Physiology in Childbearing

with Anatomy and Related Biosciences

THIRD EDITION

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Pregnancy—The Mother

Hormonal control of calcium and phosphorus metabolism

Regulation of calcium balance is closely associated with that of phosphate. There is continuous exchange of calcium between different sites (calcium pools) in the body. Three hormones control calcium and phosphorus metabolism by maintaining the concentration of calcium in ECF. These are parathyroid hormone (PTH), vitamin D and calcitonin. Plasma inorganic phosphate is more loosely controlled than calcium (Hinson et al 2007).

If there is no change in the amount of skeletal calcium, ECF calcium level depends on the balance between calcium absorption in the gut and its excretion in urine and faeces. About 50% of calcium in the blood passing through bone capillaries is exchanged in a single passage and about 300 mmol of calcium is involved in calcium exchange between blood and bone every day.

Parathyroid hormone

Four parathyroid glands which are embedded in the thyroid gland secrete parathyroid hormone (PTH). PTH increases the concentration of Ca^{2+} in blood and depresses plasma phosphate concentration by acting on bone and kidneys. PTH increases osteocyte reabsorption of bone with a rapid release of calcium and phosphorus into the blood. Calcium reabsorption in the kidney tubules is increased but the excretion of phosphate is increased. This results in a rise in plasma calcium and a fall in plasma phosphate. PTH activity is directly related to serum calcium concentration. When plasma calcium level rises, PTH production falls, resulting in calcium deposition in bone, and vice versa.

Vitamin D

The D vitamins are steroid substances formed from ergosterol in plants and 7-dehydrocholesterol in animals. Ultraviolet radiation modifies these to ergocalciferol (vitamin D_2) and cholecalciferol (vitamin D_3). Humans can either ingest vitamin D from plants and animals or manufacture it by the action of sunlight on skin to form cholecalciferol. Vitamin D has to be further metabolised by adding hydroxyl groups before it can become active. The liver first converts it to 25-hydroxycholecalciferol and the kidney produces the active form 1,25-dihydroxycholecalciferol (calcitriol) in response to PTH stimulation. Calcitriol is released into the circulation and transported to its target organs of intestine, bone and kidneys (Hinson et al Chew 2007).

Calcitonin

Calcitonin is secreted by the parafollicular cells (clear or C cells) of the thyroid gland. Its main effect is opposite to PTH, causing a fall in plasma calcium and phosphate concentrations. This hormone may play a part in skeletal growth in children but appears to have no role in adults other than in pregnant women. Calcitonin secretion is directly related to plasma calcium concentration.

The pelvic girdle

The pelvic girdle offers attachment for the lower limbs and for support of the pelvic and, to some extent, the abdominal organs. In an upright posture the pelvic girdle transmits the weight of the trunk to the legs, so the sacroiliac joints must be strong and stable. The size, shape and rigidity of the pelvic girdle is related directly to bipedal locomotion and the human pelvis compared to other primates is short, squat and basin-shaped (Trevathan et al 1999).

The mammalian spine is highly efficient for walking on four legs as the abdominal organs are suspended from a single horizontal arch (the backbone). This single arch is present in the human neonate but when babies sit up their spines develop a forward curve near the top. When babies stand their spines develop a second forward curve near the base. Both curves are essential for maintaining an upright posture.

The evolving changes in pelvic shape placed limits on the baby’s head size, limiting human gestation length and resulting in an immature baby (Morgan 1990), a feature referred to as altricial (see Ch. 57). The gynaeocoid pelvis is adapted for giving birth to a comparatively
The nature of bone—the female pelvis and fetal skull

![Diagram of the female pelvis](image)

**Figure 24.3** The outer or lateral surface of the right innominate bone. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)

large-headed baby but mechanisms of labour are necessary to facilitate descent of the head through the pelvis. These include passive alterations to fetal position and moulding of the fetal skull.

**Pelvic bones**

Although diagrams and text can illustrate features of the pelvis there is no substitute for handling a life-size model. Familiarity with the shape and size of the pelvis may enable life-saving decisions to be made. During vaginal examinations relevant pelvic features must be identified in vivo.

The pelvis is made up of four irregularly shaped bones: **two innominate bones** forming the lateral and anterior walls, and the **sacrum** and **coccyx** forming the posterior wall. Each innominate bone consists of three fused bones: the ilium, ischium and pubis. These were formed as cartilage in the fetus and their ossification centres begin to fuse at puberty and is completed about age 25. The description of these bones is mirrored to the left and right of the pelvis.

**The ilium**

The ilium has an upper flat plate of bone and forms part of the **acetabulum** below (Figs 24.3, 24.4). The external part of the plate of bone is curved and has a roughened surface for attachment of the **gluteal muscles** which form the buttocks. The inner surface forms the **iliac fossa** which is smooth and concave. The **iliacus muscle**, which forms a platform on which the abdominal organs rest, originates from this surface. The upper ridge of the ilium is called the **iliac crest** and is S-shaped. The muscles of the abdominal wall have attachments to this surface.

At the anterior end of the iliac crest is the **anterior superior iliac spine**, which can be identified under the skin. At the posterior end is the **posterior superior iliac spine**, marked externally by a dimple at the level of the second sacral vertebra. Two **inferior iliac spines**, anterior and posterior, can be found below the superior spines. The lower margin of the ilium forms two-fifths of the acetabulum where it fuses with the ischium and pubis. Behind the acetabulum the ilium forms the **greater sciatic notch**, through which nerves from the sacral plexus pass. Above the greater sciatic notch is the area of the ilium which articulates with the sacrum at the **sacroiliac joint**.

**The ischium**

The ischium forms the lowest aspect of the innominate bone. The upper part forms two-fifths of the acetabulum, where it fuses with the ilium and pubis. Below the acetabulum, a thick buttress of bone called the **ischial tuberosity** takes the weight of the seated body. The **hamstring muscles** of the thigh arise from this bone. Passing upwards and inwards from the ischial tuberosity,
a shaft of ischium meets the inferior ramus of the pubic bone to form the pubic arch.

The ischium also forms the lower border of the obturator foramen, a large opening in the lower part of the innominat bone below the acetabulum. On its internal surface, protruding from its posterior edge and about 5 cm above the tuberosity is the ischial spine, an important landmark to be found on virginal examination. The ischial spine separates the greater sciatic notch from the lesser sciatic notch.

The pubis

This square-shaped bone forms the anterior aspect of the innominat bone. The two pubic bones articulate medially to form a joint called the symphysis pubis. Laterally, the superior ramus of the pubic bone forms one-fifth of the acetabulum. The superior ramus also forms the upper boundary of the obturator foramen. The inferior ramus passes downwards and outwards to join the ischium and form the pubic arch. The upper surface of the pubis forms the pubic crest ending laterally in the pubic tubercle.

The sacrum

The sacrum is a shield-shaped mass of bone formed from five fused sacral vertebrae (Fig. 24.5). It articulates with the two innominat bones at the sacroiliac joints. The anterior surface is smooth and concave, both from above downwards and from side to side, forming the hollow of the sacrum. The first sacral vertebra overhangs the sacral hollow and the central point of this projection is called the sacral promontory. Through the centre of the bone, sacral and coccgeal nerves pass in the sacral canal.

Four pairs of foramina (openings) are present anteriorly between the five fused sacral vertebrae where sacral nerves exit to form the sacral plexus. Posteriorly, posterior branches of the sacral nerves pass through eight small foramina to supply the skin of the buttocks and the muscles of the lower back. On its upper surface a smooth oval area forms an articular surface for the fifth lumbar vertebra to form the lumbosacral joint. Lateral masses of bone on either side of the sacrum are called the wings of the sacrum or sacral alae.

The coccyx

This small triangular bone with its base uppermost is made of four fused coccgeal vertebrae. The first coccgeal vertebra articulates with the lower end of the sacrum to form the sacrococcygeal joint. The rudimentary vertebrae forming the rest of the coccyx are smooth on their inner surface and support the rectum. The external anal sphincter is attached to the lowest point.

Pelvic joints

There are four pelvic joints: one symphysis pubis, two sacroiliac and one sacroccygeal joint:

- The symphysis pubis consists of an oval disc of fibrocartilage about 4 cm long lying between the two pubic bones. The joint is reinforced by ligaments crossing from one pubic bone to the other.
- The sacroiliac joints are synovial joints with a cavity filled with synovial fluid, a capsule formed of synovial membrane and tough external supporting ligaments. There are very strong posterior ligaments which transmit the weight of the trunk, head and arms to the legs. Movement of these joints is slight but increases in range during pregnancy when relaxin softens the ligaments.
- The sacroccygeal joint lies between the sacrum and coccyx. There is sometimes a small synovial joint cavity present. Slight movement can occur backwards and this is increased greatly when the baby’s head passes through the pelvis in labour.

Pelvic ligaments

Besides the ligaments supporting the pelvic joints, there are three other pairs of ligaments:

- The sacrotuberous ligament crosses from the posterior superior iliac spine and the lateral borders of the sacrum and coccyx to the ischial tuberosity. It bridges the greater and lesser sciatic notches.
- The sacrospinous ligament passes in front of the sacrotuberous ligament from the side of the sacrum and coccyx, crosses the greater sciatic notch and attaches to the ischial spine.
- The inguinal ligament (Poupart’s ligament) runs from the anterior superior iliac spine to the pubic tubercle and forms the groin.
Regions of the pelvis

There is a clear line of bone called the pelvic brim separating the upper flare of the iliac fossae which is the false pelvis from the basin-shaped part of the pelvis which is the true pelvis. The true pelvis has a cavity and outlet through which the fetus passes during birth.

The pelvic brim

Landmarks are identifiable on the pelvic brim (inlet) and important measurements are made between them. In the normal gynecomid (female) pelvis the brim is oval in shape with the anteroposterior diameter reduced. The sacral promontory and the symphysis pubis, the landmarks are (Fig. 24.6):

- The sacral promontory.
- The sacral ala.
- The upper border of the sacroiliac joint.
- The iliopectineal line.
- The iliopectineal eminence.
- The inner upper border of the superior pubic ramus.
- The inner upper border of the body of the pubis.
- The inner upper border of the symphysis pubis.

If a piece of paper is placed across the landmarks, an imaginary flat surface is formed. This is called a plane and the concept is also applied to the cavity and outlet. The pelvic diameters are measured from landmarks across the planes.

The pelvic cavity

The cavity is that part of the pelvis between the brim and the outlet. It is a curved canal with a short anterior surface measuring 4.5 cm, formed by the inner aspect of the pubic bones and symphysis pubis and a longer posterior surface measuring 12 cm formed by the hollow of the sacrum. The lateral walls are formed from the greater sciatic notch, the inner surface of part of the ilium, the body of the ischium and the obturator foramen. The plane of the pelvic cavity is taken from the midpoint of the symphysis pubis anteriorly to the junction of the second and third sacral vertebrae posteriorly.

The pelvic outlet

Two pelvic outlets, the anatomical and the obstetric outlets, may be described. The anatomical outlet is traced from the lower border of the symphysis pubis along the pubic arch to the inner border of the ischial tuberosity and along the sacrotuberous ligament to the tip of the coccyx. It is of no value in labour as it is not a flat surface, just the lower border of the pelvis. It varies in size during labour because of the range of backwards tilting of the coccyx in different women. The obstetric outlet, which is the constricted lower portion of the true pelvis, is a more useful landmark and its structures are:

- The lower border of the symphysis pubis.
- A line passing along the pubis, obturator foramen and ischium to the ischial spine.
- The sacrospinous ligament.
- The lower border of the sacrum.

The plane of the outlet is an imaginary flat surface between these structures which is occupied by the muscles of the pelvic floor (Ch. 25).

Pelvic dimensions (diameters)

Measurements are taken of the planes of the brim, cavity and outlet, using the landmarks described above, in three directions: anteroposterior, oblique and transverse.

Figure 24.6 • The pelvic brim. 1, sacral promontory; 2, sacral ala; 3, sacroiliac joint; 4, iliopectineal line; 5, iliopectineal eminence; 6, superior pubic ramus; 7, body of pubic bone; 8, symphysis pubis. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier)
Table 24.1 gives the average measurements for a gynaecoid pelvis.

The brim
- The smallest diameter of the brim is the anteroposterior diameter which is measured from the upper part of the symphysis pubis to the sacral promontory. This is the anatomical conjugate which measures 12 cm. However, this is not available for accommodating the fetal head. If the measurement is taken from the inner border of the symphysis pubis to the sacral promontory the measurement is 11 cm; this is the obstetric conjugate. Both of these two measurements can be referred to as the true conjugate. The diagonal conjugate, measured during pelvic assessment, is taken from the lower border of the symphysis pubis to the sacral promontory and measures 13 cm. It is normally difficult to measure because its length exceeds the reach of most people. If the sacral promontory is reached, the obstetric conjugate is calculated by subtracting 2 cm.
- The two oblique diameters are taken from one sacroiliac joint to the opposite ileoprecinal eminence. They are right and left after the corresponding sacroiliac joint. All the oblique diameters of the pelvis are 12 cm.
- The transverse diameter is taken between points on the ileoprecinal lines that are further apart and measures 13 cm. The descending colon passes the left sacroiliac joint and may limit the space available for passage of the fetus.
- The sacrococcygeal diameter is a brim measurement taken from the sacral promontory to the ileoprecinal eminence. It measures 9.5 cm and in an occipitoposterior presentation the fetal parietal eminences may become caught in this diameter, causing the head to extend.

The cavity
- The cavity is considered to be circular in diameter and the measurements taken through its plane are 12 cm.

The obstetric outlet
- The outlet is diamond-shaped with its longer diameter being anteroposterior. This is measured from the lower border of the symphysis pubis to the sacrococcygeal joint and is 13 cm.
- The oblique diameter has no fixed points but is between the obturator foramen and the opposite sacrospinous ligament. It is 12 cm.
- The transverse diameter is measured between the two ischial spines and is 11 cm.

Pelvic inclination
When a person stands up the pelvic basin is tilted with the plane of the brim forming an angle of 80° to the horizontal. If the reader stands facing and pressed up against a vertical surface, the two points touching that vertical surface are the pubic bones and the anterior superior iliac spines. The plane of the cavity forms an angle of 30° and that of the outlet 15° (Fig. 24.7). Three other angles are important indicators of pelvic size all of which should measure at least 90°:
1. The subpubic angle of the pubic arch.
2. The sacral angle lying between the plane of the brim and the anterior surface of the first sacral vertebra.
3. The greater sciatic notch.

Axes of the pelvic canal
If imaginary lines are drawn at right-angles through the pelvic planes, axes can be created. If these lines are joined together a curve called the curve of Carus can be traced because each plane is at a different angle to the horizon. This unique feature of the human pelvis is the price paid for an upright posture as it makes delivery of the
fetus more difficult. Instead of an easy journey through a straight pelvic canal, the fetus must be moved passively by mechanisms to overcome the changing curves and diameters (Figs 24.8, 24.9).

Basic types of pelvis

There are four basic types of pelvis described according to the shape of the brim and other features (Fig. 24.10). These are gynaecoid, android, anthropoid and platypelloid. However, many pelves cannot be classified as easily as they contain features of different types. It is now considered that the size of the pelvis in relation to the fetus is more important than a slight abnormality of shape and there is a saying that ‘the fetal head is the best pelvimeter’.

The gynaecoid pelvis

This ideal female pelvis which is associated with women of average height and shoe size 4 or over has:

- A rounded brim.
- Large forepelvis (that portion in front of the widest transverse diameter).
- A transverse diameter that bisects the anteroposterior diameter.
- Parallel side walls.
- A shallow cavity.
- Blunt ischial spines.
- A wide sciatic notch.
- A pubic angle of 90°.

The android pelvis

This pelvis has male features:

- A brim that is more heart-shaped.
- A narrow forepelvis.
- A widest transverse diameter set towards the back.
- Side walls which converge.
- A straight sacrum.

- A funnel-shaped cavity.
- Prominent ischial spines.
- Subpubic and greater sciatic notch angles of less than 90°.

Figure 24.8 • The axis of the birth canal. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)

Figure 24.9 • The curve of the birth canal. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)

Figure 24.10 • Shapes of the pelvic brim. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)
Women with this type of pelvis may be of short stature, heavily built and tend to be hirsute. There may be an occipitoposterior position of the fetal head at the commencement of labour and this is the least suitable pelvis for childbearing as it becomes narrower as the fetus descends (Fig. 24.11).

The anthropoid pelvis

This pelvis has an oval brim with the anteroposterior diameter greater than the transverse. This is found in other primates and anthropoid means ape-like. There is:

• Reduction in the transverse diameter but the pelvis tends to be large all over.
• The side walls diverge.
• The sacrum is long and deeply concave.
• There may be a sixth sacral vertebra present, especially in tall African women. This is called a high assimilation pelvis.
• The ischial spines are not prominent.

• The angle of the greater sciatic notch is wide.
• The subpubic angle may be normal or wide.

The fetus may present with the occiput anterior or posterior but the pelvis is so large that delivery occurs without rotation.

The platypelloid pelvis

This pelvis (Fig. 24.12) is flat with:

• A reduced anteroposterior diameter.
• A kidney-shaped brim.
• Side walls that diverge.
• A flat sacrum.
• A shallow cavity.
• Blunt ischial spines.
• The greater sciatic notch and subpubic angles are wide.

The fetal head may have difficulty negotiating the brim, a feature that will be discussed in the chapters on labour, but once through the brim there should be no further difficulty.
Maternal physiological adaptations in pregnancy

Calcium and phosphorus metabolism in pregnancy

Calcium

Maternal calcium metabolism is altered during pregnancy to meet fetal needs for skeletal mineralisation, especially in the third trimester. Absorption and urinary excretion are increased. Maternal serum levels begin to fall shortly after fertilisation and reach their lowest at 30 weeks of pregnancy. These changes are reversible following delivery and cessation of lactation. Although bone mineral density falls during lactation, prolonged breastfeeding does not lead to permanent osteoporosis.

Fetal plasma calcium level exceeds that of the mother, suggesting that the mineral is actively transported across the placenta. Calcitonin and PTH cannot cross the placenta so the fetus must manufacture its own. The placenta can transfer vitamin D to the fetus and also synthesise vitamin D. During pregnancy maternal calcium, phosphorus and magnesium levels fall due to increased production of PTH, calcitonin and vitamin D. There may be an increase in calcium storage in preparation for lactation, but an increase in dietary calcium does not increase bone density. Any increase in bone calcium due to hPL is counterbalanced by oestrogen causing decreased reabsorption.

Diet

These changes are independent of calcium intake and supplements are unnecessary in countries where dietary intake is adequate. Supplementation may be needed in adolescents and where dietary insufficiency is suspected. The total extra calcium needed by term is about 25–30g (Blackburn 2007). Some foods such as those containing excessive fats, phytates (found in some vegetables) and oxalates interfere with the absorption of calcium by forming calcium salts in the intestine. High sodium intake may also interfere with calcium absorption.

Vitamin D

Levels of active vitamin D (calcitriol) show a small rise by 10 weeks of pregnancy although staying within normal limits. They rise above normal in the last few weeks. However, there is little elevation in either intact PTH or calcitonin levels. Intestinal absorption of vitamin D is enhanced throughout pregnancy.

Diet

An increased intake of vitamin D is needed to ensure maternal and fetal needs for calcium are met and 400 IU/day is advised. Supplementation is advisable if dietary intake is poor or there is poor exposure to sunlight. Milk is an excellent source of calcium, phosphorus and vitamin D. Women who cannot drink milk should take cheese, yoghurt, sardines, whole grain foods or green leafy vegetables.

Phosphorus and magnesium

Serum inorganic phosphate and magnesium levels fall slightly until 30 weeks and return to non-pregnant levels by term. These changes are related to haemodilution.

Diet

Although phosphorus is essential during pregnancy, high intake levels limit calcium absorption while high plasma levels increase urinary excretion of calcium. Processed
meats, snack foods and cola drinks all have high phosphorus but low calcium levels.

Clinical implications

Leg cramps

Pregnant women may suffer from intense, sudden cramping pain in the calf muscles, especially during the third trimester. These tend to occur in bed. Lowered serum ionised calcium and increased phosphates are thought to be responsible for the muscle spasm. Respiratory alkalosis may precipitate muscle spasm. Thrombophlebitis causing calf pain must be ruled out. Cramps may be prevented by reducing milk and processed food intake and performing stretching exercises before retiring. Jimenez (1994) suggested that taking calcium salts that are phosphate-free or taking the antacid aluminium hydroxide may prevent phosphorus absorption and correct the balance.

Restless leg syndrome

This disorder is seen in about 10–15% of pregnant women and usually occurs about 15 min after going to bed. There is a burning, twitching feeling in the lower leg and the more the wish to fidget is resisted, the worse the sensation becomes. The cause is unknown. Iron and folic acid deficiency have been implicated and replacement therapy has helped. Circulatory problems may be involved. Walking about and applying a cold compress help.

Backache in pregnancy

About 50% of pregnant women experience backache and it is more likely to be reported in very young women, women reporting back pain before pregnancy and multiparous women. Postural changes, overstretched abdominal muscles, strained back muscles and the effect of relaxin on the pelvic ligaments may contribute to backache. Other problems such as urinary tract infection should be ruled out before offering advice. Occasionally the woman may be in labour. More rarely, demineralisation of bone may cause back and hip pain (Davis 1996).

Relaxin

Relaxin is a small peptide which probably acts as a growth hormone affecting collagen. It appears to be a potent stimulator of uterine growth in pregnancy and is involved in the softening and effacement of the cervix and in the onset of labour. During pregnancy it helps to restrain uterine muscle contractility.

With progesterone, relaxin causes relaxation of the ligaments and muscles, reaching its maximum effect in the last few weeks of pregnancy. Relaxation of the symphysis pubis and sacroiliac joints leads to instability of the pelvic girdle and relaxation of the sacrooccipital joint allows extra backwards movement. These changes increase the pelvic diameters to facilitate birth. Some women develop a rolling gait and, as the developing weight and position of the uterus change the centre of gravity, the woman leans backwards to compensate, exaggerating the normal lumbar curve which leads to backache. Assessment of backache includes:

- Location and extent of pain.
- Onset and duration of pain.
- Nature and degree of pain.
- Any other symptoms.
- Relationship to activities.
- Self-treatment strategies.

In the absence of serious pathology localised heat or massage may help. The woman should rest and take analgesics. A supporting elasticated sacroiliac belt may help and a maternity girdle will support the uterus and relieve strain. Early advice on posture with exercise to strengthen the back muscles may be preventative. Shoes should have a heel of no more than 0.5–1.0 inch.

Rickets and osteomalacia

Malabsorption of calcium is caused by a deficiency in vitamin D due to a low intake. This is sometimes combined with low exposure to sunlight. The bones are poorly ossified and soft and become deformed. In childhood the condition is called rickets and in adults osteomalacia. Distortion of the pelvis may occur, leading to severe problems in childbirth, possibly requiring caesarean section. Low bone density is still more common in young South Asian women due to hypovitaminosis D (low vitamin D) (Roy et al 2007).

Spinal cord injury

Paraplegic or quadriplegic women can have a successful outcome to their pregnancy. Although there are dangers of urinary tract infections, constipation and pressure sores, these can be avoided. Uterine contractions in labour are mainly independent of neurological control and labour should progress normally. Pain may be perceived if the spinal lesion is below T10. Delivery of the baby may need to be assisted if the control of muscles used in active expulsion is lost.
The fetal skull

The shape and size of the human pelvis creates difficulties in the birthing process not found in other primates. This is further compounded by the large size of the fetal brain. At birth babies weigh about 3300g of which 335g is brain. The brain continues to grow at fetal rates for the next 20 months to reach 1000g. Brain growth then slows down to reach adult size of 1400g by age 8 years. A newborn gorilla weighs 2000g of which only 225g is brain, already half the adult size of 450g after a gestation only 6 days shorter than the human pregnancy (Morgan 1994). Gorillas have very easy births! In humans evolutionary changes have developed to facilitate delivery:

- Birth when the fetus is very immature.
- Rapid brain growth after delivery.
- Flexion of the fetal head on its neck so that the narrowest diameters pass through the pelvis.
- Moulding of the skull bones to change the shape from ovoid to cylindrical.

Anatomy of the skull

The fetal skull is ovoid in shape and the bones can be divided into the vault, the face and the base. The vault extends from the orbital ridges to the base of the occiput and contains the brain which rests on the base of the skull. For the purposes of measurement and to describe the degree of flexion and extension in the different presentations, the fetal skull is divided into regions of face, brow, vertex and occiput (Fig. 24.13).

- The face extends from the chin to the orbital ridges.
- The brow or sinciput is the area of the two frontal bones, extending from the orbital ridges to the anterior fontanelle.
- The vertex is bounded by the anterior fontanelle, the posterior fontanelle and the two parietal eminences.
- The occiput is the area over the occipital bone, extending from the posterior fontanelle to the nape of the neck.

The face and base of the skull are laid down in cartilage and are almost completely ossified by birth. The vault is composed of flat bones which develop from membrane. Ossification centres within the membrane lay down bone around them.

Bones: the vault

Five main bones make up the vault with two others helping to form the lateral walls – the squamous (flattened) portion of the temporal bones. Each bone is named for the portion of the brain lying beneath it:

- Two frontal bones whose ossification centres are indicated by the frontal bosses.
- Two parietal bones whose ossification centres are indicated by the parietal eminences.
- Two squamous portions of the temporal bones.
- One occipital bone whose ossification centre is indicated by the occipital protuberance.

Ossification is incomplete at birth and membranous sutures remain between the bones and membranous fontanelles where two or more sutures meet. These membranous areas facilitate moulding of the fetal skull during birth. They also provide landmarks that can be identified during vaginal examination (Fig. 24.14).

The sutures

- The frontal suture lies between the two frontal bones.
- The sagittal suture runs from the anterior to the posterior fontanelle, uniting the two parietal bones.
- The lambdoidal suture (it resembles the Greek letter lambda—ƛ) lies between the posterior edges of the parietal bones and the occipital bone.
- The coronal suture separates the posterior edges of the two frontal bones from the anterior edges of the two parietal bones.

The fontanelles

There are two main fontanelles:

- The anterior fontanelle or bregma is diamond-shaped and formed at the junction of four sutures: the frontal,
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*Figure 24.14* The fetal skull, showing the bones, fontanelles and sutures. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)

Parietal and two halves of the coronal sutures. It measures 2.5 cm across by 3 cm long and is not fully closed by ossification until 18 months of age.

- The posterior fontanelle or lambda is much smaller and triangular in shape and formed at the junction of three sutures: the sagittal suture and the two halves of the lambdoidal suture. It closes by the 6th week after birth.

Besides these two non-significant fontanelles there are four minor fontanelles on the side walls of the vault. There are two temporal fontanelles at the ends of the coronal suture and two mastoid fontanelles at the ends of the lambdoidal suture. These are not of any significance in childbearing.

**Bones: the base**

The fused bones of the base of the skull are perforated by the foramen magnum which allows passage of the spinal cord leading from the brain.

**Diameters of the fetal skull**

Measurements of the skull are used to assess its size in relation to the maternal pelvis. Longitudinal diameters are taken between key landmarks so that the diameters presenting at the pelvis in different degrees of flexion or extension can be estimated (Figs 24.15, 24.16):

1. **Suboccipitobregmatic** is measured from the nape of the neck to the centre of the anterior fontanelle. It is 9.5 cm and presents when the head is fully flexed.

2. **Suboccipitofrontal** is measured from the nape of the neck to the centre of the frontal suture. It is 10 cm and presents when the head is almost completely flexed.

3. **Occipitofrontal** is measured from the glabella (bridge of the nose) to the occipital protuberance. It is 11.5 cm and presents when the head is deflexed as in an occipitoposterior position.

4. **Mentovertical** is measured from the point of the chin to the highest point on the vertex. It is 13.5 cm and presents when the head is midway between flexion and extension in a brow presentation.

5. **Submentovertical** is measured from the junction of the chin with the neck to the highest point on the vertex. It is 11.5 cm and presents when the head is not fully extended in a face presentation.

6. **Submentobregmatic** is measured from the junction of the chin with the neck to the midpoint of the anterior fontanelle. It is 9.5 cm and presents when the head is fully extended in a face presentation.

Transverse diameters are also taken:

1. The **biparietal** is measured between the parietal eminences. It is 9.5 cm and is the widest transverse diameter.

2. The **bitemporal** is measured between the widest aspects of the coronal suture. It is 8 cm.

Circumferences of the skull are:

- **Suboccipitobregmatic**: 33 cm presents when the head is well flexed. The head engages, fits well onto the cervix and labour should progress easily.

- **Occipitofrontal**: 35 cm presents when the head is deflexed. Engagement is delayed, the membranes may rupture early and labour may be difficult.
The nature of bone—the female pelvis and fetal skull

Figure 24.16 • The diameters of the fetal skull in relation to the maternal pelvis. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Diameters increased</th>
<th>Diameter decreased</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex</td>
<td>Suboccipitobregmatic Biparietal</td>
<td>Mentovertical</td>
</tr>
<tr>
<td>Brow</td>
<td>Mentovertical Biparietal</td>
<td>Suboccipitobregmatic</td>
</tr>
<tr>
<td>Face</td>
<td>Submentobregmatic Biparietal</td>
<td>Occipitofrontal</td>
</tr>
<tr>
<td>Occipitoposterior</td>
<td>Occipitofrontal Biparietal</td>
<td>Submentobregmatic</td>
</tr>
</tbody>
</table>

- **Mentovertical**: 39 cm presents when the head is midway between flexion and extension. The head cannot descend into the pelvis unless it completes extension and labour is obstructed.

**Moulding**

Moulding of the fetal skull results in a change in shape but not size of the vault brought about by the pressures of the pelvis and pelvic floor during labour. The diameters which are compressed reduce in size by at least 0.5 cm while those at right-angles to them are elongated (Table 24.2). Vertex and brow presentations affect the same diameters but in opposite ways as do face presentation and occipitoposterior position. The sutures and fontanelles allow overlap of the bones in a typical way:

- The frontal bones are pushed under the anterior edge of the parietal bones.
- The occipital bone is pushed under the posterior part of the parietal bones.
- The medial edge of the leading parietal bone is pushed under the other parietal bone.
Moulding is abnormal if it involves wrong diameters (Fig. 24.17), if it is too rapid or too extreme so that the brain is compressed, all with a risk of intracranial damage.

**Caput succedaneum**

During labour, especially after rupture of the membranes, the fetal head is pressed against the ring of the dilating cervix. In cephalic presentations venous return of the scalp circulation is impeded and oedema forms in the loose tissues. This is a caput succedaneum and varies in size with the length and difficulty of the delivery (Fig. 24.18). Caput forms on the leading parietal bone which is the left one when the occiput is to the right and vice versa.

It forms on the anterior part if the position is occipitoanterior and posteriorly if the position is occipitoposterior.

**External features of the fetal skull**

The fetal scalp consists of five layers. From the inside out these are:

1. The *pericranium* which covers the outer surface of the bones and is firmly attached to the edges of the bones. Bleeding may occur between the bone and the pericranium to form a swelling called a *cephalhaematoma*. The size of the haematoma is limited by the attachment of the pericranium to that of the bone over which it forms.

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**Figure 24.17** Moulding of the fetal head. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)

**Figure 24.18** Caput succedaneum. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)
2. A loose layer of areolar tissue that permits limited movement of the scalp over the skull.

3. A layer of tendon known as the galea that is attached to the frontalis muscle anteriorly and the occipitalis muscle posteriorly.

4. A layer of subcutaneous tissue containing blood vessels and hair follicles. This is the part of the scalp affected by the caput succedaneum (see Fig. 24.18).

5. The skin.

Internal structures of the fetal skull

The meninges

The brain is surrounded by three membranes; from the inside out these are:

1. The pia mater is very delicate and has many tiny blood vessels. It is closely applied to the surface of the brain.

2. The arachnoid mater forms a loose brain covering and is attached to the pia mater by thread-like extensions which cross the subarachnoid space which contains the cerebrospinal fluid. Knob-like extensions of the arachnoid are called arachnoid villi and protrude into the dura mater into the dual sinuses which carry venous blood.

3. The outer, tough dura mater which is a double-layered membrane lines the skull with its periosteal layer and is reflected back onto the surface of the brain as the meningeal layer. In places the dura extends inwards to form septa that anchor the brain to the skull and limit movement.

Sinuses and venous drainage

There are two main folds of the dura mater. The falx cerebri is a double fold forming a partition between the two cerebral hemispheres. It is attached to the skull following the line of the frontal and sagittal sutures from the root of the nose to the internal aspect of the occipital protuberance. Its lower edge is unattached and sickle-shaped.

The tentorium cerebelli lies horizontally, separating the cerebrum from the cerebellum. It is at right-angles to the falx cerebri and is horseshoe-shaped. Each side of the horseshoe is attached laterally to the sphenoid bone and along the inner surface of the petrous portion of the temporal bone. It meets the falx at the inner aspect of the occipital protuberance. The brainstem passes in front of this junction of the two folds of dura mater.

Venous drainage is by channels in the dural folds called sinuses (Fig. 24.19):

1. The superior longitudinal sinus (sagittal) runs along the upper border of the falx cerebri.

2. The inferior longitudinal sinus (sagittal) runs along the lower border of the falx cerebri.

3. The straight sinus is a continuation of the inferior longitudinal sinus which runs posteriorly to join the superior longitudinal sinus.

4. The great vein of Galen joins the straight sinus at the junction with the inferior longitudinal sinus.

5. From the confluence of sinuses, the lateral sinuses pass along the line of attachment of the tentorium cerebelli and emerge from the skull to become the internal jugular veins of the neck.

When moulding is abnormal these membranes and sinuses may be torn, especially at the junction of the two folds of dura. The tentorium is most likely to be damaged and bleeding involves the great vein of Galen, the straight sinus and the inferior longitudinal sinus.

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Figure 24.19 • Internal structures of the fetal skull. (From Henderson C, Macdonald S 2004, with kind permission of Elsevier.)

Figure 24.20 • Arterial blood supply to the brain including the circle of Willis.
Blood supply to the brain

The arterial blood supply is by two internal carotid arteries and two vertebral arteries. The internal carotid arteries give off pairs of anterior, middle and posterior cerebral arteries. Each vertebral artery gives off a branch which supplies the cerebellum and medulla oblongata before uniting with its partner to form the basilar artery. The basilar artery gives off two pairs of arteries to the cerebellum and upper brainstem before dividing into two terminal branches that link up with the ends of the internal carotid arteries. In 25% of people three cerebral arteries remain on both sides of the brain but in the majority of people the vertebral arteries take over from the posterior cerebral arteries. The intercommunicating arteries at the base of the brain are called the circle of Willis (Fig. 24.20).

Main points

- Bone is a connective tissue consisting of an organic matrix called osteoid, a mineral matrix of calcium and phosphorus and bone cells. Bone can be divided into compact bone and spongy bone.
- Most bones have a tough outer perioseum and a cavity lining of endoosteum. Endoosteum contains osteoblasts, osteoclasts and their precursor cells. Osteoblasts synthesise bone and promote mineralisation of the cortex. Osteoclasts contain enzymes that remove both organic and mineral matrix.
- The skeleton contains 99% of the calcium and 85% of the phosphorus present in the body. Three hormones control calcium and phosphorus metabolism: parathyroid hormone, vitamin D and calcitonin.
- The pelvic girdle provides attachment for the lower limbs and support for the abdominal organs. The shape, size and rigidity of the pelvic girdle and the curved spine are related to bipedal locomotion and maintaining an upright posture.
- The pelvis is made up of two innominate bones, one sacrum and one coccyx. Each innominate bone consists of three fused bones: the ilium, ischium and pubis.
- The four pelvic joints are the symphysis pubis, two sacroiliac joints and the sacrocccygeal joint. Ligaments support each joint and three other pairs are present: the sacrotuberous, sacrospinous and inguinal ligaments.
- The pelvic brim separates the upper flare of the iliac fossae as known as the false pelvis above the brim from the basin-shaped true pelvis below the brim. The true pelvis forms the birth canal.
- Measurements are taken of the planes of the pelvic brim, cavity and outlet in three directions: anteroposterior, oblique and transverse.
- In the upright posture the pelvic basin is tilted in relation to the horizontal. Imaginary lines drawn at right-angles to the pelvic planes and joined together form the curve of Carus through which the fetus passes during birth. There are four basic pelvic types: gynaecoid, android, anthropoid and platypelloid.
- Maternal calcium metabolism alters to meet fetal needs for calcium and phosphorus for skeletal mineralisation. Serum calcium begins to fall soon after fertilisation and reaches its lowest level at about 39 weeks of pregnancy. Serum inorganic phosphate and magnesium levels fall slightly until 30 weeks and return to non-pregnant levels by term.
- Adequate calcium, phosphorus and vitamin D are essential in pregnancy. Foods which contain phytates and oxalates interfere with calcium absorption.
- Pregnancy problems related to calcium include leg cramps, restless leg syndrome and backache. Serious problems include rickets, osteomalacia and spinal cord injury.
- The bones of the fetal skull are divided into vault, face and base. The face and base are laid down in cartilage and are almost completely ossified by term. The vault is composed of flat bones which develop from membranes.
- The fetal skull is divided into regions of face, brow, vertex and occiput. Measurements of the skull are used to assess its size in relation to the maternal pelvis.
- Vault ossification is incomplete at birth so that membranous sutures and fontanelles remain between the bones. This allows the change in shape but not size, called moulding, to occur. Moulding is abnormal if it involves wrong diameters, is extreme or too rapid.
- The brain is surrounded by three meninges: the pia mater, the arachnoid mater and the dura mater. The dura mater covers the outer surface of the brain and dips down to form compartments. The two main folds are the falx cerebri and the tentorium cerebelli. Venous drainage is by sinuses lying in the dural folds.
- The arterial blood supply to the brain is from two internal carotid arteries and two vertebral arteries. The internal carotid arteries give off three pairs of anterior, middle and posterior cerebral arteries. The intercommunicating arteries at the base of the brain are known as the circle of Willis.
References


Annotated recommended reading


This endocrinology textbook is presented in a straightforward, easily readable manner. The content is of adequate depth for degree students but the text ensures that those with no previous knowledge can understand the principles.


This book is written by a specialist in human evolution. She discusses why our babies are so small and helpless at birth compared with other species. There are also insights into family relationships.


Prentice has collated what is currently known about calcium in pregnancy and lactation in a succinct manner. Although detailed, it is well set out and highly readable at the right level for midwifery students.


This is a slightly technical paper but important in its discussion of an ongoing medical phenomenon within a population in the UK.