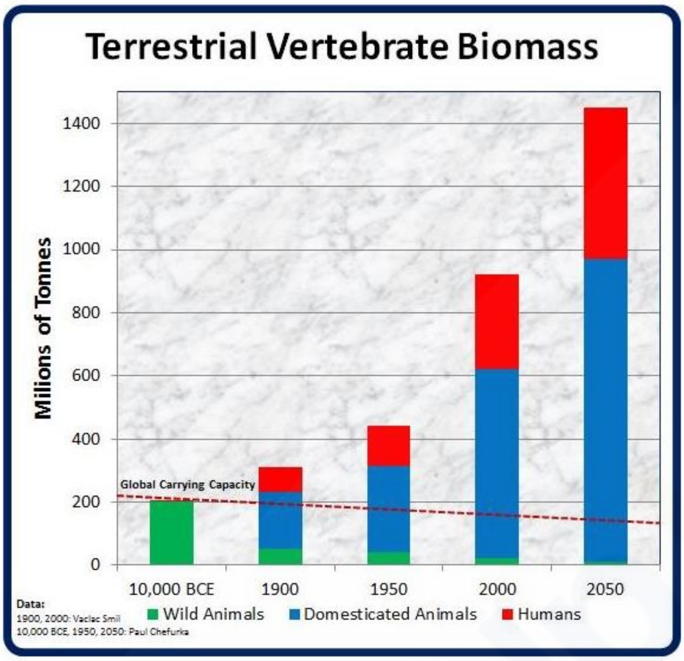
Sometimes of course there would be conflicts between different species of either predatory animals of prey animals. They can of course develop a symbiotic relationship like zebras and wildebeests, zebras eat the tall tough grass and wildebeests eat the shorter tender grass. But if this doesn't happen, one species must adapt to another niche or go extinct.
This is not a fast process, sometimes taking many thousands of years to play out, depending on the size of the territory and the lifespan of the animals involved. And over many millions of years the balance was always maintained. Every species lived in and defended its niche and life went on. Only a universal disaster, like massive volcanism poisoning the air and seas could really disrupt this balance.

Every animal had adaptations that allowed it to survive in the wild. But no animal had a "super adaptation", that is no animal evolved an adaptation that gave it ultimate control over other animals. There was no colossus in the animal world. No matter what the adaption, no animal could be that strong.

But the first hint of such an adaptation evolved about 5 million years ago. Somewhere in Africa a species of great ape evolved that had all the other survival adaptations of other great apes plus one more, that ape was just a wee bit smarter than other apes. And among these smarter apes, some were smarter than others. These smarter apes had a slightly higher survival and reproductive rate than the ones in their own group who were not so smart. But even these "smarter" apes were not really all that smart.

Brain size, which is correlated with intelligence, increased very slowly over two and one half million years. But the ultimate competitive weapon, the weapon that would give this one great ape a huge survival weapon over all other species had begun to evolve. From this point on the fate of the earth, the fate of all other species, was set. And about 100,000 years ago modern humans appeared.

The competitive exclusion principle usually describes the competition of animals for a particular niche. But humans are animals also. We have been in the competition for territory and resources for thousands of years. And we have been winning that battle for thousands of years. But it is only in the last few hundred years that our complete dominance in this battle has become overwhelming. We are winning big time, we are quite literally wiping them off the face of the globe.



One very important thing that can be derived from the above graph is that we are wiping out all the wild species. 10,000 years ago, humans were about .1 percent of all the land vertebrate biomass of the planet. In 2000 we and our domesticated animals were about 97 percent of the land vertebrate biomass. Today it is closer to 97.5 percent. And we continue to wipe them out. The Earth has lost half its wildlife in the last 40 years.

ADAPTIVE RADIATION

In evolutionary biology, adaptive radiation is a process in which organisms diversify rapidly from an ancestral species into a multitude of new forms, particularly when a change in the environment makes new resources available, creates new challenges, or opens new environmental niches. Starting with a recent single ancestor, this process results in the speciation and phenotypic adaptation of an array of species exhibiting different morphological and physiological traits. The prototypical example of adaptive radiation is finch on the Galapagos ("Darwin's finches"), but examples are known from around the world.

Adaptive radiations are best exemplified in closely related groups that have evolved in a relatively short time. A striking example is the radiation, beginning in the Paleogene Period (beginning 65.5 million years ago), of basal mammalian stock into forms adapted to running, leaping, climbing, swimming, and flying.

Conditions

Adaptive radiation tends to take place under the following conditions.

- A new habitat has opened up: a volcano, for example, can create new ground in the middle of the ocean. This is the case in places like Hawaii and the Galapagos. For aquatic species, the formation of a large new lake habitat could serve the same purpose; the tectonic movement that formed the East African Rift, ultimately leading to the creation of the Rift Valley Lakes, is an example of this. An extinction event could effectively achieve this same result, opening up niches that were previously occupied by species that no longer exist.

- This new habitat is relatively isolated. When a volcano erupts on the mainland and destroys an adjacent forest, it is likely that the terrestrial plant and animal species that used to live in the destroyed region will recolonize without evolving greatly. However, if a newly formed habitat is isolated, the species that colonize it will likely be somewhat random and uncommon arrivals.
- The new habitat needs a wide availability of niche space. The rare colonist can only adaptively radiate into as many forms as there are niches.

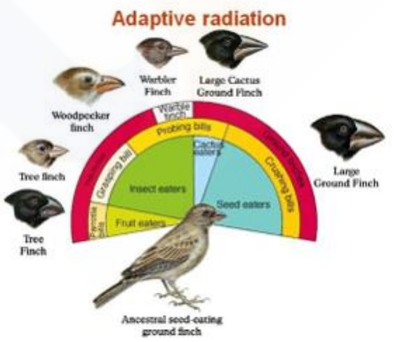
Characteristics

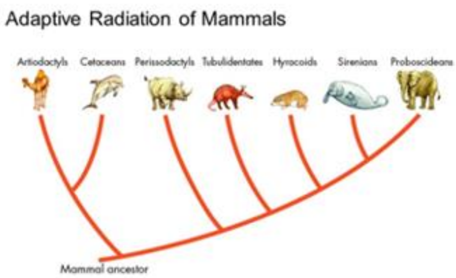
Four features can be used to identify an adaptive radiation.

- **A common ancestry of component species:** specifically, a recent ancestry. Note that this is not the same as a monophyly in which all descendants of a common ancestor are included.
- **A phenotype-environment correlation**: a significant association between environments and the morphological and physiological traits used to exploit those environments.
- **Trait utility**: the performance or fitness advantages of trait values in their corresponding environments.
- **Rapid speciation**: presence of one or more bursts in the emergence of new species around the time that ecological and phenotypic divergence is underway.

Example

The most famous example where adaptive radiation is seen is with Darwin's finches. Darwin's finches occupy fragmented landscape of Galpagos islands and have different size and shape of beaks. This occurred largely to promote specialization upon each island. Adaptive radiation led to evolution of different beaks which could access different food and resources. Those with short beaks are better adapted to eating seeds on the ground, those with thin, sharp beaks eat insects, and those with long beaks use their beaks to probe gfor food inside cacti.





CONVERGENCE:

In evolutionary biology, convergent evolution is the process whereby organisms not closely related (not monophyletic), independently evolve similar traits as a result of having to adapt to similar environments or ecological niches. Convergence ordinarily applies to one or a few characteristics rather than to overall makeup.

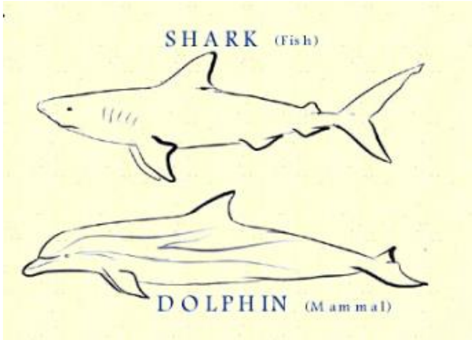
Foe eg :- Humming birds and Humming Moths have converged in their flying habits as a result of their common search for nectar in flowers as a source of food.
It is impossible that any instance of evolutionary convergence has been as dramatic and complete as to hide all traces of diversity of origins.

Wings and wing-like structures have evolved independently several times, in insects, reptiles (pterosaurs and birds) and in mammals (bats). Flight first evolved in insects about 330 million years ago (mya), second in pterosaurs (about 225 mya), later in birds (about 150 mya), and still later in bats (50-60 mya). Some frogs, lizards, and mammals have also evolved the ability to glide, presumably a precursor to flight. In order to land safely, such hang gliders must time their stall precisely at the right moment and place.

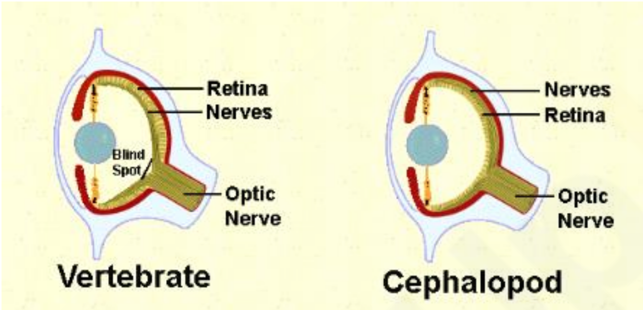
Arid regions of South Africa support a wide variety of euphorbeaceous plants, some of which are strikingly close to American cacti phenotypically. They are leafless stem succulents, protected by sharp spines, presumably adaptations to reduce water loss and predation in arid environments. Similarly, evergreen sclerophyll woody shrubs have evolved convergently under Mediterranean climates in several different regions (Mooney and Dunn 1970).

New World Cactus African Euphorb

Still another example of convergent evolution is seen in the similar shape and coloration of fish and cetaceans, both of which have adapted to the marine environment by developing a fusiform body and neutral buoyancy (an extinct group of marine reptiles known as ichthyosaurs evolved the same body plan). Sharks and dolphins are also countershaded, with a light underbelly and a darker upper surface, which makes them less visible from both below and above. However, countershading is actually the rule among both arthropods and vertebrates, so it is presumably an ancestral state that has been retained throughout the evolution of both groups.



A very striking example of evolutionary convergence involves the eyes of vertebrates and cephalopod molluscs. Both have independently evolved complex camera-like eyes complete with an aperture, lens, and retina.



PARALLELISM:

An evolutionary development similar to convergence but in related forms is known as parallelism. Parallelism implies a similar in origin and that remained similar as they evolved. It implies Similarity in biological makeup of the ancestral forms, whereas convergence doesn't.

If the organism belongs to same order and the common ancestor were not very ancient and if evolution in the descendant lines followed more or less same course, the term parallelism is used. The term is usually applied to two species of organisms that were similar in origin and that remained similar as they evolved like having some of the same changes occurring in both of them.

Old world and new world monkeys provide an excellent example of parallelism.

Absence of tail in man, great apes and gibbon. They had same ancestor and tail must have lost its course of evolution in separate line but in parallel fashion.