

1. What are the “consequences” of fertilization?

Fertilisation leads to completion of the second meiotic division, restores diploidy, determines chromosomal sex and initiates cleavage. The genetic uniqueness of gametes leads to a genetically unique new individual.

These are the core points expected. In addition, you should understand the background of these phenomena. Also correlate the coverage from the gametogenesis lecture.

The “genetic uniqueness of gametes” is due to crossing over during meiosis, when members of a pair exchange genetic material. Before this exchange, one chromosome of a pair is maternal (from the mother) and one is paternal. After crossing over, each one has a random, and therefore unique mixture of genes from the mother and the father. Imagine this happening for 23 pairs. Each gamete is therefore unique (having a different mix of genes) and therefore the resulting individual is also unique.

The oöcyte has a huge amount of cytoplasm. Ordinary body cells have a manageable range of cytoplasm-nucleus ratio. Cleavage brings this about.

Since sperms can have X or Y chromosomes and oöcytes can have only an X chromosome, the event of fertilization also determines the chromosomal sex of the new individual. (Though not relevant to this discussion, you may be aware that the manifestation of sex and sexual behaviour depends on many other factors, like the actual development of genital organs, hormones and behaviour is even influenced by the nervous system).

Restoration of diploidy does not require further explanation.

2. What are the factors involved in implantation?

What we are seeking here is explanations for the embryo not implanting prematurely, and what helps implantation when it does happen.

The zona pellucida prevents implantation. The embryo (blastocyst) must “hatch” before it can be implanted. Once it loses the zona pellucida, the exposed trophoblast, which is highly invasive in nature, burrows into the endometrium.

Make sure you understand the terms zona pellucida, corona radiata and trophoblast.

The zona pellucida is a non-cellular layer immediately surrounding the oöcyte.

The corona radiata is a cellular layer, a part of the granulosa cells of the ovarian follicle. This layer accompanies oöcyte at ovulation but soon disappears.

Trophoblast is a part of the blastocyst. It is a highly cellular mass.

3. What are the possible implications of implantation at abnormal sites?

First of all, make sure you do not confuse between fertilization and implantation. *In MCQs many students fall into this self-created trap, largely because they do not read a question properly!*

The common site of *fertilisation* is the ampulla of the uterine tube.

The normal site of *implantation* is the fundus of the uterus.

Abnormal implantation may occur at a number of sites. The more common ones are :

Uterine tube : the tube is too narrow, and not capable of supporting the embryo. Either the embryo dies and is expelled, or the tube ruptures due to distention. We shall learn more about the implication when we study the pelvis.

Lower down in the uterus. By itself this would not have serious consequences. However, the placenta grows to a fairly large size (20 - 25 cm). If the embryo is implanted low down, the placenta may partially or completely cover the outlet of the uterus (precise anatomical terms will be explained with the pelvis). This can cause potentially fatal bleeding before or during childbirth. *Rarely*, implantation can even occur in the abdominal cavity. In *even rarer* instances, such a pregnancy can even reach full term.

Do not get carried away by the dramatic nature of rare events. Understand the usual!

4. Discuss the meaning of the terms “embryonic period” and “foetal period”.

The entire duration of intrauterine life is generally divided into three parts, based on some landmark changes. From ovulation through implantation to the establishment of the three germ layers takes a little over two weeks. Implantation is complete before the end of two weeks. This is usually described as the period of early development.

From the *third to eighth week*, most of the body systems develop until they acquire their final form, with most of the organs having an appearance close to their final form. Dramatic changes occur during this period, with massive amount of cell differentiation and even cell death, to shape the organs. This is the period of organogenesis or the embryonic period. At the end of this period the embryo begins appear ‘human’ in form. During this period the embryo is most vulnerable to damaging influences leading to malformations of organs or systems.

From the third *month* until birth, there is massive growth, and the ‘human-like’ form is called the foetus. This long period is therefore foetal period.

Though these are the usually accepted figures for the division of pregnancy into these periods, it is extremely important to understand that these are not rigid landmarks in time.

Different systems develop at different rates and have different ‘end points’ *topographically* speaking. For example, at the beginning of the foetal period a part of the intestine is still outside the abdomen (explained later with various embryology topics). The male external genitals reach their final shape and form well into the fourth month.

At the histological level, many systems continue to develop well into the foetal period. Histologically the lungs reach compatibility with life outside the uterus well into the seventh month. The gas-exchange mechanism (“alveoli”) begin to develop towards the end of the foetal period and indeed, continue developing histologically even after birth, well into childhood.

In this unit, you are not expected to remember these precise timelines. However, it is the concept that is important.

Week 2 MCQ exercise : next page.

MCQ Exercise

This MCQ has a single most appropriate (“correct” answer).

Step 1 : Mark your answer by marking a cross (‘X’) in the appropriate box.

The function of rough endoplasmic reticulum is

- A. synthesis of fats
- B. synthesis of proteins for the cell’s own use.
- C. digestion of ingested foreign material.
- D**. synthesis of protein for delivery outside the cell.
- E. synthesis of mRNA.

Step 2 : In the space below, qualify each statement by an explanation of why it is true or false.

A. Synthesis of fats is done in smooth ER.

B. Proteins synthesized for the cell’s own use are made by “free” ribosomes. The term “free” indicates that they are not attached to the reticulum.

C. Ingested foreign material is in membrane-bound structures called phagosomes. These combine with lysosomes containing enzymes.

D. It stands to logic that proteins for “delivery” should be in membrane-bound reticulum, transferred to another membrane-bound organelle, the Golgi complex and delivered. Ribosomes attached to the reticulum give it the “rough” appearance.

E. mRNA is synthesized in the nucleolus.

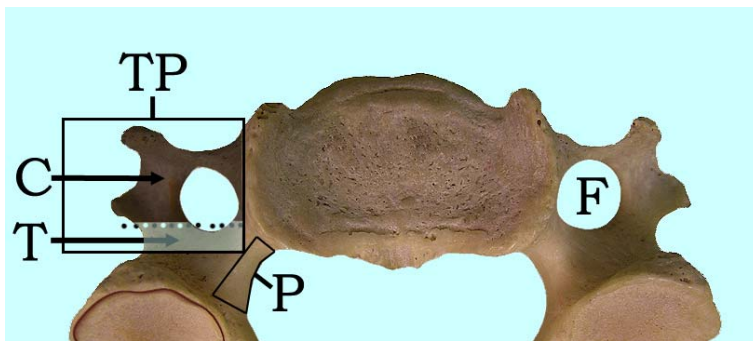
1. Explain the terms costal element and transverse element.

The transverse process as we see it is made of two developmental parts. The costal element is the more anterior (ventral) one, the transverse element is the posterior (dorsal) one.

In thoracic vertebrae the costal element becomes the rib, which is an independent bone with joints with the vertebral column. The entire transverse element thus forms the transverse process. In a cervical vertebra the two elements form the bone around the foramen transversarium. The major portion of this bony 'ring' is the costal element, a small posterior part is the transverse element. The 7th cervical vertebra is especially prone to the costal element forming a cervical rib.

In lumbar vertebrae almost the entire topographical transverse process is formed by the costal element. The transverse element is reduced to a tubercle on the posterior side. The same is true for sacral vertebrae. The most obvious transverse process (costal element really) is the ala of the sacrum.

The picture of the cervical transverse process in the lab manual is reproduced here :



TP is the entire transverse process. C is the costal element, forming the anterior and lateral bony boundaries of the foramen. T is the true transverse element.

2. Describe the movements of the vertebral column with reference to its regions.

This refers mainly to the possible movements in the different regions. The students must first understand the terminology used for these movements and then explain the anatomical factors that allow or impede these movements.

Bending forwards and its reverse are simply 'flexion' and extension. In the vertebral column the term "lateral flexion" is used for bending sideways (as against abduction/adduction elsewhere in the body).

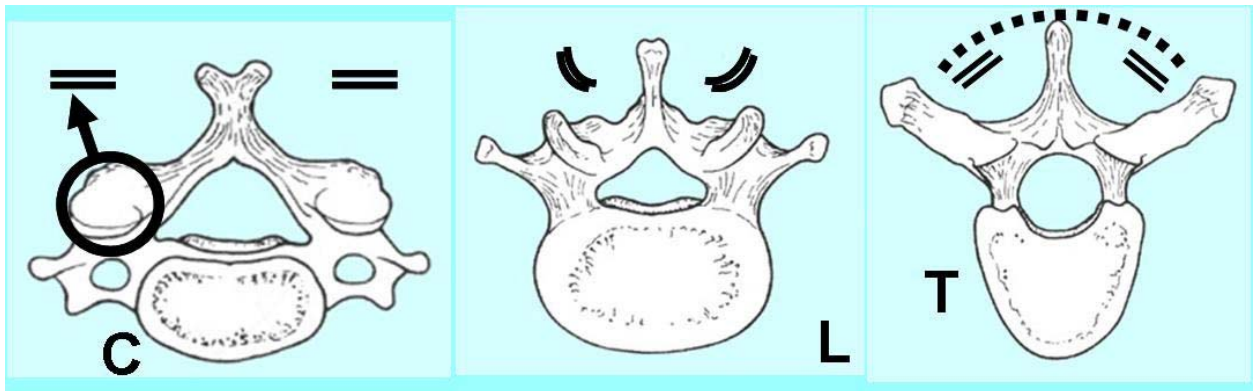
Deformability of the fibrocartilaginous intervertebral disc between the bodies of vertebrae is the main factor allowing these movements. The fibrocartilage effectively also prevents excessive movement between adjacent vertebrae which would be deleterious to the delicate spinal cord contained within. The plane synovial joints between the articular facets have simple gliding movements which allow the posterior parts of the vertebrae to adjust during these movements.

All these movements are best seen in the cervical and the lumbar column. The ribs restrict them to a significant degree in the thoracic column.

Axial rotation between vertebrae is again dependent on the torsional deformation of the discs. However, here the articular facets determine whether such movements are facilitated or not. In the cervical column the facets are sloping; rotation is limited somewhat, and is accompanied by some degree of lateral flexion.

In the lumbar column the facets are reciprocally curved (the superior facets are concave, the inferior facets convex. This 'locks' the vertebrae so far as rotation goes. Virtually no rotation is possible here.

In the thoracic column the facets are flat and vertical, and the right and left facets are located along an 'arc'. The thoracic column is best suited for axial rotation.

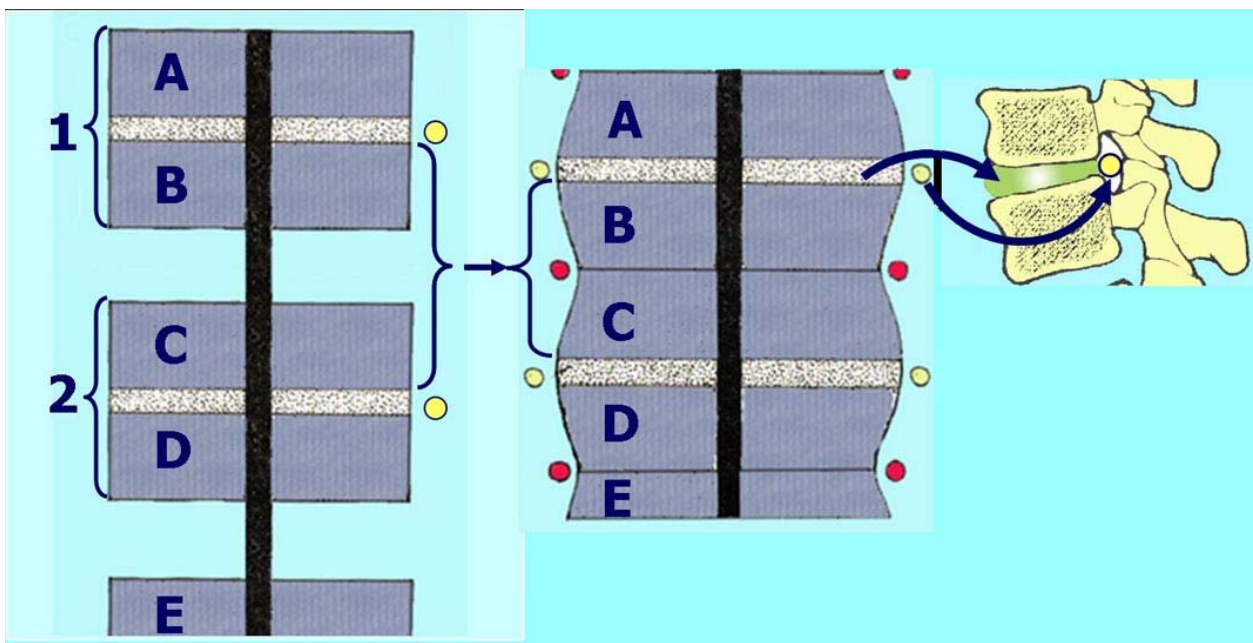


(The picture above cannot show the slope of the cervical facets.)

In animals which are arboreal 'swingers' the thoracic column is longer.

3. Explain the statement : "A vertebra is intersegmental, while a spinal nerve is segmental".

A vertebra develops from the fusion of adjacent halves of neighbouring somites. In each segment, the nerve more-or-less is in the centre, lined up against the future intervertebral disc. This is best explained with the help of a diagram.



4. Discuss the functional role of the intervertebral disc in terms of its histological structure.

Cartilage in general tends to resist compression. In white fibrocartilage, which is what the bulk of an intervertebral disc comprises, the abundance of collagen gives it some pliability. It can be deformed slightly. In all flexion/extension movements, one side of the disc is compressed while the opposite side is stretched. The collagen bundles also have a spiral disposition – fibres runs in spirals in opposite directions. This arrangement allows and at the same time, keeps within limits the twisting of the disc in movements of axial rotation.

(small amounts of movement between adjacent vertebrae are summed up, giving the entire column significant range of movement.)

Essay Question

Explain the primary and secondary curvatures of the human vertebral column.

The body of the foetus is highly curled up inside the uterus. The foetal vertebral column conforms to this and is curved with a concavity forwards. A curvature of the vertebral column which is concave forwards is described as a primary curvature, as it is the first curvature seen in the column.

After birth, though the baby can now stretch, the column retains its primary curvature for a few weeks.

Around three months after birth, the posterior neck muscles become stronger as the baby learns to “hold the head”, and gradually the cervical column changes its curvature to one that is convex forwards.

By six months of age the baby begins to sit, and the soon learns to stand and to walk. This involves strength in the lumbar column and the posterior muscles in this region become stronger. Now the lumbar column also changes its curvature to one that is convex forwards. The thoracic and sacral parts of the columns do not change their curvature.

The curvatures of the cervical and lumbar column appear later, and are called secondary curvatures.

1. Explain the terms epaxial and hypaxial with reference to the development of muscles.

The axis of the embryo is determined by the notochord. Soon the vertebral column develops around it, enclosing the spinal cord.

Muscles which are developmentally dorsal to the axis, that is, the vertebral column in topographic description, are epaxial (“epi-axial”) muscles. Muscles ventral to the column are hypaxial (“hypo-axial”). Epaxial muscles are supplied by the dorsal rami of spinal nerves, hypaxial muscles by the ventral rami.

The above description is the core of the topic. However, ensure that you understand the following :

- Some hypaxial muscles (limb muscles) are attached to the posterior sides of vertebrae. The topographical attachment does not make a muscle epaxial. (You do not need to identify or know the details of such muscles in this unit, but the latissimus dorsi and the rhomboid muscles of the upper limb are examples of hypaxial, limb muscles attached to the vertebral column).
- Epaxial muscles develop from epimeres, which are dorsal parts of myotomes, which in turn are parts of somites. Students often confuse these terms.
- The only epaxial muscles are those dorsal to the vertebrae. All other *trunk and limb* muscles are hypaxial.
- Finally, make sure you understand the roots and rami of spinal nerves! (See the diagram with the MCQ exercise below).

2. Discuss the statement : “The anatomical location of a muscle does not necessarily indicate its development, whereas its nerve supply does”.

Though the segmental pattern is evident in the thoracic and abdominal walls, some muscle masses do migrate from the original site of development. Almost always, a migrating muscle carries its nerves (especially motor nerves) with it. The migrating muscle mingles with its new surroundings, but the *real clue to its development is therefore in its nerve supply*.

The best example you have come across in this unit is that of the diaphragm. Its attachment to the ribs is intimately associated with the transversus abdominis. However, the bulk of diaphragmatic ***muscle*** tissue develops from cervical segments 3, 4 and 5. It is supplied by the phrenic nerve, which carries fibres from segments C3, 4 and 5, indicating its development.

(Having said this, I must state that the development of the diaphragmatic muscle is a subject of debate. It is believed that at least a part of the muscle develops in situ from local mesenchyme and that it does receive a part of its nerve supply from intercostal nerves in the vicinity. On the other hand, it is also said that the intercostal supply is mainly sensory. **This debate is *not* core material for this unit.**)

Other notable examples (not core material again), include the brachioradialis, a flexor of the elbow by action, but is supplied by the nerve of the extensors (radial nerve).

The trapezius on the other hand, is attached to vertebral spines, functionally a muscle of the upper limb. But it is neither epaxial nor hypaxial. Indeed, it is a big mystery – the muscle develops along the lines of branchial arch muscles, but there is no known arch that can be said to give rise to the trapezius. Those of you who study Functional Anatomy ANHB 2213 will learn about this and the branchial arches next semester.

3. Explain the nerve supply of the abdominal wall muscles in terms of their development.

This topic has two aspects.

One : All “body wall” muscles are hypaxial; therefore supplied by ventral rami of spinal nerves.

Two. When head folding is completed, there is still a large “defect” in the ventral body wall. This is the umbilical portal, which gradually narrows down to become the umbilicus. ***Muscle masses from the thoracic part of the body wall converge obliquely on to this defect as the abdominal wall develops.*** These muscle masses carry their nerves with them. Thus, the abdominal wall muscles are supplied by ventral rami of nerves T6 to T12. The only lumbar nerve contributing to this wall is L1.

4. What are the functional differences between the abdominal and thoracic walls?

Structurally, both have some common features : they are layered from outside inwards – skin, muscle (with connective tissue on either side) and coelomic cavity lining. There is a specific major neurovascular plane in both.

The thoracic wall has ribs, which separate the segmental muscle strips, each supplied by a segmental nerve. The ribs act as anchors / levers for the muscles to act, bringing about movements of respiration.

The abdominal muscles essentially form a “pressure jacket” around the cavity and are largely concerned with maintaining and changing intra-abdominal pressure.

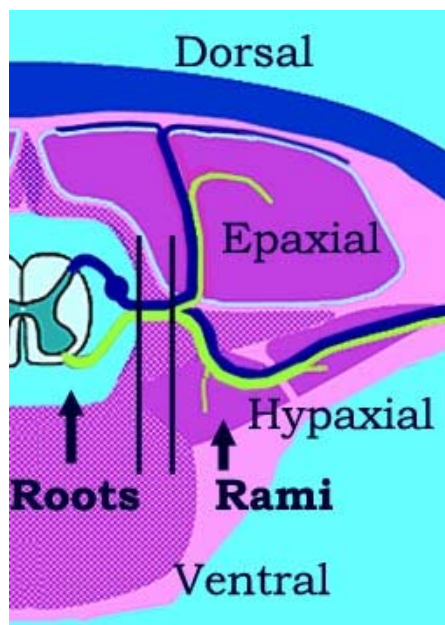
It is very tempting to say that the ribs have a protective function towards the delicate lungs. I do not deny that there is some truth in this. However, delicate abdominal organs require similar protection, which they lack! I personally like to think of ribs as levers for respiratory movements. Needless to say that in the event of a fracture, a rib can be an instrument of death if the pleura or a lung is punctured!

MCQ exercise

Regarding epaxial muscles :

- A. They are muscles which connect the limbs to the spines of the vertebrae.
- B. They are supplied by the dorsal roots of the spinal nerves.
- C. They are supplied by the ventral rami of the spinal nerves.
- D. They include BOTH erector spinae and transversospinalis groups of muscles.
- E. They include all muscles that act on the vertebral column.

Discussion.



A. Limb muscles are hypaxial, irrespective of their attachments. Some limb muscle anchor the limbs to the vertebral column by attaching to spines of vertebrae. Some anatomists and textbooks call such muscles “extrinsic muscles of the vertebral column”. *This term is misleading and should be avoided, as primarily they are not muscles of the vertebral column at all.*

B. Confusion between roots and primary rami is eternal! Roots are either sensory (dorsal) or motor (ventral), are located within the vertebral canal, and form a mixed spinal nerve.

Primary rami are mixed nerves, outside the vertebral canal.

Dorsal rami supply epaxial muscles and a band of skin overlying them.

Ventral rami supply hypaxial muscles and the rest of the skin (except in the head region where cranial nerves and branchial arch muscles are present).

C. Explanation as above!

D. Yes, both these groups are developmentally epaxial. The group also includes suboccipital muscles.

E. "All muscles acting on the column" include ventral muscles like longus colli. Even psoas major belongs to this category (though they do not know that yet). These are hypaxial. Besides, muscles of the abdominal wall, and in certain circumstances even those like latissimus dorsi (they do not know this) can act on the vertebral column. These muscles are not epaxial.

1. Compare and contrast the development of the right and the left atria.

Both atria have parts which develop from the primitive common atrium and parts that develop from 'absorption' of other embryonic structures.

The parts that develop from the primitive atrium have a rough internal surface. (It is important to note that this 'roughness' at an anatomical level, as seen in a specimen; not histological. Histologically endothelium gives any blood vessel or a chamber of the heart a smooth surface.)

The rough part of the right atrium is its right wall, in front of the crista terminalis. The 'roughness' is due to parallel bands of atrial myocardium raising ridges on the interior. These are the 'pectinate muscles'. The auricle also has a rough surface with criss-cross muscle bands.

The smooth part of the right atrium develops from the sinus venosus. This part receives the superior and inferior venae cavae and the coronary sinus. *Note that the facts that this part develops from the sinus venosus and that it receives the vein are mutually supportive.*

In the left atrium the rough part is confined to a small area of and around the auricle. The rest of the left atrium develops by absorption of the pulmonary veins.

Even the smooth parts do have myocardium, it is just that the muscle is uniformly spread and does not raise ridges on the interior.

For the interested student : the left 'horn' of the sinus venosus becomes the coronary sinus.

2. Explain the mechanism of the passage between the right and left atria and its closure at birth. (You do not have to begin the story with the cardiogenic mesoderm! 😊)

The interatrial partition is formed by **two septa, each with a foramen** in it.

The **two foramina do not overlap**.

During foetal life blood flows through one foramen, then between the septa and into the left atrium through the second foramen.

At birth, the first breath opens up capillary beds in the lung and there is a rush of blood from the lungs into the left atrium. This equalises the pressures in the atria and the septa are pressed together. Since the two foramina do not overlap, no blood flow is possible across the partition.

This causes 'functional closure' of the passage. Over the subsequent weeks/months, connective tissue develops between the partitions and the septum becomes a single anatomical entity.

This functional explanation is the core material we are looking for. It is 'nice to know' the names of the septa and the foramina. Facing the right atrium is the septum secundum with the foramen ovale; facing the left atrium is the septum primum with the foramen secundum. (The foramen primum is lost pretty early during development.)

Do not feel burdened with too many Latin terms. The names can be easily remembered if you understand their meanings. This is quite easy as the names are phonetically similar to English words. Primum = first, secundum = second, ovale = oval.

We do NOT want details of the appearance and progress of the two septa and their foramina – not core material; in fact, not necessary. We are driving concepts as against detail.

The fact that the septum secundum is thicker is explained in the discussion on Question 4.

3. Explain in brief the functions of the ductus arteriosus and the ductus venosus.

Ductus arteriosus. Blood flowing out from the right ventricle has “nowhere to go” as the pulmonary circulation is minimal. This blood must be diverted to the aorta. This is done by the ductus arteriosus.

Ductus venosus. Blood from the placenta is brought to the foetus by the umbilical vein. The vein enters the area of the liver and joins the portal vein. This ordinarily would cause all the placental blood to flow through the liver. Ductus venosus acts as a bypass to direct the flow to the inferior vena cava. The liver gets its due share of this blood through its artery.

Besides this basic explanation, these statements raise some question/s, the answers to which are of fundamental importance. One might ask :

1. Why does blood need to flow into the right ventricle at all, if there is a passage between the atria?”.

If all blood flowed from the right atrium to the left and none through the right ventricle, the right ventricle would not develop properly. It is a basic embryological principle that a blood vessel (or a chamber of the heart) which not used for blood flow, disappears. In the foetal heart, the openings of the SVC and IVC are so arranged the blood from the IVC flows to the left atrium, and blood from the SVC has a direct route to the right ventricle.

2. If the blood in the aorta distal to the ductus arteriosus is mixed with deoxygenated blood, does it not affect the development of the lower half of the body?

Agreed, the blood coming through the ductus arteriosus is blood originally from the SVC. However, despite the mixture, it has enough oxygen content for the lower part of the body to develop.

It is interesting how nature has favoured some parts of the body during foetal development.

Blood flowing through the umbilical vein (from the placenta) indeed has the highest oxygen content. This blood is not used in this state by any part of the body. The next in line is the blood in the IVC. Now, this blood *largely* goes to the left atrium through the septum, and it is this blood that flows through the branches of the aorta going to the head (brain), neck and the upper limbs.

It is not surprising to see that during foetal life and at birth the head is the best developed and the largest part of the body. The abdomen is smaller, the pelvis still smaller and the lower limbs are the smallest.

4. What are the anatomical features in or around the heart which tell some story about its development?

1. Fossa ovalis. This is an oval depression, facing the right atrium, on the interatrial septum. The septum secundum is a fairly thick structure. When the two septa come together, the outline of the foramen ovale remains.

For the interested student : The closure of the passage between the atria is functional to start with. Fibrous tissue unites the septa later, and this ‘anatomical closure’ may not always be complete or perfect. By careful dissection, one can often separate the septa in a specimen.

2. Ligamentum arteriosum. This is the fibrous remnant of the ductus arteriosus. It connects the pulmonary trunk (more accurately the left pulmonary artery, but that is not core material) to the aorta. The connection to the aorta is at a point beyond (distal to) the origins of the three major branches of the arch. This is explained with Q 3 above.

3. The smooth and rough parts of the right atrium reflect the development from the sinus venosus and the embryonic atrium respectively, with the crista terminalis separating them.

The smooth part of the left atrium is the absorbed portions of pulmonary veins.

Other vascular remnants which are not really “in or around the heart”. All foetal blood vessels which are not required after birth undergo functional closure first and are later replaced by fibrous cords. These are : Umbilical arteries (two in number) from the internal iliac arteries to the umbilicus.

Umbilical vein (one) : becomes the round ligament of the liver (ligamentum teres). (None of the following is core material : Note that there are two umbilical veins to start with, but the right one disappears very early. Throughout most of embryonic life and all foetal life, there is only one umbilical

vein. It brings blood from the placenta and leads towards the portal vein – again, to be precise, the left branch of the portal vein.)

Ductus venosus : bypasses the liver by connecting the left branch of the portal vein to the inferior vena cava. This becomes the fibrous cord called ligamentum venosum.

Yet another interesting fact (*definitely NOT core material!*): since the closure of the umbilical vein is functional to begin with, this vein can be used to give a blood transfusion to a newborn baby during the first few days of life. Babies suffering from the effects of a Rhesus factor incompatibility have widespread destruction of their RBCs and may need a transfusion. Indeed, even the ligamentum teres in adult life shows a fibrous wall with an endothelial lumen within.

No MCQ exercise or essay this week!

1. Explain the term “fibre” as used in the histology of connective tissue, muscle and nervous tissue.

“Fibre” is a descriptive term used for a long, threadlike structure. This leads to considerable conceptual confusion.

In connective tissue fibres are noncellular (and extracellular!) structures. They are the products of the principal cells of connective tissue. Thus we speak of collagen, elastic and reticular fibres. In nervous tissue, nerve fibres are processes of neurons – either axons or peripheral processes of sensory neurons. (I personally do *not* prefer the use the term dendrite for the latter, as dendrites are short, thick and branched structures. The peripheral processes of sensory neurons, like axons, can be myelinated conduct impulses at high speeds and usually do not summate small potential changes).

The use of the word fibre for a muscle cell is unfortunate. It stems from the long appearance of a skeletal muscle cell. A skeletal muscle ‘fibre’ is a skeletal muscle cell : this concept needs to be driven home.

The use of the term fibre for a cardiac or smooth muscle cell is even more unfortunate, because these cells are in fact rather short.

While we do not aim to change the way the terms are used, every effort must be made to avoid misconceptions.

2. Explain the terms “muscle fascicle” and “motor unit”.

A lot of confusion was seen regarding the use of these terms in CA 1.

A muscle fascicle is a structural concept – it includes skeletal muscle cells in a bundle that is wrapped in a connective tissue envelope.

A motor unit is a functional concept. It includes one motor nerve fibre and all the muscle cells supplied by it through terminal arborizations. The key point is : *muscle cells belonging to a motor unit can be scattered in different fascicles.*

When a motor neuron fires an action potential, all muscle cells in the motor unit contract as one cell. A few motor units contracting leads to a contraction that is not very strong. When greater force is required, more and more motor units are ‘recruited’.

3. Explain, on developmental and functional basis, the fact that skeletal muscle cells are multinucleated.

A skeletal muscle cell necessarily spans long distances, both on histological and anatomical scale. It is impractical for such long cells to be maintained by a single nucleus, due to the sheer volume of active cytoplasm to be supported.

Fewer cells need fewer neurons to control them. (*Remember : skeletal muscle is paralysed without neuronal control!*)

During development, skeletal muscle cells are formed by the fusion of many smaller cells resulting in long, multinuclear cells.

In this sense, a single skeletal muscle cell is a true syncytium – structural and functional. (Syncytium literally means “cells together”.)

4. Discuss : “Cardiac muscle combines the functional properties of skeletal and smooth muscle, and is unique in its own way”.

Cardiac muscle is striated. Striations are due to an orderly arrangement of myofibrils. A well-organised muscle cell is capable of a very rapid contraction. In this sense it is like a skeletal muscle cell.

However, like smooth muscle, it is made of short, uninucleate cells. Both cardiac and smooth muscle cells form sheets around a cavity and control the pressure within the cavity. Like smooth muscle, cardiac muscle is autorhythmic, regulated by nerves, not dependent on nerves.

Thus, cardiac muscle shares properties with both skeletal and smooth muscle.

Unlike both, cardiac muscle must go on contracting regularly and without stopping. Physiologically, cardiac muscle has a long ‘refractory’ period. After one action potential, no stimulus can make it contract prematurely until the refractory period is over. This maintains both regularity and efficiency. A mass of cardiac muscle cells also *functions* as a syncytium, due to intercalated discs being gap junctions. (Syncytial properties are also seen in smooth muscle, but structurally obvious discs are a feature of cardiac muscle.)

Essay guidelines :

Describe the connective tissue components in a skeletal muscle and their functional importance.

Fine layers of connective tissue cover all muscle cells individually. These are called endomysium. Fascicles (bundles) of muscle cells are enveloped by partitions called perimysium. The connective tissue sheet covering an entire muscle is called epimysium.

Connective tissue sheets surrounding muscles and separating adjacent muscles allow them to function independently of each other. Such partitions also create additional areas for muscle attachments. Within a muscle, connective tissue partitions allow passage of nerves and blood vessels.

All connective tissue elements converge towards the ends of muscles where they help in attachment to bones. Many muscles have long tendons. Composed largely of dense bundles of collagen, they resist stretching and effectively transmit the force of a muscle to the bone. Tendons also have a smaller sectional area and can concentrate the force of the muscle on a small area of a bone.

1. Explain the nature of the sphincters at the two ends of the stomach.

In general : a sphincter is a mechanism which guards the passage between two organs. It is a relatively thick mass of muscle cells arranged in a circular manner. A sphincter allows controlled passage of contents from one organ to the next and also prevents backflow.

The sphincter between the oesophagus and the stomach primarily prevents backflow from the stomach. The striking feature of this sphincter is that there is no visible, anatomical thickening of the circular muscle. It is just the state of contraction (tone) of muscle that makes it function as one. However, other factors are believed to aid in this function. These are : The angle between the oesophagus and the fundus and the oesophageal opening in the right crus of the diaphragm which acts as a 'pinchcock'.

The pyloric sphincter is an anatomical sphincter, a thickening of the circular muscle. After food has stayed in the stomach for a while, this sphincter allows gradual release of the contents into the duodenum. For the interested (not core material) : disturbed function of the oesophageal sphincter cause 'reflux' of acidic contents in the oesophagus.

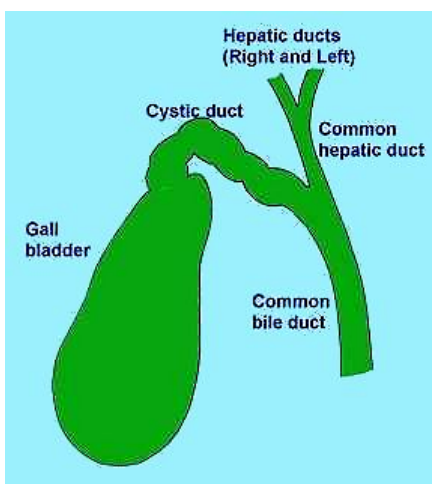
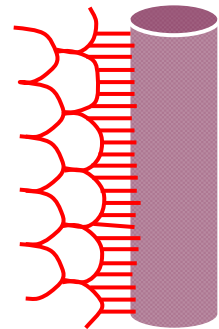
2. Explain the anatomical and histological basis of the rich blood supply of the digestive tube.

At the gross anatomical level, the arteries that supply branch and anastomose before entering the digestive tube. In the stomach and the colon, such anastomotic channels run close the wall. In the small intestines, the repeated branching and anastomosis gives the appearance of arterial arcades (illustrated here).

Within the gut wall, the arteries run to the submucosa where they aform a rich plexus. From this plexus branches go inwards to the mucosa and outwards to the external muscle coat.

The veins of the GI tract follow a similar pattern in reverse.

Make sure you understand the concept of 'anastomosis'.



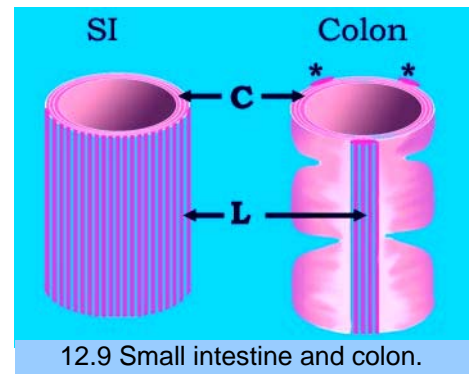
3. Describe the "extrahepatic biliary apparatus" with the help of a simple diagram.

This is what is expected, with the little bit about the duct opening in the duodenum thrown in. No, the colour is meant to enhance *this* illustration, their drawing needs only lines!

Continued on the next page...

4. Compare and contrast the anatomical features of the small intestine and the colon.

The small intestine is a tube of fairly uniform diameter, the interior shows folds which run along the circumference (plicae circulares). The colon has its longitudinal muscle coat arranged in three bands, the taeniae coli. The colon is also “gathered up” to have sac- or pouch like appearance (haustration).



MCQ exercise

The division of the liver into two functional lobes is based on the

- A. attachment of the falciform ligament.
- B. attachment of the lesser omentum.
- C. areas supplied by the branches of the portal vein.**
- D. A and C.
- E. A, B and C.

Discussion.

A and B are the false ones as they are *anatomical landmarks, not functional features.*

The functional lobes are determined by the areas of supply of the right and left branches of the portal vein, hepatic artery and the two bile ducts. C is the only option that relates to the functional division.

The exact line between the functional lobes is not core material. For the interested student : on the visceral surface this line runs between the IVC and the caudate lobe and continues between the gall bladder and the quadrate lobe. On the diaphragmatic surface the line is drawn about 2 cm to the right of the falciform ligament.

1. Describe the structure of the walls of the pelvis.

The key points are :

When we say 'walls of the pelvis' we mean the true pelvis. The bony components are the ischium and the pubis, part of the ilium below the arcuate line and the sacrum.

These parts have gaps in between – the obturator foramen and the greater sciatic notch (also the lesser sciatic notch). These are closed by the obturator membrane and muscle and the piriformis respectively.

Mention must be made of the pelvic diaphragm for closing the inferior aperture; and the fact that a large part of this muscle is attached to fascia lining the obturator internus.

2. Discuss : “The pelvic diaphragm is the most important support of the pelvic organs”.

Pelvic diaphragm is the strong muscular sheet closing the inferior aperture of the pelvis. Even though pelvic organs have other ligamentous structures anchoring them to the walls, these usually cannot compensate for a weak diaphragm. The urinary bladder is in a safe position and prolapse is rare. The organ most susceptible to prolapse is the uterus. In case of the uterus, the round and the broad ligaments are not much by way of supports. The strongest ligament is the transverse cervical. Yet, a pelvic diaphragm weakened by repeated childbirth (not common these days!) is a key factor in prolapse.

3. Explain the anatomical basis of measuring the dimensions of a bony pelvis.

During childbirth the baby passes through the inlet, cavity and the outlet of the pelvis. All these must be adequate for the passage.

The A-P diameter of the inlet is between the promontory of the sacrum and the anterior (upper) border of the pubic symphysis. There are no bony landmarks for the transverse diameter – it is simply the greatest dimension at right angles to the A-P.

At the outlet the A-P diameter is between the tip of the coccyx (movable) and the posterior (lower) border of the symphysis. The transverse diameter is between the ischial tuberosities.

For this unit, obstetrical details like all oblique diameters, dimensions of the mid-cavity are not core knowledge.

(Though not a part of this question, it is worth mentioning that these are dimensions of the dry bones. In real life there are soft tissue of the wall which in turn are somewhat compressible; and factors like laxity of ligaments under hormonal influence and the moulding of the foetal head. We shall learn about the ossification of the foetal head in Week 13.)

4. What are types of a normal female pelvis? How are they likely to influence the process of childbirth?

A perfect gynaecoid pelvis is best suited for childbirth. An android pelvis (heart-shaped inlet) is likely to cause difficulty. An anthropoid pelvis has an A-P diameter greater than the transverse at the inlet, but this not necessarily a cause of difficulty in childbirth. A platypelloid pelvis has a disproportionately large transverse diameter – again it is a cause of difficulty only in extreme cases.

1. Describe the anatomical differences between the male and female urinary bladder.

The bladder in the male has the prostate around the exit of the urethra, is posteriorly related to the ductus deferens, seminal vesicles and the rectum with the rectovesical pouch of peritoneum.

The bladder in the female is related to the uterus with the rectouterine (rectovaginal) pouch in between.

Well, I guess one doesn't have to say that the bladder in the female has no prostate around it, nor the ductus or the seminal vesicle posterior to it... 😊.

2. Describe the urogenital diaphragm. How does it differ between males and females?

The urogenital diaphragm is in the anterior region (urogenital triangle) of the perineum inferior to the pelvic diaphragm. It comprises skeletal muscle and acts as the external sphincter for the urinary passage. In the female it also surrounds the vagina, is generally smaller and somewhat weaker.

The key point is that you should not confuse it with the pelvic diaphragm.

3. Describe the sphincters of the anal canal.

The internal sphincter is made of smooth muscle and is a continuation and a thickening of the circular muscle coat of the rectum. The external sphincter surrounds the internal sphincter and is made of skeletal muscle. The external sphincter is continuous with the pelvic diaphragm, specifically levator ani.

For this unit I would consider this adequate. It is the concept, not the detail you need.

4. What are the anatomical implications of the development of the anal canal?

The upper part develops from the hindgut (epithelium is endodermal). The lower part is ectodermal.

The blood supply of the upper part is from the inferior mesenteric artery, venous drainage via inferior mesenteric vein to the portal vein, lymphatic drainage to the pre-aortic group of lymph nodes ("abdominal" would do as well), and the nerve supply is of the visceral type.

The external part has blood supply and venous drainage with the internal iliac system, lymphatics leading to inguinal nodes (like the entire perineum) and nerve supply of the somatic type.

The veins in the wall (submucosa) are an example of porta-systemic anastomoses.

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Tutorial : Week 12**Date : 21 May 2009****Topic : Ontogeny and phylogeny; Lobules lobules etc.**

1. **How does the development of the kidney reflect the statement “Ontogeny recapitulates phylogeny”?**
2. **What other examples can you cite in support of the statement? What are its limitations?**

Combined discussion for Q 1 and 2 :

Ontogeny refers to the development of an organism, particularly the process of organogenesis. Phylogeny is the evolution of species. After the publication of Darwin's Origin of Species, many biologists thought that during its development an organism passes through all the stages of its evolutionary history. This was the origin of the famous phrase "Ontogeny recapitulates phylogeny" by Ernst Haeckel. Since Darwin's time, however, many studies have demonstrated that the relationship between ontogeny and phylogeny is not as simple as Haeckel originally thought. We know now, for example, that in the course of development, structures can be added or subtracted from those of ancestors, or their development can be accelerated or retarded.

It may be said (with some reservations) that the embryonic development of an organism recapitulates embryonic developmental stages of ancestors.

The development of kidneys is perhaps a good example, where successive stages in vertebrate evolution appear to be recapitulated in mammalian development. The pronephros functions as the kidneys in the adults of a few species. Most fishes and amphibians have a mesonephric kidney. Mammals have a kidney which develops from the metanephros.

The development of the heart is another example. The early heart with no left-right partition, but with the primitive chambers resembles that of a fish. An incompletely partitioned heart (atria separate, common or incompletely partitioned ventricle) resembles that of some amphibia. The reptilian heart is rather complex, adapted to special circumstances, and the pattern differs among reptilian species. In general it can be said that the partitioning is better than in amphibia. Some mixing of oxygenated and deoxygenated blood does occur in these three classes, though in amphibia and reptiles a basic ‘spiral’ valve separates the two streams. In birds and mammals the partitioning of the ventricles is complete. Partitioning of ventricles allows the left side of the heart to develop high pressure without the risk of damaging pulmonary circulation. Higher left ventricular pressure ensures speedy and efficient delivery of blood to the body. These classes also have the sinus venosus absorbed in the atrium – it is no longer required to pump low-pressure venous blood to the atria.

Another good example of how structures are added to or deleted from a common blueprint is provided by the evolution of branchial arch pattern. These structures form the respiratory apparatus in fishes. With the evolution of lungs we do not need these gill arches. The genetic mechanism for the development of these structures has been modified and used in land vertebrates to form some structures of the head and neck. This is studied in the second semester unit 213! (Though a reference was made to this during a lecture).

3. Give examples of organization of lobes and lobules from your area of study of anatomy and histology.

Lobe simply means a part of a solid organ. Lobule is the diminutive form, meaning a smaller part. In this limited sense, it is a descriptive term, based on gross observation. Lobes are *visually* defined by fissures or other landmarks. Sometimes the boundaries are landmarks with little or no functional significance (as in the case of *anatomical* lobes of the liver), or may even be arbitrary, as in the case of the cerebrum. (We are **not** concerned with the lobes of the cerebrum here).

The anatomical and histological concept goes deeper than that. In the case of a gland, portions served by the major tributaries (“branches” if you like!) of the main duct can be considered as lobes, which in many cases are separated by major partitions of connective tissue from the capsule. Smaller portions served by smaller ducts are the lobules. Lobes and lobules may therefore be considered as smaller and smaller units in the functional hierarchy, *built around some central structures*.

The concept is played out as modifications of the same theme in different organs.

In the lung, the anatomical landmarks correspond with the functional and histological organisation – each functional unit has a bronchus or a bronchiole along a branch of the pulmonary artery as the central structures.

In the liver, the functional lobes bear little correspondence with anatomical landmarks. Even the line joining the IVC and the gall bladder coincidentally demarcates the lobes on the visceral surface. (You are NOT expected to know the details of this anatomical landmark, the *concept* of functional lobes based on the pattern of the portal vein, hepatic artery and the bile ducts is enough.)

In the kidney, one medullary pyramid with its cap of cortex is a lobe of the kidney. The concept of lobule in the kidney requires knowledge of its histology (medullary rays and surrounding nephrons) which is beyond the scope of this unit.

4. Explain the term parenchyma and stroma, giving examples.

Parenchyma refers to the principal *functional* tissue of an organ. Secretory portions of a gland, hepatocytes of the liver, alveoli of the lungs all comprise the parenchyma of these structures.

Stroma is the connective tissue framework. It may be the thick or thin partitions of connective tissue, easily seen as pink bands in H & E stained sections especially in salivary glands or the pancreas; or the fine reticular fibre networks in highly cellular, delicate tissues (like lymph nodes).

One may say that the stroma defines the pattern or the “architecture” of an organ. Interestingly, the origin of the term parenchyma bears this out. Parenchyma means something that is poured in beside... you build the framework and pour in the functional mass!