12. Lateral amniotic folds, anterior omphalomesentric vein and vitelline artery have appeared.

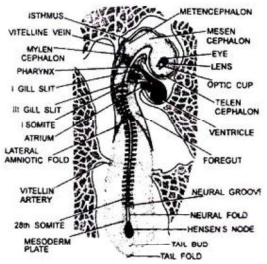


Fig. 17.9. W.M. of 48 hr (27 pairs somites) chick embryo.

72 Hours or 36 Pairs of Somites Stage of Chick Embryo:

1. It is W.M. of 72 hours chick embryo.

2. At this stage area opaca and area pellucida are not visible.

3. The extra embryonic area has grown in size.

4. Primitive streak has disappeared.

5. The mesoderm, in front of Hensen's node, has given rise to 36 pairs of somites.

6. The brain has differentiated into telencephalon, mesencephalon, metancephalon and mylencephalon.

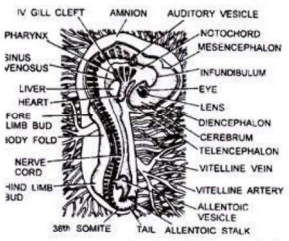


Fig. 17.10. W.M. of 72 hr (36 pairs somites) chick embryo

7. The heart has been differentiated into ventricle and atrium.

8. The eye has differentiated into optic cup and lens and optic vesicle has also developed sufficiently.

9. The head region has bent on right side due to cranial flexion.

10. Four pairs of gill-slits have been differentiated.

11. Tail bud is greatly developed and has given rise to allentoic stalk and tail.

12. Lateral amniotic folds, vitelline artery and anterior omphalomesentric vein have developed.

13. In the middle region a pair of fore limb buds and in front of tail a pair of hind limb buds have developed, which will give rise to fore and hind limbs.

14. Olfactory pit, visceral arches, amnion, allantois and amniotic cavity have also developed.

96 Hours Chick Embryo:

1. In the chick embryo of 96-hours of incubation, the entire body has been turned through 90 degree and the embryo lies with its left side on the yolk.

2. At the end of 96 hours the body folds have undercut the embryo so that it remains attached to the yolk only by a slender stalk.

3. The yolk salk soon become enclogated, allowing the embryo to become first straight in the mid-dorsal region and then convex dorsally.

4. The progressive increase in the cranial, cervical, dorsal and caudal flexures results in the bending of the embryo on itself so that its originally straight long axis becomes C-shaped and its head and tail lie close together.

5. Optic cup shows the more developed lens.

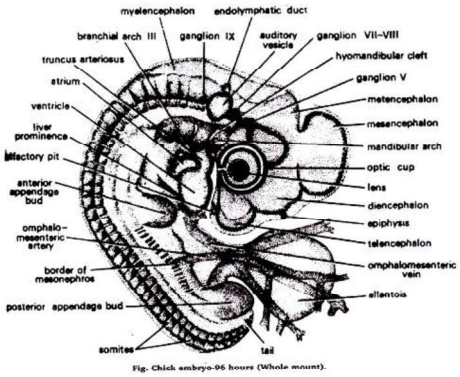


Fig. Chick embryo-96 hours (Whole mount).

6. Endo-lymphatic duct arises from the auditory vesicle.

7. Visceral arches have become very much thickened.

8. Appendage buds increase rapidly in size and become elongated.

9. The number of somites increases to 41 pairs.

10. Allantois has also appeared.

11. Omphalomesenteric artery and omphalomesenteric vein are also developed.

METAMORPHOSIS

Amphibian Metamorphosis

▶Morphological changes associated with metamorphosis

In urodeles (salamanders), these changes include the resorption of the tail fin, the destruction of the external gills, and a change in skin structure. In anurans (frogs and toads), the metamorphic changes are more dramatic, and almost every organ is subject to modification. Regressive changes include the loss of the tadpole's horny teeth and internal gills, as well as the destruction of the tail. At the same time, constructive processes such as limb development and dermoid gland morphogenesis also evident. The means of locomotion changes as the paddle tail recedes while the hindlimbs and forelimbs develop. Tadpole's cartilaginous skull is replaced by the predominantly bony skull of the frog. The horny teeth used for tearing pond plants disappear as the mouth and jaw take a new shape, and the tongue muscle develops. Meanwhile, the large intestine characteristic of herbivores shortens to suit the more carnivorous diet of the adult frog. The gills regress, and the gill arches degenerate. Lungs enlarge, and muscles and cartilage develop for pumping air in and out of the lungs.

The lateral eyes of the tadpole are typical of preyed-upon herbivores, whereas the frontally located eyes of the frog befit its more predatory lifestyle. To catch its prey, the frog needs to see in three dimensions.

System	Larva	Adult
Locomotory	Aquatic; tail fins	Terrestrial; tailless tetrapod
Respiratory	Gills, skin, lungs; larval hemoglobins	Skin, lungs; adult hemoglobins
Circulatory	Aortic arches; aorta; anterior, posterior, and common jugular veins	Carotid arch; systemic arch; cardinal veins
Nutritional	Herbivorous : long spiral gut; intestinal symbionts; small mouth, horny jaws, labial teeth	Carnivorous: Short gut; proteases; large mouth with long tongue
Nervous	Lack of nictitating membrane; porphyrospsin, lateral line system, Mauthner's neurons	Development of ocular muscles, nictitating membrane, rhodopsin; loss of lateral line system, degeneration of Mauthner's neurons; tympanic membrane
Excretory	Largely ammonia, some urea (ammonotelic)	Largely urea; high activity of enzymes of ornithine – urea cycle (ureotelic)
Integumental	Thin, bilayered epidermis with thin dermis; no mucous glands or granular glands	Stratified squamous epidermis with adult keratins; well-developed dermis contains secreting antimicrobial peptides

▶Biochemical changes associated with metamorphosis

In tadpoles as (in freshwater fishes), the major retinal photopigment is porphyropsin. During metamorphosis, the pigment changes to rhodopsin, the characteristic photopigment of terrestrial and marine vertebrates. Tadpole hemoglobin is changed into an adult hemoglobin that binds oxygen more slowing and releases more rapidly than does tadpole hemoglobin. Tadpoles, like most freshwater fishes, are ammonotelic, that is, they excrete ammonia.

Many adult frogs (such as the genus Rana, but not the more aquatic Xenopus) are ureotelic, excreting urea, like most terrestrial vertebrates, which requires less water than excreting ammonia.

▶Hormonal control of amphibian metamorphosis

The metamorphic changes of frog development are all brought about the secretion of the hormones thyroxine (T_4) and triiodothyronine (T_3) from the thyroid during metamorphosis. It is though that T_3 is the more important hormone, as it will cause metamorphic changes in thyroidectomized tadpoles in much lower concentrations than will T_4.

The degeneration of tail structures is relatively rapid, as the bony skeleton does not extent to the tail, which is supported only by the notochord. The regression of the tail is brought about by apoptosis, and it occurs in four stages.

First, protein synthesis decreases in the striated muscle cells of the tail. Next, there is an increase in concentrations of digestive enzymes within the cells. Concentrations of lysosomal proteases, RNase, DNase, Collagenase, phosphatase, and glycosidases all rise in the epidermis, notochord, and nerve cord cells. Cell death is probably caused by the release of these enzymes into the cytoplasm. After cell death occurs, macrophages collect in the tail region, digesting the debris with their own proteolytic enzymes

The result is that the tail becomes a large sac of proteolytic enzymes involved appear to be collagenases and other metalloproteinases whose synthesis depends on thyroid hormones. If a metalloproteinase inhibitor (TIMP) is added to the tail, it prevents tail regression.

The timing of metamorphosis appears to be regulated by the sensitivity of different tissues to thyroid hormones.

To ensure that this timing system works, two of the organs most sensitive to thyroxine are the thyroid itself and the pituitary gland, which regulates thyroid hormone production.

▶ Parental care of tadpoles:

(A) Tadpoles of the reticulate poison dart frog *Dendrobates* are carried on their parent's back to small pools of water in the Peruvian rain forest canopy.

(B) The female *Rheobatrachus* of Australia brooded over a dozen tadpoles in its stomach. They emerged after completing metamorphosis.

⇨⇨⇨⇨The pluteus larva of the sea, can travel on ocean currents, whereas the adult urchin leads a sedentary existence. The caterpillar larvae of butterflies and moths are specialized for feeding, whereas their adult forms are specialized for flight and reproduction, often lacking the mounthparts necessary for eating.

Metamorphosis in insects

Types of insect metamorphosis

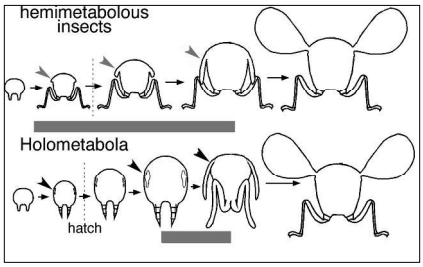
Whereas amphibian metamorphosis is characterized by the remodeling of existing tissues, insect metamorphosis often involves the destruction of larval tissues and their replacement by an entirely different population of cells.

⇨There are three major patterns of insect development.

1. A few insects, such as springtails and mayflies, have no larval stage and undergo direct development. These are called the **ametabolous insects.** These insects have a pronymph stage immediately after hatching, bearing the

structures that have enabled it to get out of the egg. But after this transitory stage, the insect begins to look like a small adult; after each molt, they are bigger, but unchanged in form.

2. Other insects, notably grasshoppers and bugs, undergo a gradual, hemimetabolous metamorphosis. After spending a very brief period of time as a pronymph (whose cuticle is often shed as the insect hatches), the insect looks like an immature adult. This immature stage is called a nymph. The rudiments f the wings, genital organs, and other adult structures are present, and these each molt.



3. In the holometabolous insects, there is no pronymph stage. The juvenile form that hatches from the egg is called a larva. The larva (caterpillar, grub, maggot) undergoes a series of molts as it becomes larger. The stages between these larval molts as it become larger. The stages between these molts are called instars. The number of molts before becoming an adult is characteristic for the species, although environmental factors can increase of decrease the number.

After the last instar stage, the larva undergoes a metamorphic molt to become a pupa. The pupa does not feed, and its energy must come from those foods it ingested while a larva. During pupation, the adult structures are formed and replace the larval structures. Eventually, an imaginal molt enables the adult ("imago") to shed the pupal case and emerge. While the larva is said to hatch from an egg, adults are said to eclose from the pupa.

⇨**In holometabolous insects, the transformation from juvenile into adult occus within the pupal cuticle**.

- Most of the old body of the larva is systematically destroyed by apoptosis, while new adult organs develop from undifferentiated nests of cells, the imagnial discs.
- Thus, within any larva, there are two distinct populations of cells : the larval cells, which are used for the functions of the juvenile insect, and the thousand of imaginal cells, which lie within the larva in clusters, awaiting the signal to differentiate.
- **In Drosophila**, there are ten major pairs of imaginal discs, which construct many of the adult organs, and an unpaired genital disc, which forms the reproductive structures.
- **The largest disc, that of the wing, contains some 60,000 cells, whereas the leg and haltere discs contain around 10,000. AT metamorphosis, these cells proliferate, differentiate and elongate.**

- This is also called zonal orientation and geographical orientation which involves distance, direction and landmarks that make topography of the area and help the animal in homing to its nest.

NAVIGATION & HOMING

- Migratory animals which cover long distances either to reproduce or to escape from the harsh climate must find their way accurately over oceans, deserts, forest and mountains.
- Fishes, birds and many invertebrates possess extraordinary capabilities to cross oceans, deserts and mountains in order to reach their destination.
- Invertebrates such as crustaceans, amphipods, ants, bees and wasps possess strong homing and navigational instinct and are guided by the sun, moon, stars and topography of the area in following accurate route.
- Monarch butterflies migrate thousands of kilometers from Canada to Mexico to escape harsh winter and return back accurately to the same place.

FISH NAVIGATION

- How fishes find their way in huge expanses of sea and reach their destinations which lie thousands of kilometers away has been a mystery.
- It is believed that they orient by the positions of stars and moon in the night sky and sun in daytime to find the direction of swimming.
- They also make use of temperature gradients and ocean currents which help them in swimming and also in navigation. However, it has been experimentally proven by A.S. Hasler that salmons are guided by the odour of their parent stream during return journey.
- Odour map gets imprinted in their brains when they migrate as larvae from tributaries to the sea and they can navigate back from the sea using this odour map when they become adults.
- Eels can also migrate to Sargasso Sea using similar odour maps but how their larvae, *leptocephali* find their way back to the river mouths, crossing vast stretches of Atlantic Sea is a mystery. Probably their parents leave some kind of odour trails during their journey.

NAVIGATION IN BIRDS

Birds use a number of methods to find their way during migration.

- Many use celestial navigation, a method of orienting the body to the arc of the sun, to the phases of the moon, or to the pattern of stars in a particular season, which is called menotaxis.
- Hummingbirds and pigeons are able to determine the position of the sun even on overcast days because they can detect the ultraviolet radiation it emits.
- Experiments in planetarium on night migrant birds, such as white throated warblers and indigo buntings reveal that they orient themselves by the position of stars in the night sky.
- Some birds are sensitive to coriolis force that arises by deflection of winds in the northern hemisphere by earth's rotation.
- Some diurnal birds use topographical landmarks such as mountains, river valleys, and forests to orient themselves on the migration route.
- Some are able to detect infrasound or low-frequency sounds that are produced by ocean waves. Many birds, particularly seabirds, identify their destinations by characteristic odours.

- Many birds possess instinct or some kind of internal compass or biological clock that guide them through the route of migration.
- Young birds follow the migration route accurately without previous training or experience by their inherent capacity to navigate.
- Some birds such as oil birds of South America and Himalayan cave swift possess echolocation and can be guided by it.
- The classic experiment proving the internal-clock theory was done by German Gustav Kramer during the early 1950's. He placed Starlings wanting to migrate in a cage from which they could see the sun.
- The birds would sit looking in the direction toward which they wanted to fly. Significantly, if the Starlings couldn't see the sun, they didn't face in any particular direction.
- Also during the 1950's, the German Franz and Eleonore Sauer did a similar experiment with birds that could and could not see the night stars and arrived at similar results. Certain species can orient themselves according to the sky's major stars.
- In fact, an experiment with Mallard Ducks found that if the moon is so bright that important stars are hidden by glare, released ducks can't orient themselves as well as on darker, moonless nights.
- Some birds, such as pigeons, are sensitive to changes in the earth's magnetic field because of the presence of magnetite in their head and neck muscles. During early 1970's, W.T. Keeton tied small, bar magnets on the backs of pigeons. When released at locations the birds had never seen before, the pigeons with non-magnetic bars found their ways home but those with bar magnets got confused.
- In a 2007 German scientists found tiny iron oxide crystals in the skin lining of the upper beak of pigeons, which might be of help to the birds to sense the earth's magnetic field and assist them to identify their geographical position.
- The researchers also discovered cryptochromes, which change their chemistry in the presence of a magnetic field, in the retinas of migratory birds' eyes.
- The molecules might then affect light-sensing cells in the retina to create images due to magnetic field and help the bird to navigate during flight.
- Infrasound travels much farther than ordinary sound and it comes from many different natural sources, including ocean waves, surf, winds, storms, earthquakes and other geologic events. It is believed that birds can hear infrasounds that we cannot hear and hence they possess this accessory navigational capability.

AADHAR INSTITUTE

[RPSC College Lect. Zoology]

Paper - I

UNIT - 7

Genetics

[By: Harimohan Thakuriya]

Office Address :27, Kissan Marg, Near Ruchika Complex, Tonk Road, Jaipur

www.aadharinstitute.com & www.iguruji.in

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CONTENTS

- It would appear that proper development of virtually all organs (brain, pancreas, GI tract, heart, blood vessels, mammary glands — to name a few) depends on notch signaling. Notch signaling appears to be a mechanism by which one cell tells an adjacent cell which path of differentiation to take (or not take).
- Defects in notch signaling have been implicated in some cancers, e.g. melanoma.

5. Cytokine Receptors

Dozens of cytokine receptors have been discovered. Most of these fall into one or the other of two major families:

1. Receptor Tyrosine Kinases (RTKs) and 2. Receptors that trigger a JAK-STAT pathway.

Receptors

These consist of 2 identical single-pass transmembrane proteins (i.e., homodimers) embedded in the plasma membrane. Each of their cytoplasmic ends binds a molecule of a **Janus kinase** (**"JAK"**).

Ligands

Many ligands trigger JAK-STAT pathways:

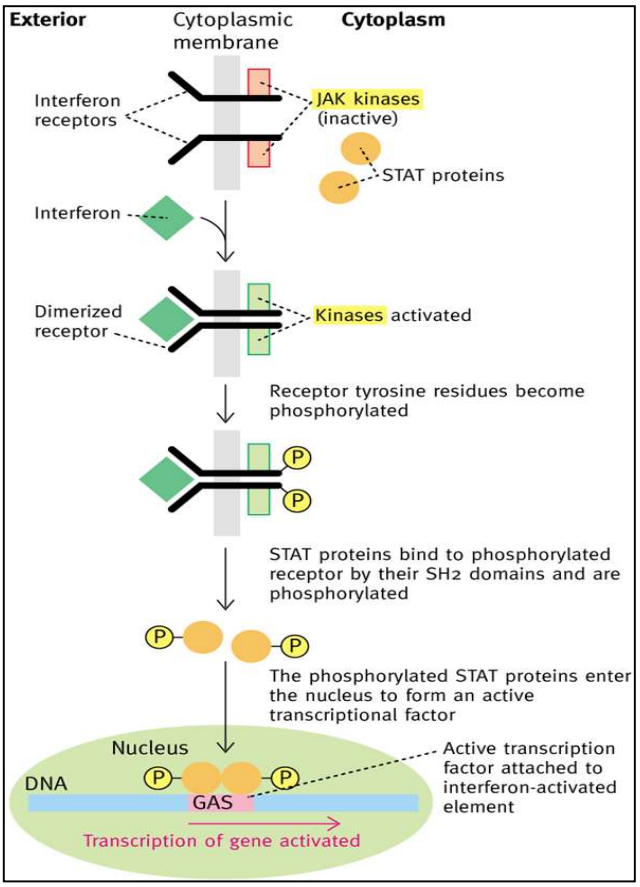
- Interferons
- Most of the **interleukins**, e.g.,IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-11, IL-12, IL-13
- Growth hormone (**GH**)
- Leptin
- Prolactin (**PRL**)
- Erythropoietin (**EPO**)
- Thrombopoietin
- Granulocyte-Macrophage Colony-Stimulating Factor (**GM-CSF**)

Mechanism

Binding of the ligand activates the JAK molecules which phosphorylate certain tyrosine (Tyr) residues on each other as well as on one or another of several **STAT** ("**S**ignal **T**ransducer and **A**ctivator of **T**ranscription) proteins. These, in turn, form dimers which enter the nucleus and bind to specific DNA sequences in the promoters of genes that begin transcription.

The JAK-STAT pathways are much shorter and simpler than the pathways triggered by RTKs and so the response of cells to these ligands tends to be much more rapid.

JAK-STAT Pathways



6. Tumor Necrosis Factor-alpha (TNF-α) Receptors and the NF-κB Pathway

TNF-α is made by macrophages and other cells of the immune system.

Receptors

Trimers of 3 identical cell-surface transmembrane proteins.

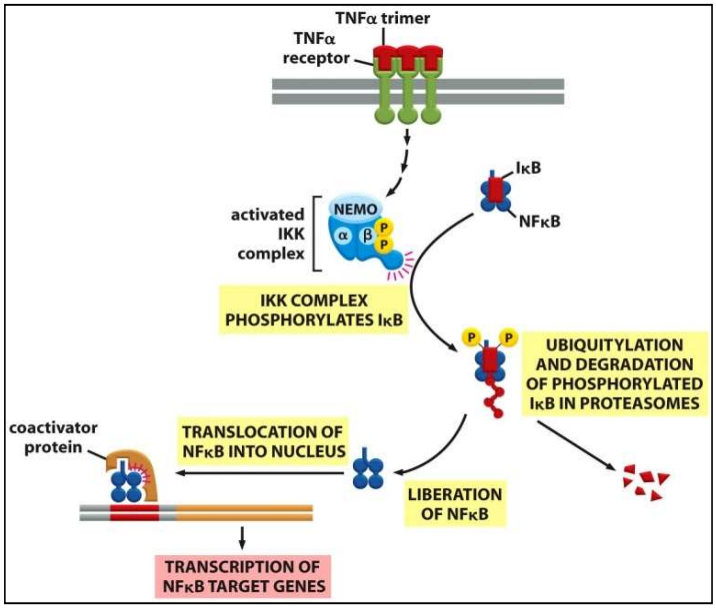
Ligands

- TNF-α (hence the name)
- Lymphotoxin (LT; also known as TNF-β)

Mechanism

- NF-κB resides in the cytosol bound to an **inhibitor** called IκB.

- Binding of ligand to the receptor triggers phosphorylation of IκB
- IκB then becomes ubiquinated and destroyed by proteasomes.
- This liberates NF-κB so that it is now free to move into the nucleus where
- it acts as a transcription factor binding to the promoters and/or enhancers of more than 60 genes:
  - NF-κB got its name from its discovery as a transcription factor bound to the enhancer of the kappa light chain antibody gene.
  - However, it also turns on the genes encoding IL-1 and other cytokines that promote inflammation.
  - The immunosuppressive and anti-inflammatory effects of glucocorticoids are caused by their enhancing the production of IκB.
  - NF-κB also turns on genes needed for cell proliferation, cell adhesion, and angiogenesis.



The T-Cell Receptor for Antigen (TCR)

T cells use a transmembrane dimeric protein as a receptor for a particular combination of antigen fragment nestled in the cleft of a glycoprotein encoded by genes in the major histocompatibility complex.

Activation of the TCR (when aided by costimulator molecules also present in the plasma membrane causes a rise in intracellular Ca^{2+} which

- activates **calcineurin**, a phosphatase which removes phosphate from **NF-AT** ("**N**uclear **F**actor of **A**ctivated **T** cells").
- Dephosphorylated NF-AT enters the nucleus, and with the help of accessory transcription factors (designated AP-1), binds to the promoters of some 100 genes expressed in activated T cells.

⇨The immunosuppressant drugs **tacrolimus** and **cyclosporine** inhibit calcineurin thus reducing the threat of transplant rejection by T cells.

Activation of the TCR, when accompanied by an as-yet-unidentified second signal, causes NF-AT to associate with a different transcription factor Instead of activating the T cell, this turns on

⇨Proto-Oncogenes

One might expect that anything which leads to the inappropriate expression of receptors that trigger cell division could lead to cancer (uncontrolled cell division). And, in fact,

- The gene encoding **PDGF** is ***SIS***; it is a proto-oncogene, and mutated versions participate in making the cell cancerous.
- The genes encoding **receptors** for **EGF** are also proto-oncogenes and are expressed at abnormally high levels in several human cancers. Two monoclonal antibodies that target these receptors

▶ trastuzumab (Herceptin®) that inactivates HER2 ("Human Epidermal growth factor Receptor 2") and

▶ cetuximab (Erbitux®) that inactivates HER1 show promise against breast cancer.

- **Two tyrosine kinase inhibitors**
  - **gefitinib (Iressa®) and**
  - **erlotinib (Tarceva®)**

Block the action of the EGF receptors on the cells of certain lung cancers and have shown some promise against these cancers.

Mutant versions of some of the "second-order" kinases are also associated with cancer:

⏩The oncogene ***SRC*** encodes a mutated version of a normal tyrosine kinase associated with the inner face of the plasma membrane.

⏭⏭⏭⏭⏭The fusion protein BCR/ABL produced by the Philadelphia chromosome activates constitutively (all the time) the cytosolic tyrosine kinase ABL that normally would be activated only when the cell is stimulated by a growth factor (e.g., PDGF).

The Philadelphia Chromosome (Ph1)

In most cases of CML, the leukemic cells share a chromosome abnormality not found in any nonleukemic white blood cells, nor in any other cells of the patient's body. This abnormality is a reciprocal translocation between one chromosome 9 and one chromosome 22. This translocation is designated t (9;22). **It results in one chromosome 9 longer than normal and one chromosome 22 shorter than normal. The latter is called the Philadelphia chromosome and designated Ph1.**

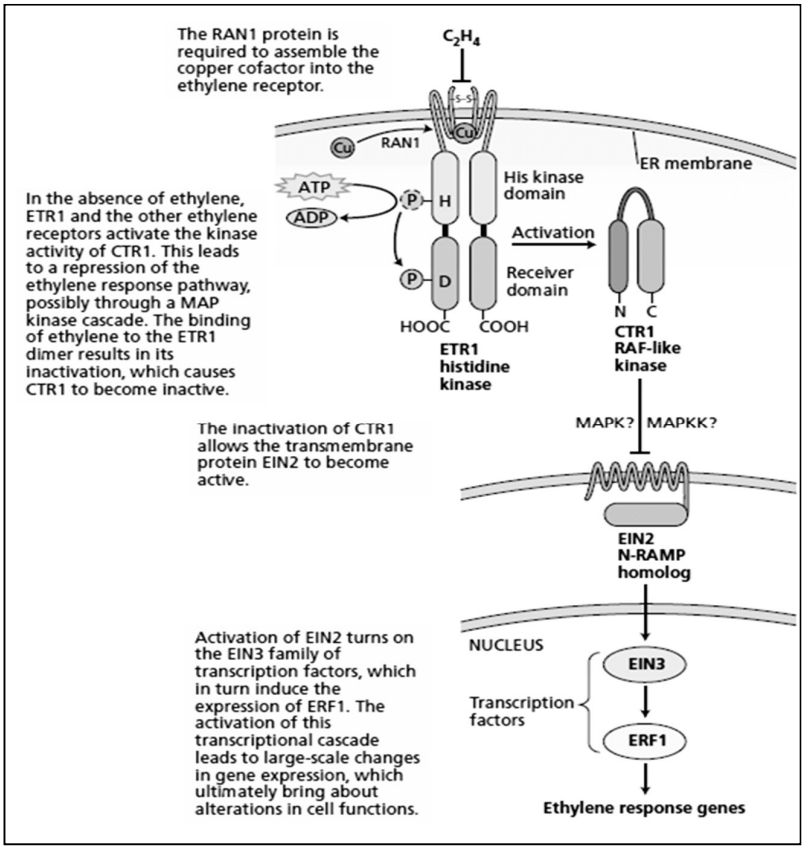
⏭The DNA removed from chromosome 9 contains most of the proto-oncogene designated c-ABL. The break in chromosome 22 occurs in the middle of a gene designated BCR. The resulting Philadelphia chromosome has the 5' section of BCR fused with most of c-ABL.

RAF. This kinase participates in a signaling pathway that links RTKs to gene activation. Binding of a ligand to the RTK activates an intracellular molecule called RAS, which then activates RAF. In mammals, this pathway promotes mitosis. Excessive activity of the RAS gene or mutations in RAS and/or RAF are associated with many types of cancer so RAS and RAF are proto-oncogenes.

15% of all human tumors contain a mutated RAF, and 66% of melanomas -a highly-malignant skin cancer of melanocytes - contain a mutated RAF (called BRAF).

Signaling in plants

In plants, proteins with homology to histidine kinases have been implicated in signal transduction by the plant hormone ethylene.



- Ethylene is a simple two-carbon gas important at many stages of the plant's life, including seed germination, seedling growth, leaf and petal abscission, organ senescence, and pathogen responses .
- Several components of the ethylene signal transduction pathway have been identified by a mutational approach with *Arabidopsis thaliana*. One of these components is the *ETR1* gene product, which functions as an ethylene receptor in *Arabidopsis*
- The ETR1 protein contains an ethylene-binding site in its aminoterminal half and regions with homology to histidine kinases and response regulators in its carboxyl-terminal half.
- This modular design is similar to that of many bacterial histidine kinases, which contain a sensory domain in the amino-terminal region and a histidine kinase domain in the carboxyl-terminal region . Based on this similarity in design, it has been proposed that the ETR1 ethylene receptor could function analogously to these bacterial sensor proteins, with ethylene binding regulating activity of the proposed histidine kinase domain.
- **ETR1 is not the only putative histidine kinase implicated in plant signal transduction**. The ERS1 protein contains sequence similarity to ETR1 throughout its entire length, including the ethylene binding and histidine kinase domains, but lacks a response regulator domain .

TWO-COMPONENT SIGNALING SYSTEMS

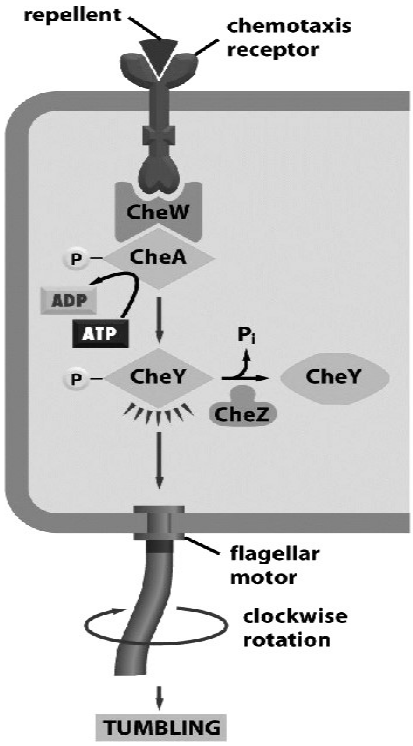
- Two-component signaling system is the most common form of signaling pathway that responds to extra-cellular events in bacteria and plants. A two component system consists of a sensor protein *histidine kinase* that is located in the membrane.

- It can be activated by binding a ligand that is in the extracellular medium. Activation causes the kinase to autophosphorylate. The reaction transfers the phosphate from ATP on to a histidine residue in the kinase.

- The sensor interacts with an effector protein (also called a *response regulator).* The effector protein has two domains - regulatory domain and effector domain. The regulatory domain catalyzes transfer of the phosphate group from the histidine on the sensor to an aspartic acid residue in its own domain. This activates the effector domain.

- The usual end target of a two-component pathway is the regulation of gene transcription.

Signaling in Bacterial chemotaxis



- Motile bacteria such as *E*. Coil will swim toward higher concentrations of nutrients ***(attractants)***, including sugars, amino acids, and small peptides, and away from higher concentrations of various noxious chemicals **(repellents).**

- They swim by means of **four to six flagella**, each of which is attached by a short, flexible hook at its base to a small protein disc embedded in the bacterial membrane.

- This disc is part of a tiny motor that uses the energy stored in the transmembrane H^+ gradient to rotate rapidly and turn the helical flagellum. Because the flagella on the bacterial surface have an intrinsic "handedness," different directions of rotation have different effects on movement.

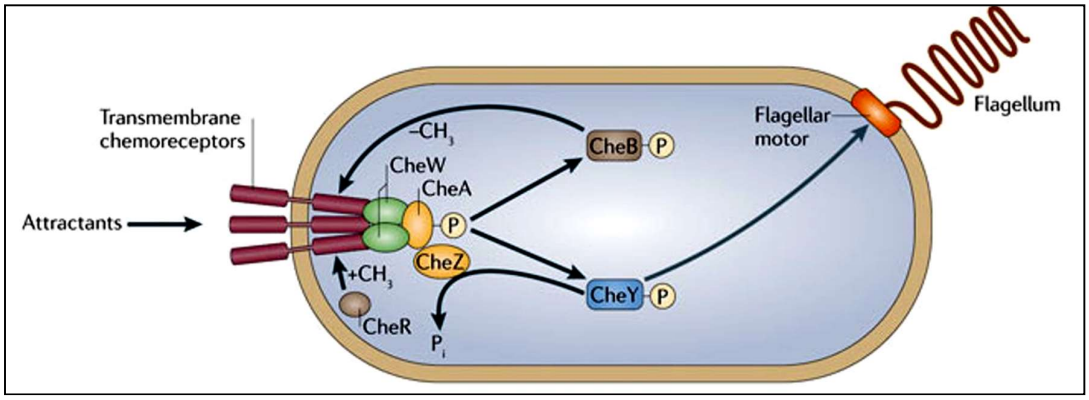
- **The flagella spend most of the time rotating counterclockwise, which draws all the flagella together into a coherent bundle, so that the bacterium swims uniformly in one direction.**

- In the absence of any environmental stimulus, every second or so, one or more of the motors transiently reverses direction so that the attached flagellum breaks out of the bundle, causing the bacterium to tumble chaotically without moving forward.

- This sequence produces a characteristic pattern of movement in which smooth swimming in a straight line is interrupted by abrupt, random changes in direction caused by tumbling.

- When bacteria are swimming in a **favouable direction** (toward a higher concentration of an attractant or away from a higher concentration of a repellent), **they tumble less frequently** than when they are swimming in an unfavorable direction (or when no gradient is present). Since the periods of smooth swimming are longer when a bacterium is traveling in a favourable direction, it will gradually progress in that direction – toward an attractant or away from a repellent.

- **Histidine – kinase – associated chemotaxis receptors mediate these responses.** The receptors typically are dimeric transmembrane proteins that bind specific attractant and repellents on the outside of the plasma membrane.



- The cytoplasmic tail of the receptor is stably associated with a histidine kinase *Che*A via an adaptor protein *CheW*.
- **Repellent binding activates the receptors, whereas attractant binding inactivates them**; a single receptor can bind either type of molecule, with opposite consequences. The binding of repellent to the receptor activates *CheA,* which phosphorylates itself on a histidien and almost immediately transfers the phosphoryl group to an aspartic acid on a response regulator protein *CheY*.
- The **phosphorylated *CheY* dissociates from the receptor,** diffuses through the cytosol, binds to a flagellar motor, and causes the motor to **rotate clockwise, so that the bacterium tumbles**. CheY has intrinsic phosphatase activity and dephosphorylates itself in a process that is greatly accelerated by the *CheZ* protein.
- The change in tumbling frequency in response to an increase in the concentration of an attractant or repellent occurs within less than a second, but it is only transient.
- **Even if the higher level of ligand is maintained, within minutes, the bacteria adapt (desensitize), to the increased stimulus.** The adaptation is a crucial part of the response, as it enables a bacterium to compare its present environment with that in its recent past and thereby respond to *changes* in the concentration of ligand rather than to steady-state levels.

- **The adaptation is mediated by the covalent methylation (catalyzed) by a *methyl transferase*) or demethylation (catalyzed by a *methylase*) of the chemotaxis receptors, which change their responsiveness to ligand binding as a consequence of the covalent modification**.
- **When an attractant binds to a chemotaxis receptor, for example, it has two effect** :

(1) It decreases the ability of the receptor to activate CheA, resulting in a decreased rate of tumbling.

(2) It slowly (over minutes) alters the receptor so that it can be methylated by the methyl transferase, which returns the receptor's ability to activate CheA to its original level. Thus, the unmethylated receptor without a bound ligand has the same activity as the methylated receptor with a bound ligand, and the tumbling frequency of the bacterium is therefore the same in both cases.

- **Prototypical histidine kinases were identified in bacteria as belonging to ''two-component'' signaling systems.** In these systems, histidine kinases autophosphorylate a conserved histidine residue, often in response to an environmental stimulus; this phosphate then is transferred to an aspartic acid residue on a second component referred to as the response regulator.

Quorum sensing

Bacterial quorum sensing

Bacteria use quorum sensing to coordinate certain behaviors based on the local density of the bacterial population. Quorum sensing can occur within a single bacterial species as well as between diverse species, and can regulate a host of different processes, essentially serving as a simple communication network.

A variety of different molecules can be used as signals.

Bacteria that use quorum sensing constantly produce and secrete certain signaling molecules (called autoinducers or pheromones).

✹These bacteria also have a receptor that can specifically detect the signaling **molecule (inducer**). When the inducer binds the receptor, it activates transcription of certain genes, including those for inducer synthesis.

✹There is a **low likelihood of a bacterium detecting its own secreted N-Acyl Homoserine Lactones (AHL).** Thus, in order for gene transcription to be activated, the cell must encounter signaling molecules secreted by other cells in its environment.

✹**When only a few other bacteria of the same kind are in the vicinity, diffusion reduces the concentration of the inducer in the surrounding medium to almost zero, so the bacteria produce little inducer.**

✹However, as the population grows the concentration of the inducer passes a threshold, causing more inducer to be synthesized. This forms a positive feedback loop, and the receptor becomes fully activated. Activation of the receptor induces the up regulation of other specific genes, causing all of the cells to begin transcription at approximately the same time.

✹This coordinated behavior of bacterial cells can be useful in a variety of situations. **For instance, the bioluminescent luciferase produced by *V. fischeri* would not be visible if it were produced by a single cell.**

✹By using quorum sensing to limit the production of luciferase to situations when cell populations are large, *V. fischeri* cells are able to avoid wasting energy on the production of useless products.

Examples

Vibrio fischeri

- Quorum sensing was first observed in Vibrio fischeri, a bioluminiscent bacterium that lives as a mutualistic symbiont in the photophore (light-producing organ) of the Hawaiian bobtail squid.
- When V. fischeri cells are free-living (or planktonic), the autoinducer is at low concentration and thus cells do not luminesce.
- However, when they are highly concentrated in the photophore (about 1011 cells/ml) transcription of luciferase is induced, leading to bioluminescence.

Escherichia coli

- In the Gram-negative bacteria Escherichia coli, cell division may be partially regulated by AI-2-mediated quorum sensing. This species uses AI-2, which is produced and processed by the lsr operon. Part of it encodes an ABC transporter which imports AI-2 into the cells during the early stationary (latent) phase of growth.
- AI-2 is then phosphorylated by the LsrK kinase, and the newly produced phospho-AI-2 can either be internalized or used to suppress LsrR, a repressor of the lsr operon (thereby activating the operon).
- Transcription of the lsr operon is also thought to be inhibited by dihydroxyacetone phosphate (DHAP) through its competitive binding to LsrR. Glyceraldehyde 3-phosphate has also been shown to inhibit the lsr operon through cAMP-CAPK-mediated inhibition.
- This explains why when grown with glucose E. coli will lose the ability to internalize AI-2 (because of catabolite repression). When grown normally, AI-2 presence is transient
- Autoinducer-2 (AI-2) is a family of signaling molecules used in quorum sensing.
- AI-2 is produced by both gram-negative and gram-positive bacteria**.**

Pseudomonas aeruginosa

- The opportunistic bacteria Pseudomonas aeruginosa uses quorum sensing **to coordinate the formation of biofilms, swarming motility, exopolysaccharide production, and cell aggregation.**
- These bacteria can grow within a host without harming it, until they reach a certain concentration. **Then they become aggressive, their numbers sufficient to overcome the host's immune system and form a biofilm, leading to disease.**
- In this species, AI-2 was found to increase expression of sdiA, a transcriptional regulator of promoters which promote ftsQ, part of the ftsQAZ operon essential for cell division.

Signalling in Social Insects

- Social insect colonies are an excellent example of a decentralized system, because no individual is in charge of directing or making decisions for the colony.
- Several groups of social insects have been shown to use quorum sensing when making collective decisions.

Ants

- **Colonies of the ant Temnothorax albipennis nest in small crevices between rocks**. When the rocks shift and the nest is broken open, these ants must quickly choose a new nest to move into.

- During the first phase of the decision-making process, a small portion of the workers leave the destroyed nest and search for new crevices. When one of these scout ants finds a potential nest, she assesses the quality of the crevice based on a variety of factors including the size of the interior, the number of openings (based on light level), and the presence or absence of dead ants.
- The worker then returns to the destroyed nest, where she will wait for a short period before recruiting other workers to follow her to the nest she found using a process called tandem running.
- The waiting period is inversely related to the quality of the site- for instance a worker that has found a poor site will wait longer than a worker that encountered a good site.
- As the new recruits visit the potential nest site and make their own assessment of its quality, the number of ants visiting the crevice increases. During this stage ants may be visiting many different potential nests.
- However, because of the differences in the waiting period the number of ants in the best nest will tend to increase at the greatest rate. Eventually, the ants in this nest will sense that the rate at which they encounter other ants has exceeded a particular threshold, indicating that the quorum number has been reached.
- Once the ants sense a quorum, they return to the destroyed nest and begin rapidly carrying the brood, queen, and fellow workers to the new nest. Scouts that are still tandem-running to other potential sites are also recruited to the new nest and the entire colony moves.
- Thus although no single worker may have visited and compared all of the available options, quorum sensing enables the colony as a whole to quickly make good decisions about where to move.

Honeybees

- **Honey bees (Apis mellifera)** also use quorum sensing to make decisions about new nest sites.
- Large colonies reproduce through a process called budding, in which the queen leaves the hive with a portion of the workers to form a new nest elsewhere.
- After leaving the nest, the workers form a swarm that hangs from a branch or overhanging structure. This swarm persists during the decision-making phase until a new nest site is chosen.
- **The quorum sensing process in honey bees is similar to the method used by Temnothorax ants in several ways.**
  - A small portion of the workers leave the swarm to search out new nest sites, and each worker assesses the quality of the cavity she finds. The worker then returns to the swarm and recruits other workers to her cavity using the honey bee waggle dance. However, instead of using a time delay, the number of dance repetitions the worker performs is dependent on the quality of the site.
  - Workers that found poor nests stop dancing sooner, and can therefore be recruited to the better sites.
  - Once the visitors to a new site sense that a quorum number (usually 10 to 20 bees) has been reached, they return to the swarm and begin using a new recruitment method called piping.
  - This vibration signal causes the swarm to take off and fly to the new nest location. In an experimental test this decision-making process enabled honey bee swarms to choose the best nest site in four out of five trials.

Subclass (a) Archaeornithes Subclass (b) Neornithes

(a) Sub class - Archaeornithes :-

(1) Primitive **"Lizard like birds"** are included in this subclass, which belong to Jurassic period. All the members have become extinct.
(2) Wings are ill developed, i.e. capacity of flying was very less.
(3) Their tail was long and lizard like, which contains 2 parallel rows of feathers on it.
(4) 18 - 20 free caudal nerves were present in tail. Pygostyle was absent,
(5) Keel on sternum was absent.
(6) There were present 3-3 clawed digits of forelimb at the free edges of wings and metacarpels were separate.
(7) Uncinate processes on ribs were absent.
(8) Teeth were present in the jaws of skull which were inserted in the alveoli.

All the members of this subclass are the connecting links between reptiles and birds.

Examples **1. Archaeopteryx** = Lizard bird 2. **Archaeornis**

Both the members are extinct today and are supposed to be the connecting link between reptiles and birds.

(b) Sub class - Neornithes.-

(1) This subclass includes mostly live animals and extinct animals of post Jurassic period.
(2) Except some species (which are extinct) rest all the birds are toothless.
(3) Wings are well developed which are used in flying (except some birds)
(4) Sternum is bigger and with keel.
(5) Thoracic ribs are having uncinate processes, but abdominal ribs are absent.
(6) Caudal vertebrae are always less than 13 in number. Last few vertebrae fuse to form **pygostyle.**
(7) Metacarpels are fused together.
(8) Digits of forelimbs are fused and claws absent.
(9) In live members of this subclass, **vertebrae** are **heterocoelus.**
This subclass is classified under **four superorders.**

(i) Super *order - Odontognathae*:-

1. These extinct animals were found in creataceus era. These animals wer teethed.
2. Pygostyle was absent.
3. Keel in sternum is absent.

Examples

(1) **Hesperornis** (2) **Enaliornis** **(Both extinct)**

(ii) Super order - *Palaeognathae or Ratitae* :-

(1) It includes large and massive birds, which are flight less in nature. Wings are rudimentary. These are able to run fast.
(2) Wings are reduced, rudimentary, vestigeal or absent.

(3) Sound producing organ syrinx is absent.
(4) Sternum is **raft like** which lacks **Keel.**
(5) **Oil glands** or **preen glands** absent.
(6) Caudal vertebrae are free and pygostyle is absent.
(7) Uncinate processes on ribs are absent.
(8) Coracoid and scapula are comparatively small. Copulatory organ in males is absent.
(9) These animals are not found in India.

Examples

(1) **Struthio : African ostrich :- It** is the **largest living bird** of modern period. It is almost 8 feet in height. It is also called "Camel - bird' In this bird **urinary bladder** and **panis** are present.
(2) **Rhea :- American ostrich :-** It also has **urinary - bladder** and **penis.**
(3) **Apteryx** = Kiwi - It is found in New Zealand. It has hair like feathers all over its body.
(4) Acryornis **= Elephant bird.**
(5) **Casowaries** = Bird of Australia
(6) Emu = It is a monogamous bird in which only males look after their young ones and eggs.
(7) **Mulleornis**

(iii) Super *order - Impennae*:-

(1) All the members of this super order are aquatic birds
(2) forelimbs are modified into flippers
(3) Limbs are webbed.
(4) Teeth are absent

Example

Spheniscus = Penguine - It is also called **"sea bird of Antarctica"**

(iv) Super order - *Neognathae or Carinatae* :-

(1) This super order includes small sized **flight birds** of modern era.
(2) Wings are well developed
(3) Hooked barbules in barbs are present
(4) Keel in sternum is highly developed - Its crop glands secrete pigeon milk
(5) Pygostyle is present
(6) Beak is **toothless**
(7) Oil glands or preenglands are found,
(8) Uncinate processes at ribs are well marked.
(9) Pectoral muscles are large.
(10) Copulatory organs are lacking in males.

Examples

(1) Pavo - cristatus - Peacock - It is the national bird of India.
(2) Psittacula krameri - Indian parrot

(3) **Orthotomus - Tailor** bird.
(4) Columba livia - Blue rock pigeon its crop glands secrete pigeon milk.
(5) **Passer domestieus - sparrow** - It shows commonsalism with man.
(6) Corvus splendens - Crow
(7) Anas : Wild duck - Aquatic bird having webbed limbs.
(8) Cygnus : Swan - Aquatic bird having webbed limbs
(9) Bobo bobo : or Bubo - owl.
(10) **Cuckoo** : It lays its eggs in the nest of other birds (Crow)
(11) Indian Koel **: Eudynamis scolopaceous.**
(12) Albatross = Diomedea :- **Largest wings** are present in this bird.
(13) Kite
(14) Falcon **all are predatory birds**
(15) Vulture
(16) **Dinopium : Wood pecker :** Kathphorva
(17) **Raphus didus : Dodo** : It is the bird to Mauritius , now it is extinct**.**
(18) **Choriotis nigriceps = Great Indian bastard**. It is also called Godavan. It is the **state bird of Rajasthan**
(19) **Helena : Humming bird** : It is also called sonbird. It feeds on nector of flowers. It is the smallest bird. It is found in cuba. It can fly in forward and backward both the directions. It can fly like helicopter i.e. it shows stable flight so it is called Natural Helicopter. Its size is about 3 to 4 cm.
(20) **Ploceous = Weaver bird** (Baya)

Migratory Birds:-

(1) Pluvialis Dominica: - It is an American bird which migrates from south to north and from north to south.
(2) Scolopax eusticola: - It migrates from hill area to planes.
(3) Himalyan partiges :- It can fly over 6000 miles
(4) Pitohiudicthous/pathua: - It is the only one poisonous bird, which is found in Newguinea.
(5) Spine tailed swift: - Fastest flying bird, it is found in Japan.
(6) Poor bill :- Bird which shows sleeping stage

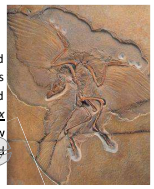
Largest Indian bird sanctuary **Ghana Bird sanctuary Bharatpur Rajasthan.** Largest serpentorium - In **Madras.** Largest Indian aquarium **Tarapur aquarium Bombay.** Flamingo bird breeds in **Chilka Lake.**
Reminges are the feather arranged in **wings and Retrices** are the feather arranged **in tail.**

Origin of feathers & Birds

Cold blooded animals obtain their body heat from the environment, as their energy output is low and they do not need to sustain activities over prolonged periods. Thermoregulatory mechanism in reptiles depends on low metabolic rate, with little insulation of skin, resulting in rapid exchange of heat with environment. Any insulation on the body will be a handicap for ectotherms because it will prevent body from warming up by external heat. To maintain warmth, feathers evolved in birds and hairs in mammals, both descendants of ancient reptiles and both warmblooded animals.

Discovery of thecodont fossils such as *Sinosauropteryx* from Sihetun in China prove this theory, because their bodies were covered with two inches long dense filamentous feathers Use of vaned feathers for flight must have been a later development in some small-sized species which grew them in asymmetrical aerodynamic form on the arms and tail and which could then be used for flight.

FOSSIL BIRDS



FEATHERED, BIRD-LIKE DINOSAURS

In the last few years, many fossils of feathered dinosaurs have been found near Yianxin, in Liaoning Province, China. Two new Chinese feathered dinosaurs dating from between 145 and 125 million years ago (during the late Jurassic and early Cretaceous periods) have been found,*Protarchaeopteryx robusta* and *Caudipteryx zoui*. Feathered dinosaur *Sinosauropteryx*, found a few years ago, also in the same region of China, and the bird-like *Unenlagia* found in Argentina.

THE OLDEST-KNOWN BIRDS

Archaeopteryx is one of the most famous and oldest-known fossil birds, and dates from the late Jurassic period (about 150 million years ago). *Compsognathus* was a bird-sized and bird-like dinosaur. Huxley argued that birds and reptiles were descended from common ancestors. In 1986, J. A. Gauthier looked at over 100 characteristics of birds and dinosaurs and showed that birds belonged to the clade of coelurosaurian dinosaurs. [Gauthier, J.A., 1986. *Saurischian monophyly and the origin of birds*, in The Origin of Birds and the Evolution of Flight, California Academy of Sciences Memoir No. 8].

BIRD-LIKE ANIMALS

In the chain of creatures leading from dromaeosaurid dinosaurs (advanced theropods) to birds, *Sinosauropteryx* is the earliest bird-like dinosaur. For now, the bird-like animals include the following:

- **Protoavis** – (meaning "first bird") genera. Fossils have been found in Texas, USA.
- **Archaeopteryx** – The oldest known bird had asymmetrical feathers.
- **Sinosauropteryx** – *Sinosauropteryx* had a coat of downy, feather-like fibers and it was a bipedal thecodont reptile. Fossils from Sibetun in China.
- **Protarchaeopteryx** had long, symmetrical feathers on arms and tail. Fossil from China.
- **Caudipteryx** – a small, very fast runner covered with primitive, symmetrical feathers and therefore it was flightless but feathers were perhaps meant for display.
- **Iberomesornis** (meaning "Iberian=Spanish intermediate bird") was a small, early, toothed bird.
- **Unenlagia** – a much larger ground-dwelling theropod that had feathers but could not fly.

- **Beipiaosaurus** was 7 feet long bipedal dinosaur, with 2 inches long feathers covering the body and longer feathers on arms and head that did not assist in any way in flight. Beak had thecodont teeth.
- **Oviraptosaurus** fossil was found from Mongolia, had feathers but could not fly.
- **Patagonykus** (meaning "Patagonia claw") was a lightly-built meat-eater with a single, clawed finger on each hand.
- **Velociraptor** – a larger, ground-dwelling carnivore with a swiveling wrist bone.
- **Mononykus** (meaning "single claw") was a small, insect-eater from the Late Cretaceous period.
- **Hesperornis** (meaning "western bird") was an early, flightless bird that lived during the late Cretaceous period.
- **Ichthyornis** (meaning "fish-bird") was 8 inch (20 cm) long, toothed, tern-like, extinct bird.
- **Eoalulavis** (from Spain) – the earliest bird that had good maneuverability while flying.
- **Diatryma** was a giant terrestrial bird whose fossils were found in USA, was carnivore.
- **Phororhacos** height was about 6 feet, hooked beak and was a ferocious predator.
- **Neocathartes** was a terrestrial vulture that could not fly.
- **Osteodontornis** was a giant oceanic bird much like extant albatroses.
- **Aepyornis & Mullerornis** were elephant birds of Madagascar.
- **Dromornis stirtoni** fossils were found by Peter F. Murray from Australia.
- **Moas *(Dinornis)*** was 10-12 feet in height, became extinct recently in 13th century.
- **Shuvuuia** was a bird-like bipedal dinosaur with feathers covering the whole body and forelimbs and tail having long feather. But this animal was not able to fly.

CLASS - MAMMALIA

Study of mammals is known as **Mammology.** Mammals are originated by mammals like reptiles - therapsids in triassic period. **Coenozoic era** is called the **"Golden era of mammals".** This class includes about 5000 living species.

MAIN CHARACTERS:-

(1) The members of this class are **cosmopolitan.** These are highly developed animals,

(2) Mammals are **warm blooded and homeothermic** or endothermic animals

(3) Their body is covered by a coat of **hair,** called **pelage.**

(4) **Mammary glands** are found in females for baby feeding, so on the basis of this, the class mammalia was so named,

(5) External ear is present in the form of ear pinna (except monotremes)

(6) Body is divided into **head, neck, trunk and tail.**

{7) A horizontal, **diaphragm** is present in the body cavity of all the members of this class without any exception. This diaphragm is present in between thorax and abdomen. Diaphragm helps in **respiration defaecation, micturition and parturition.**

(8) Endoskeleton is bony, skull is **dicondylic.**

(9) Two pairs of limbs are present in trunk. Limbs are pentadactyle which help in swimming, walking running etc. Hind limbs are absent in **cetaceans and siren ians,**

(10) **Suspensorium** of their jaws is craniostylic type.

(11) Lower jaw is made up of only one bone dentary.

(12) Teeth are fixed in sockets in the buccal cavity, so teeth are called **Thecodont.** Teeth are of **four types** i.e. such type of teeth are called **Heterodont** teeth. Teeth comeout two times in a life span in most of the animals so these are also called **diphyodont** teeth.

(13) Alimentary canal is complete, its proximal end is called mouth and distal end is called anus, anus and urinogenital apertures are separate. Cloaca is absent [Exception-members of **Prototheria** have cloaca]

(14) Vertebrae are **acoelous or amphiplatyan** type i.e. centrum is flat at both the sides. Cartilagenous pads are found at the edges of centrum, that are called **epiphysis.**

(15) Neck is having 7 cervical vertebrae,

Exceptions :- Bradypus/sloth has 9 or 10 cervical vertebrae. Sea - cow/mantees has 6 cervical vertebrae.

(16) Skin of mammals is thick, **water proof,** glandular. So many types of glands are present in the skin as sweat glands, oil glands or sebaceous glands and mammary glands.

(17) Mostly horns are present at head **nails** at digits, **claws or hoof** are found, which provide protection.

(18) **Premaxilla, Maxilla and palatine** bones fuse/combine to form or **secondary bony palate or hard palate** which separates nasal passage from **buccal cavity,**

(19) Only **left aortic** arch is found in mammals.

(20) Larynx or sound organ is found in the neck region for the production of sound.

(21) Ribs are **bifid.**

(22) Heart **four chambered.** Double **circulatory system** is present.

(23) **RBCs small, circular and non nucleated.**
Exceptions :- Family camilidae,Camel and Lama have nucleated RBCs.

(24) Nasal passage is separate from buccal cavity and opening into buccal cavity) remains covered by **epiglottis,**

(25) **Nasal, maxilla and ethmoid** bones are found in nasal chamber, which from a **spiral passage** which removes dust particles, bacteria, microbes etc. coming with air.

(26) Cranial nerves are **12 - pairs.**

(27) Respiration is by one pair of lungs. Lungs are situated in **pleural cavity.**

(28) Brain is comparatively large and highly developed. Cerebrum and cerebellum are very complex in structure and highly developed,

(29) A special structure is present for the connection of both the cerebral hemispheres of brain, which is called **corpus - callosum.** It is absent in monotrems and marsupials.

(30) Optic lobes are four in number and are solid. All the 4 optic lobes collectively known as corpora quadrigemina

(31) **Cochlea** of internal ear is highly coiled spirally.

(32) **Malleus, Inous** and **stapes** are the three ear ossicles in middle ear

(33) One pair of **metanephric kidneys** are situated in abdominal cavity.

(34) These animals are **ureotelic.**

(35) Mammals are **unisexual** animals. Testes of males are situated (out side the body) in the **scrotal sacs.** A distinct penis is present in males for copulation.

(36) Ovaries and a reduced penis **clitoris** is found in females

(37) Eggs are developed in uterus. Embryonic membranes amnion, chorion and allantois and yolk sac are found in embryoso these are grouped under group Amniota

(38) Mostly mammals are **viviparous,** which give birth to their young ones. Some mammals are oviparous [Prototherians], some mammals are ovoviviparous [Metatherians]

(39) Eggs are **alecithal** or **microlecithal** but eggs of prototherians are megalecithal

(40) Fertilization is **internal** and it takes place in fallopian tubes.

(41) At the time of fertilization, **acrosome** which is present at the head of sperm, secretes **Hyaluronidase** enzyme which helps to penetrats through extramembranes of egg,

(42) Cleavage **holoblastic** and **equal type.**

(43) Embryo is attached through the uterus of mother by **placenta,** so these animals are also called **"placental animals".** Placenta helps in the **nutrition, respiration** and **excretion** of embryo

(44) Parental care is well marked in mammals. Mother feeds the child by milk secreted by her mammary glands and looks after her child.

Livings mammals are classified into two subclasses :-

(i) Subclass :- Prototheria

(1) In this subclass primitive egg laying mammals are included.

(2) These are **partially homeothermic** animals,

(3) Eggs are large, yolky and shelled.

(4) Mammary glands are without nipples.

(5) Pinnae are absent and cochlea is less coiled.

(6) Cloaca is present.

(7) Testes in males are situated inside the body (abdominal cavity)

(8) Corpus **-** callosum is absent in brain.

(9) A toothless horny beak is found in adult animals, but teeth are present in child hood.

(10) Gynaecomastism is found in these animals i.e. male and female both feed their child. Mammary glands are functional in males and females both.

(11) Oviducts in females do not fuse to form **uterus** and **vagina** in the posterior part.

(12) Members of this subclass are found in **Australia, Newguine** and **Tasmania.** Only one order is included in this subclass.

Order - Monotremata:-

1. Megalecithal eggs are present.

2. Presence of cloaca.

Examples

(1) Ornithohynchus or **Duck billed platypus** poison glands are found in **male platypus.**

(2) **Tachyglossus** or **Echidna** or **spiny anteater.**

(3) **Zaglossus**

(ii) Subclass - Theria

1. These are viviparous animals.
2. Pinnae are present
3. Teeth are found in adult and children both,
4. Testes are situated in scrotal sacs.
5. Uterus and vagina both are found in females.
6. Embryo is attached with ulterus of mother by placenta.

Subclass Theria is subdivided into two infra classes:-

[A] Infraclass - Metatheria or Marsupials:-

(1) An abdominal pouch called marsupium is found in these animals, in which immature young ones are developed till maturity.

(2) Mammary glands are present and nipples are also found on these mammary glands, these are situated in **marsupium.**

(3) External ears (pinnae) present and **corpus callosum** is also absent.

(4) Cloaca is absent.

(5) Teeth are present in adult animals, which are **monophyodont** and **heterodont** type.

(6) Testes are present out side the abdominal cavity, in the scrotal sacs, just in front of penis.

(7) Penis is bifid two vagina, two clitoris and two uteri are present in a female animal.

(8) Yolk, sac and placenta are found.

(9) Cochlea is more coiled in internal ear. Only one order is included in this infraclass.

Order - Marsupialia:- Characters like metateria. Animals are ovoviviparous.

Examples

1. Macropus - Kangaroo found in Australia only.

2. Opossum - Didelphys

3 Dasyurus - Tiger cat

[B] Infra class - Eutheria

(1) These are true mammals; that give birth to a mature child.

(2) Nipples are well marked in mammary glands.

(3) Completely **endothermic** animals.

(4) External ears or pinnae are present.

(5) **Corpus** callosum is found in brain.

(6) Cloaca is absent.

(7) Testes are situated in the scrotal sac outside the abdominal cavity.

(8) A true placenta is found, which is Allanto - chorionic type.

(9) Uterus and vagina are single i.e. only one uterus and only one vagina are present in a female.

(10) Cochlea is highly coiled.

(11) These are cosmopolitan.

Infraclass Eutheria is divided into 16 orders:-

(1) Order: Insectivora :-

(1) These are most primitive and smallest mammals

(2) Movement is palmatigrade type.

(3) These are burrowing nocturnal and insectivorous animals.

Examples

1. **Hedge Hog : Erinaceous :** Jhau - Chuha
2. **Sorex : shrews** : smallest mammals size is about 3 - inches : Chhachhunder
3. Short tail mole = **Talpa**

(2) Order: Dermoptera/Flying lemurs :-

(1) In this group, all the false lemurs are included, which do not fly.

(2) A membranous fold of skin is present on the body which helps in gliding the animal from one tree to another tree.

(3) These are nocturnal animals

(4) These are fruit eaters (frugivorous)

Example

(1) Galeopithecus :- Flying lemur

(3) Order: Chiroptera :-

(1) In this group bats are included which can fly in air. These are true **flying mammals,**

(2) Skin between forelimbs and hindlimbs is expanded in the form of **patagium,** it works as wing, which helps in flying.

(3) Testes are situated inside the abdominal cavity.

(4) **Ecolocation sensory system** is well developed. Bats produce high frequency sound during flight (Frequency 50,000 cycles per second). Echo reflects by the hinderances in the path during flying. For the control of these echos these animals have Radar system in their body.

(5) These are **insectivorous, frugivorous** or **sanguivorous** (blood sucking) animals.

Examples

1. **Pteropus - Flying fox,** It is a frugivorous animal.
2. **Vespertilo - Insectivorous bat,** it is also called filter mice.
3. **Desmodus = Vampire bat,** it **is a sanguivorous** animal

(4) Order: Rodentia :-

(1) It is the biggest order in mammals

(2) These are small, terrestrial, herbivore or omnivore animals.

(3) It includes gnawing animals.

(4) Incisor teeth grow continuously in these animals and canines are absent and empty space of canine is called **diastema.**

Examples

1. Funambulus - **Squirrel**
2. **Ratus ratus - Rat**
3. **Porcupine - Hystrix** = Sehi = Body hair are modified into quills.
4. **Guinea pig - cavia**
5. Diopodomys - **Kangroo** Rat. It is desert rodent and never drink water

(5) Order: Edentata :- (Ant - eaters)

(1) These are insectivore animals; tongue of these animals is long, thin and sticky. Digits are clawed. Teeth ill developed or absent.

Examples

1. **Bradypus :- Arboreal sloth** :- It is having three hooves,
2. **Coloepus** :- It is having two hooves.
3. **Myrmecophaga :- Giant ant eater.**
4. **Dasypus = Armadillo** :- It shows polyembryony (4-8 embryoes)
5. It is the only mammal, which has exoskeleton of **bonyplates or horny scales.**

(6) Order: Pholidota :- (Scaly ant - eater)

Example

1. **Manis/pangolin :- Scaly ant eater**

(7) Order: Lagomorpha :-

(1) Rodent like mammals.

(2) Complete herbivore

(3) Canines absent, **diastema** is present

Examples

1. Rabbit = Oryct**o**lagus
2. Hare = **Lepus**
3. Pika = **Ochotona [Tail less]**

(8) Order: Carnivora :-

(1) Canines well developed

(2) Smart, strong and carnivore animals

(3) Upper **last premolar** and lower **first molar** are meant for tearing the flesh these are called **carnassial teeth.**

(4) Mammary glands are found in abdominal region.

(5) Testes in scrotal sac.

(6) Locomotion - **Digitigrade type.**

Examples

1. Domestic dog :- Canis familiar is

2. Domestic cat **:- Felis domesticus**
3. Lion :- **Panthera leo.** Lions in India are found only in **Gir forests** of kathiawar of Gujrat state.
4. Tendua = Panther = **Panthera pardus**
5. Tiger **= Panthera tigris :- It** is the **national animal** of India.
6. Cheetah :- **Acinonyx** :- It is the extinct animal of India.
7. **Fox :- Vutpes - bengalnensis**
8. **Phoca :-** Seal
9. Mongoose :- **Herpestes** (Nevala)
10. Sea - lion - **Zalbpus**
11. Wolf **: Canis lupus**
12. Walrus :- **Odobanus**
13. Seal

(9) Order: Cetacea :-

(1) These animals are fish like marine mammals

(2) Forelimbs are modified into **paddle like** structures which help in swimming.

(3) Body is **hairless and gland less.**

(4) Pinnae and hind limbs absent.

(5) Teeth absent or homodont type

(6) Testes situated in **abdominal cavity** in the male. In females, nipples are present

(7) A thick heat resistance layer of adipose tissue is present just beneath the skin; that is called **blubber.**

Examples

1. **Balaenoptera musculus :- Blue whale**

It is the largest and heaviest (150 tons) animal.

It is largest living animal.

Its length is about 100 feet.

Its dorsal surface is bluish in colour while, ventral surface is pale yellow in colour.

Teeth are found in embryo.

These are plankton eater,

2. **Physeter = sperm whale**
3. **Killer whale = orcinus**
4. **Dolphin = Platanista gangatica :-** It is found in Ganga river.
5. Small whale **= Porpoise phocaena**

A special solid substance is secreted by the stomach of sperm, whale, it is called **"Ambergris"**, it is used in producing cosmetics and perfumes.

(10) Order: Sirenia :-

(1) Aquatic mammals.

(2) Herbivores,

(3) Forelimbs modified into **paddles** and hind limbs absent.

(4) Pinnae absent.

Function and types of placenta in mammals.

In Eutherian mammals the embryo develops in the uterus of mother. The developing embryo will get nourishment from mother through the placenta. Placenta is not common to all mammals. It is developed well in Eutheria The term placenta was delved from Greek word it means flat cake. Placenta is a special connective tissue, which contains the uterus of mother and foetal membranes of foetus.

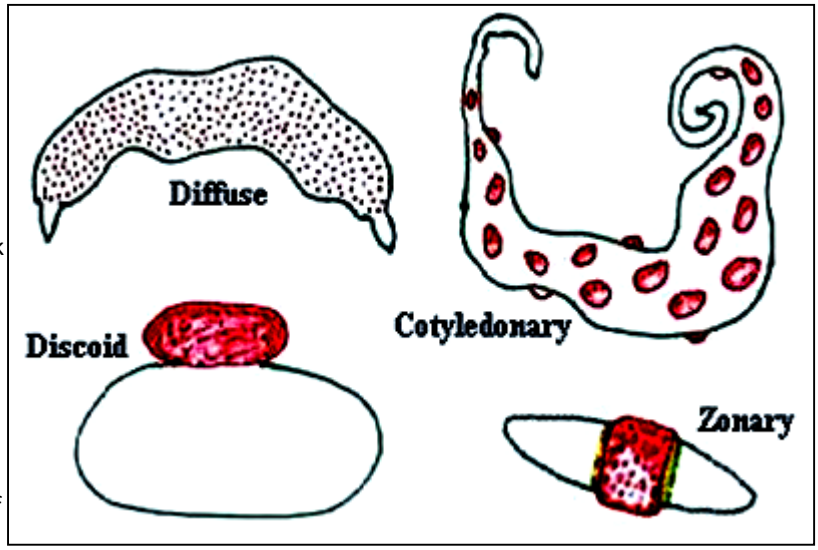
Prototherian mammals are egg laying mammals. Hence placenta is not formed in uterus.

In marsupials the embryo develops incompletely in the uterus. They show yolk sac placenta and primitive allantoic placenta:

Yolk sac placenta :

Ex : Diadelphis.

In these animals the developing embryo shows small allantois. It will never come in contact with chorion. Their yolk sac was large. It comes in contact with chorin. This part will gain blood vessels. This part will come in contact with endometrium of uterus. This is only a contact, but not fusion. Through this contact the embryo will absorb nourishment from mother. This is called chorio vitelline placenta or Yolk sac placenta.



Primitve allantoic placenta:

In paramoles simple allantoic placenta is developed Allantoic will enlarge It comes In contact with chonon This structure will be closely applied to mother's uterus. It is called chorio-allantoic placenta. In these animals yolk sac placenta is not seen.

Placenta In Eutherla:

In Eutherian mammals true allantoic placenta is seen. Allantoic becomes big and comes in contact with chorion. This part will show close association with uterine wall. This connection is called placental connection. The structure of placenta will vary in different orders of Eutheria.

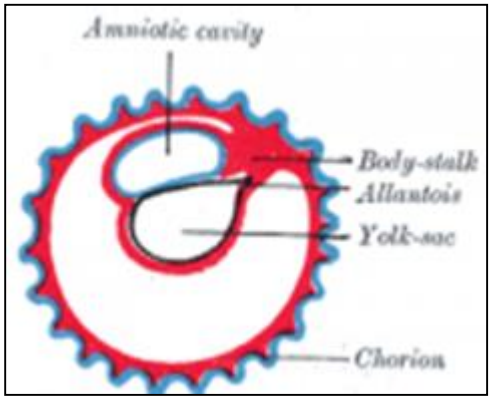
Placenta is classified in three ways.

1. The placenta classification on nature of contact.
2. Placenta is classified basis on the distribution of villi.
3. Classification of placenta basing on histology.

1. Nature of contact:

It is two types, Indeciduate and deciduate type.

Indeciduate type placenta Ex. Ungulate, Cetaceans, Sirenians. Lemurs: The chorianic villi are simple projections, they lie in contact with uterus. They have a loose contact. There is no fusion. At the time of birth of embryo uterus is not damaged.



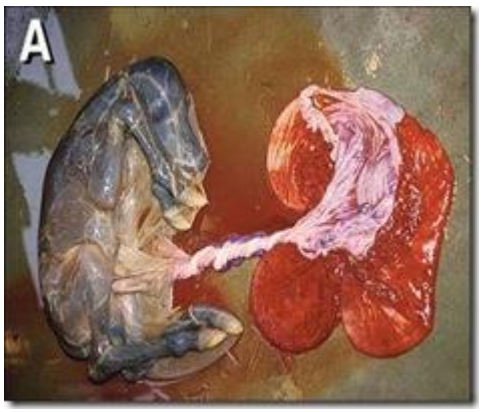
Deciduate type Placenta: Ex: Primates, Rodentia, Insectivora, chiroptera The allantochorianic villi penetrate into uterine valli. They are intimately fused. Hence at the time of birth, the uterus is damaged. Bleeding occurs, the utrine wall enters into formation of placenta is called deciduas.

2. Basing on distribution of villi

According to the distribution of villi five kinds of placenta are seen.

I, **Diffused type placenta:**Ex Horse, pig,

The villi are uniformly distributed on the surface of blastocyst, except at the extreme ends.



II. **Cotyledonary placenta** Ex Sheep, Cow, Deer.

The villi are arranged in groups. Each group is called cotyledon. Each cotyledon fits into caruncla fo uterus.

iii Intermediate type Placenta Ex : Caine!, Giraffe.

It is a rare type, it shows free villi on cotyledons. Hence it is called intermediate type placenta

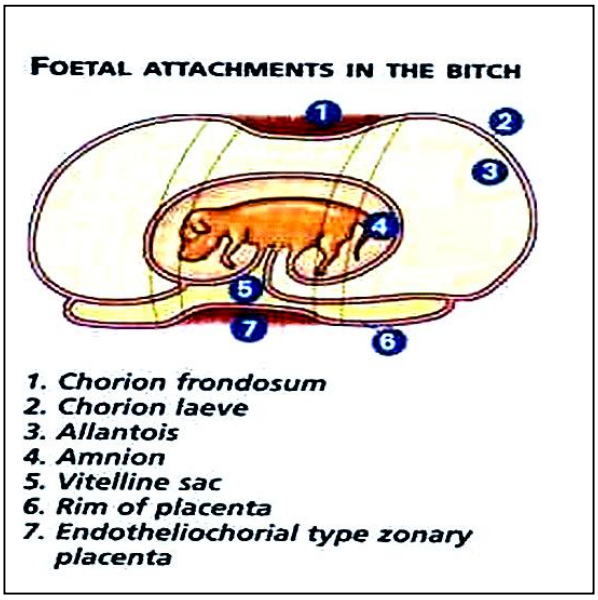
In these three types of placenta during perturition the foetus will not damage uterus.

iV,Zonary placenta: Ex Cat, Dog, Carnivores.

The villi are In the form of transverse zones. In dog a single girdle of vhf will be present. In fox two girdles of villi are present. The villi penetrate Into uterine wall. Hence during parturitlon uterine wall Is damaged.

V,Discoidal Placenta: ex Rat, Bat, Rabbit.

On the entire surface of blastocyst the villi are in the form of discs. When the embryo Is growing It movesaway from uterus hence the with look like a disc. These villi are Intimately connected with uterus. Hence during parturitlon much uterine tissue is damaged.



3. Placenta classification -Basing on histology:

According to number of layers of cells present between foetus and uterus blood supply the placenta Is classified into five types.

a) **Epithelio chorlal placenta** : Ex Pig, Horse, (Ungulates Lemmures)

The foetal chorion Is In contact with eplthelium of the uterus hence it is called epithello chorial placenta. In between foetal, maternal parts six layers are present.

I) Endothelium of mother blood vessel.

ii) Maternal syndesmose connective tissue.

Iii) Epitheliurn of mother

Iv) Chorion of foetus.

v) Foetus connective tissue (syndesmose

vi) Endothellum of foetal blood vessel.

If all the six layers are present the placenta is called epithello chorlal placenta.

b**) Syndeumose chorial placenta** : Ex Sheep, Cow.

The allanto-chorianic vith will pierce into the uterus of the mother, the chorion will come in contact with syndesmose of mother's uterus. Hence iti s called syndesmose chorial.

c**) Endothelio chorial placenta** :Ex Dog, Carnivores. The chàrion of the foetus will come in contact with the endotheli of mother ‘s uterus, hence it is called endothelio-chorial placenta.

d) **Hemochorial placenta** : Ex: Bat, Man, Primates, Insectivores.

The placental connections are more lntimate. The chorion of foetus will float In the blood pools of mother’s utiras. Hence It Is called haemochorIal placenta.

e) **Hemo endothelial placenta** Ex: Rat, Rabbit, Hence guinea-pig will float In mother’s blood. Hence it called hemo endothelial placenta.

Functions of placenta:

1) Placenta will form a physiological barrier between mother and foetus. It will possess foetal and maternal blood mixing.

2) Placenta allows the diffusion of monosacharides, amino adds, hormones, vitamins, oxygen, .carbondioxide, water and other waste materials, because of this it supplies food, oxygen to foetus.

3) It works as an excretory organ of foetus. It releases the nitrogenous waste materials Into mother blood.

4) It works as an endocrine gland. It will secretes lactogen ,progesterone,etc. hormones.

5) The placenta will manufacture fructose from glucose.

7. Vertebral Column: The vertebrae of the cervical, sacral and lumber region are hedgehogs, intercentral ossicles are present between lumbar vertebrae which strengthen the vertebral column. In Armadillos an extra pair of zygopophyses are present in the lumber vertebrae.

8. Skin: Skin of burrowing animals is protected with mucus (annelids), chitin (arthropods), scales (caecilians, and reptiles) and fur or spines (mammals).

9. Loss of Eyes: The eyes are often reduced, vestigial or non-functional. The reduction of eyes depends upon the duration and completeness of subterranean existence. In limbless lizards the eyes are white dots through skin. In snakes the eyelids are immovable and fused together forming a transparent membrane over the eyes. In moles eyes are small, reduced and functionless and are buried in the fur.

10. Disappearance of Pinnae: The external ear which collects sound waves from air has no utility in burrowing animals. Rather these will obstruct in burrowing and will get themselves obstructed by the accumulation of soil. For this reason, the pinnae are either absent or very much reduced. These are unable to receive sound waves from air but sensitive to sound waves passing through the soil.

11. Tactile Organs: The tactile organs are specially developed to compensate sight and hearing. In moles the snout is richly innervated and highly sensitive. The tail of wombat is also tactile.

12. Skull: The skull of subterranean animals is compact and roughly conical. The suture between the bones of the skull are obliterated. The jaw bones are reduced. In burrowing mammals, the zygomatic arch is absent and auditory region is reduced. The dentition is also reduced, and jaw muscles are poorly developed.

13. Winter Sleep: Most of the fossorial animals undergo winter sleep or hibernation, as these are not able to maintain a constant body temperature.

14. Digging Organs: The most important modification for fossorial life is the presence of some digging structures. The digging structures are either the snout, forelimbs or teeth:

(a) **Snout:** In majority of fossorial animals, the snout is often tubular and helps in digging. In hog-nosed snake (Heterodon), pigs and swine it is truncated and upturned at the tip. In moles and swine, a prenasal bone is developed at the tip of the nose which helps in burrowing.

(b) **Forelimbs:** The forelimbs are short, compact and strong with powerful musculature. These have strong claws for digging. In fossorial insect (mole cricket) distal segments of forelegs bear strong spines. In moles and Echidna an additional bone os falciform is present to broaden palm.

(c) Teeth: Tusks in elephants and incisors in pocket gophers are efficient organs of digging.

B. Fossorial Adaptations in Invertebrates:

- Among invertebrates Arenicola, Glycera, Spirorbis, Sabella, Serpula and earthworms (Annelids); Emerita, Albunea, Gryllotalpa termites and ants (Arthropods); Solen, Solenocurtis, Dentalium, Lamellidens (Molluscs) and Synapta (Echinodermata) are common burrowing forms.
- In burrowing annelids, the setae (locomotory organs) are reduced and in burrowing polychaetes the parapodia are reduced (Arenicola, Chaetopterus).
- The prostomium is well developed and conical in-earthworm and used for burrowing.
- These have special methods for obtaining food. In Chaetopterus, a current is established in the tube by the beating of three fan-like structures. In Serpula and Sabella the

peristomium bears a circlet of tentacles bearing groove which concentrate on or near mouth. In Arenicola the pharynx is protrusible.

- Emerita possesses a smooth carapace and reduced mouthparts. It feeds like earthworm by swallowing sand.

(d) In Balanoglossus, the proboscis becomes turgid and helps in burrowing. Albunea exhibits a special device for obtaining water inside tube. The two antennules are fused to form a siphon which remains protruding out of the earth surface to draw water inside the tube.

- In mole crickets the forelegs are short, stout and spade-like specially modified for digging. In molluscs the food is variously modified for burrowing being hatchet-shaped in Lamellidens, cylindrical in Solen and club-shaped in Dentalium.

3. ARBOREAL (SCANSORIAL ADAPTATIONS):

Animals climbing trees or other vertical surface, or stones are known as arboreal or scansorial animals. The arboreal animals can be distinguished into three categories:

(a) **Wall and rock climbers**: These can climb on vertical surfaces like walls of the houses or other rocky surfaces but not on the trees. The geckos and the common wall lizard are the most common examples of wall climbers.

- For climbing on wall, the digits of both fore and hindlimbs are provided with sharp and recurved claws and the undersurface of digits bears adhesive discs. The adhesive discs are formed of flexible folds of integument (the lamellae) beset with spines. When these lamellae are pressed against the surface, a partial vacuum is created underneath, i.e., between surface and the foot. This helps the lizard in clinging to the vertical surface.

(b) **Terrestrio-arboreal forms**: The terrestrio-arboreal forms climb on the trees only for food or for nesting but live on earth. These include sloth bear, stone marten, striped palm squirrel, Indian giant squirrel (*Funambulus pennonti*) and flying squirrels etc.

(c) True arboreal forms: The true arboreal forms live and walk on the trees for most of the time, but frequently descend to the ground. These are further differentiated into three groups on the basis of their mode of locomotion:

(i) Branch runners (running on the branches) like squirrels, lemurs, chameleons and carsupilas.

(ii) Suspended forms (which hang head down from the branches) like bats, sloths, Galeopithecus. These forms are unable to walk on the branches and move while suspended upside down clinging on the branches with the help of powerful claws.

(iii) Branchiators (which swing by their forelimbs), e.g., primates, apes and monkeys. They move from branch to branch by swinging forelimbs with great speed and accuracy.

These forms exhibit following modifications:

1. Size: Arboreal forms are usually small and slender so that the twigs and tree branches can easily withstand their body weight.

2. Body Contour: Strengthening of chest, ribs and limb girdles. The thorax is sub-circular, and ribs are more curved. The lumbar vertebrae are elongated, and number is often increased.

3. Girdles: The pectoral girdle is strongly built because the forelimbs support the body weight while hanging from tree branches. The clavicle and scapula are prominent to withstand the strain caused by the contraction of powerful breast muscles.

In the pelvic girdle the ilium is broad and supports the viscera in sloths and primates.

4. Lengthening of Proximal Segments of the Limbs: The proximal segments of forelimbs, i.e., the humerus bone is elongated. In gibbon, hands are so long that they touch the ground when it stands erect.

5. Reduction in the Number of Digits: In tree sloths there are two digits in hand and three in foot, while in three-toed sloth (Bradypus) there are three digits in each fore and hindlimb. In spider monkey the thumb is reduced. In Koala, the second and third toes are syndactylous. In almost all the birds the number of digits in each limb is reduced to three or four.

6. Syndactyly and Zygodactyly: In some arboreal forms both hindlimbs and forelimbs are of grasping type with opposable digits. In others these are nonprehensible.

(a) The prehensile limbs with opposable digits are found in birds, arboreal reptiles and mammals.

(b) Arboreal structures: The arboreal forms which lack grasping feet exhibit other modifications for climbing. Some of them are enumerated below:

(i) Claws: The digits are provided with long and curved claws as in bats, squirrels, cats and lizards. Even in birds where feet are of grasping type the claws are also well developed. Claws are modified into powerful hooks in sloths.

(ii) Adhesive discs: In tree frogs the digits are provided with adhesive discs or suction discs. In mammals tree-porcupine (Erethizon), tree coney (Dendrohyrax) and Japanese macaque (Innus) the sole of the feet are provided with adhesive pads. In tarsiers the fingertips are dilated. Lizards (Geckonids) possess elaborate adhesive organs having lamellae.

7. Tail: In majority of arboreal animals the tail is long and prehensile and acts as fifth hand. In flying squirrel (Anomalurus) the undersurface of tails provided with spines or scales which prevent the animal from slipping down.

8. Development of Accessory Organs: Parachuting mechanisms have been developed in the form of patagia in wide variety of arboreal animals such as flying lizards (Draco). Spines and tubercles are present on the forearm in some lemurs.

4. VOLANT ADAPTATIONS:

- The animals which are capable of soaring or gliding in the air exhibit aerial mode of existence and are known as volant forms or aerial creatures or flying animals.
- Volant forms are found in both vertebrates and invertebrates. some of them are capable of sustained flight for hours together. Others can glide in the air for a few hours whereas still others can glide in the air for only a brief period. The former represents true or active flight and the latter passive flight.

1. Active Flight or True Flight

- The active or true flight is seen in insects among invertebrates, and pterodactyls, birds and bats among vertebrates. These exhibits following general adaptations:

1. Presence of wings
2. Stream-lined body
3. Reduction of body weight
4. Lightness of the skeleton (pneumaticity of bones)
5. Skeleton compact and rigid due to the fusion of bones and development of additional articular surfaces.
6. Sternum bears a median keel (carina)

7. Additional surfaces for the attachment of strongly developed flight muscles 8. Strongly developed flight muscles
9. High rate of metabolism
10. Specially developed sense organs.

VOLANT ADAPTATIONS IN BIRDS OR ADAPTATIONS TO FLIGHT IN BIRDS

A. Morphological Adaptations

1. Body Contour: The resistance offered by air during flight depends much upon the shape of the body. The spindle-shaped or boat-shaped body encounters least resistance and can easily be propelled through air. The attachment of wings high upon the thorax, the high position of light organs like lungs and air sacs and low position of heavy muscles, sternum, digestive organs and consequently low center of gravity are other structural features of great significance.

2. Presence of Feathers: Possession of feathers is unique to the birds since no other group of animal kingdom has ever developed them. These form a uniform covering over the body. These are beneficial to the bird because:

(a) these form a smooth and closely fitting covering, which makes the body stream-lined and reduces the friction to minimum.

(b) these are very light and hardly add to the weight of the bird.

(c) they hold a considerable blanket of enveloping air around the body and add to its buoyancy.

(d) they form a non-conducting covering and thus prevent the loss of body heat and maintain a constant body temperature.

(e) feathers of the wings form a broad surface for striking the air.

3. Forelimbs Modified into Wings: The forelimbs become modified into unique and powerful propelling organs, which propel the body high up in the air. These are marvelously designed for this purpose being equipped with special flight muscles and feathers of large size. The feathers form a broad continuous surface for striking the air in flight supporting the bird in air.

4. Mobile Neck and Beak: The modification of forelimbs into wings is duly compensated by a long mobile neck and the beak. The mobile neck enables the beak to reach up to food and the beak which acts as a pair of forceps for picking it up.

5. Bipedal Locomotion: Since the forelimbs are no longer freely available for locomotion on ground, the hindlimbs have to support the body weight and act also as locomotory organs. Therefore, these occupy a somewhat anterior position on the trunk.

6. Perching: The hindlimb muscles are strongly developed and so modified that where a bird settles down on a perch, its bending of legs exerts a pull on the flexor tendons, which make the toes automatically to flex and to grip the perch. The perching is so efficient that the bird can sleep, while sitting on the twig without any fear of falling down.

7. Short Tail and Tail Feathers: The tail is very short but carries a tuft of long tail feathers (rectrices), which spread out in a fan like manner. These serve as rudder during flight and assist in sterring, lifting and counterbalancing.

B. Anatomical Modifications:

1. Endoskeleton: The endoskeleton is light and provides large surface for attachment of muscles. It is built on the “hollow girder principle”, which is stronger for its weight than the solid one. The

bones are pneumatic, filled with air space, the extension of air sacs. The skeletal framework is compact, centralized and relatively rigid, due to the fusion of bones.

(a) The skull: The skull bones are light and sutures between the bones are obliterated. Even there is a tendency towards the reduction in the number of skull-bones. The teeth are replaced by light horny beak to lighten the skull.

(b) Fused thoracic mass: All the thoracic vertebrae except the last are fused into a single mass, providing a firm fulcrum for the action of wings in striking air. In flightless birds the thoracic vertebrae are free.

(c) Synsacrum: The last thoracic, all lumbers, sacral and few caudal vertebrae are fused to form the synsacrum which provides a compound plate-like girder to support the entire weight of the bird's body.

(d) Vertebral column, sternum, ribs and the elements of pectoral girdle together form a coherent bony framework on basket for the protection of internal organs.

(e) Pygostyle: The posterior caudal vertebrae are fused into a pygostyle which provides surface for the attachment of tail feathers.

(f) Ribs: The vertebral ribs bear additional bony processes, the uncinate which articulate with bony sternal ribs by synovial joints, establishing a firm union between thoracic and sternal ribs.

(g) Sternum: Sternum or breastbone is large with a strongly developed midventral keel for the insertion of highly developed flight muscles. The sternum is prolonged backwards to support the floor or abdominal viscera.

(h) Pectoral girdle: The pectoral girdle is very rigid to resist the force of the pectoral muscles. The coracoids are pillar-like and heavy. The angle between the coracoid and scapula is less than 90°. The clavicles and interclavicles are fused to form a furcula found only in flying birds.

(i) Forelimbs: Skeleton of forelimbs is completely modified. There are only three digits, which are more or less fused.

9. **Muscles of Flight:** The muscles on the back are much reduced and the flight muscles on the breast are strongly developed. These form nearly 1/6th of the total weight of the body. The pectoralis major affects the lowering or depression of the wings while the pectoralis minor elevates thewing. Additional depressor and elevator muscles are also present.

10. Digestive Organs: The high rate for metabolism necessitates high food requirements and quick rate of digestion. The rectum is very much reduced and never stores the undigested food because the flying animal cannot afford to bear the weight of faeces. Hence, the undigested residue is minimum and is immediately got rid off.

11. Respiratory System: The respiratory system is highly developed. The dense, in elastic and complicated lungs are supplemented by a remarkable system of air sacs which are extensively distributed in the available spaces between internal organs even extending into the bones as air spaces. These firstly reduce the specific gravity of the bird and also facilitate complete aeration to the lungs. The lungs are aerated twice at each breath which secures perfect oxygenation of blood. The air-sacs help in regulating body temperature by internal respiration.

12. Circulatory System: The heart is large and very efficient. The oxygenated and deoxygenated bloods are separate. The blood possesses large amount of hemoglobin inside the R.B.Cs.

13. Warm Bloodedness: The constant body temperature enables the bird to take flights at high altitudes and also facilitates activeness in every season.

14. Efficient Excretion and Retention of Water: The uriniferous tubules of kidneys are added with Henle's loops which are efficient in water absorption. Similarly, the coprodaeum part of the cloaca absorbs water efficiently. The urinary bladder is absent, and the urine is immediately excreted out, not retained for long in the body lest it may add to body weight.

15. Brain and Sense Organs: The brain is highly developed consisting of well-developed centers of equilibrium, muscular coordination and instinct. Hence, the cerebellum and cerebrum are highly developed. During flight, the bird has to depend mostly on the sense of sight, therefore, the eyes and the optic lobes are well developed. The organs of smell are poorly developed and correspondingly the olfactory lobes are reduced

16. Reproductive Organs: The retention of single ovary and an oviduct in female is a weight-reducing device.

Volant Adaptations in Bats:

1. Wings: Wings of bat, actually the alar membranes, are the extensions of skin stretched on either side of the body from shoulders to hindlimbs and supported by the bones of forelimbs.

2. Limbs: The forelimbs are greatly modified since these supports the wings or patagia. All the bones of forelimbs except the carpals and thumb are greatly elongated. The metacarpals of second, third, fourth and fifth digits are long, thin and flexible. The carpus is much specialized by the fusion of bones, allowing flexion, extension and spreading of the digits. The hindlimbs are also peculiarly modified. These are rotated outwards and knee is directed backwards. The modification of limbs for aerial mode of life are so complete that these can simply shuffle on the ground with great difficulty.

3. Sternum: Like birds the sternum of bat is also keeled for the attachment of flight muscles.

4. Clavicles: The clavicles are stout and often fused with the sternum and scapula.

5. Movements of ribs are reduced because thorax is used as a fixation point for flight muscles.

6. Pectoral flight muscles are greatly developed and powerful to operate the wings. Their great development often results in an axillary or dorsal disposition of mammary tissue.

7. Rate of metabolism is very high on account of two reasons. Firstly, bats need large amount of energy for flight and secondly surface area of skin is much more than the volume of body and hence there is great and speedy loss of heat.

8. Echo-location System: Bats are equipped with special sensory system which helps in locating the objects or obstacles while flying speedily even in dark. The system is known as echo-location system. The bat in its flight emits ultrasonic sound.

2. Passive Flight or Gliding:

- The gliders exhibit passive flight. They possess large surface which may represent either enlarged fins, membranous folds of the body and extension of skin.

  1. Gliding in Fishes: Flying fishes have enlarged pectoral and ventral fins and form a sail-like structure with the help of which they zoom up from the surface of water and skim over in air for considerable distances. Exocoetus and Cypsilurus are the flying fishes from Indian coasts.

2. Gliding in Amphibians: Rhacophorus pardalis can glide among the tree twigs with the help of webbed digits of both forelimbs and hindlimbs. When it leaps in the air the membrane between digits spreads and acts as a parachute.

3. Gliding in Lizard and Snake: Flying dragon, Draco volans, and flying gecko, Ptychozoon, are two flying lizards. In Draco, the wings consist of large folds of skin (patagia) from the sides of the trunk and extending between the forelimbs and hindlimbs. These are supported by extension of ribs. In Ptychozoon the skin expands out and fringes the neck, trunk, tail and toes.

Flying snake, Chrysopelea, can glide for considerable distances from one branch of a tree to other. At the time of leap, it flattens its body by expanding ribs and swinging them outward.

4. Gliding in Mammals: Flying phalangers, Acrobates pulchellus, flying lemurs, Galaeopithecus, flying squirrel, Anomalurus exhibit gliding. All of them possess furry membrane along the sides of the body extending between the forelimbs and hindlimbs. But sometimes it extends in the interfemoral regions and also in front of the forelimbs.

5. CAVE ADAPTATIONS:

Characteristics of Cave Environment

- Caves are characterized by the absence of bright light and nearly uniform temperature, high humidity, feeble fluctuations of temperature and absence of air currents.
- But the light is plenty at the mouth of the caves and penetrates for a short distance inside. Therefore, the cave environment is separated into three distinct regions, namely:

(a) Twilight or dysphotic or transitional region.

(b) Region of fluctuating temperature.

(c) The inner cave region.

- The latter represents true cavern environment having no light, relatively high humidity and absence of air currents. The absence of light has a pronounced effect on the inhabitants of this region.

Cave Flora

The absence of light does not favor life and growth of green plants which are used as food. Therefore, only those plants exist which can bear the darkness. These are Ozonium (common fungus), green mold, long white mold, mushrooms (Agaricus sp.) and mucur etc.

Cave Fauna

Cave dwellers are classified into three groups:

1. Permanent cave dwellers: The permanent cave dwellers reside permanently in caves and do not come out of them. These turbellarians from Platyhelminthes; chaetopod worms and leeches from Annelida; amphipods, isopods, decapods etc. from class Crustacea; springtails from class Insecta; mites and true spiders from Arachnida and snails from Gastropoda.

- Amongst fishes are Amblyopsis. Typhlichthyes chologaster and the cave catfish (Gronias nigrilabris). Cave amphibians are cave salamanders such as Spelerpes maculicauda, Typhlotriton, Spelaens, Proteus anguinus. Nocturnal owls and oil-birds nest in the caves but are not permanently cave dwellers. Amongst mammals white-footed mouse (Peromyscus leucopus) is the only cave dwelling form.