# A&P Level 2

## Essay Questions

**Please provide answers on a separate answer sheet.**

1. Name the 5 types of bone.
2. Name the regions that make up the 26 vertebrae.
3. What is the largest bone in the body?

# The Reproductive System

The reproductive system or genital system is a system of sex organs within an organism which work together for the purpose of sexual reproduction.

## The Male Reproductive System

The male reproductive system includes the scrotum, testes, spermatic ducts, sex glands, and penis. These organs work together to produce sperm, the male gamete, and the other components of semen. These organs also work together to deliver semen out of the body and into the vagina where it can fertilize egg cells to produce offspring.

### Physiology of the Male Reproductive System

#### Spermatogenesis

Spermatogenesis is the process of producing sperm and takes place in the testes and epididymis of adult males. Prior to puberty, there is no spermatogenesis due to the lack of hormonal triggers. At puberty, spermatogenesis begins when luteinizing hormone (LH) and follicle stimulating hormone (FSH) are produced. LH triggers the production of testosterone by the testes while FSH triggers the maturation of germ cells. Testosterone stimulates stem cells in the testes known as spermatogonium to undergo the process of developing into spermatocytes. Each diploid spermatocyte goes through the process of meiosis I and splits into 2 haploid secondary spermatocytes. The secondary spermatocytes go through meiosis II to form 4 haploid spermatid cells. The spermatid cells then go through a process known as spermatogenesis where they grow a flagellum and develop the structures of the sperm head. After spermatogenesis, the cell is finally a sperm cell, or spermatozoa. The spermatozoa are released into the epididymis where they complete their maturation and become able to move on their own.

#### Fertilization

Fertilization is the process by which a sperm combines with an oocyte, or egg cell, to produce a fertilized zygote. The sperm released during ejaculation must first swim through the vagina and uterus and into the fallopian tubes where they may find an oocyte. After encountering the oocyte, sperm next must penetrate the outer corona radiata and zona pellucida layers of the oocyte. Sperm contain enzymes in the acrosome region of the head that allow them to penetrate these layers. After penetrating the interior of the oocyte, the nuclei of these haploid cells fuse to form a diploid cell known as a zygote. The zygote cell begins cell division to form an embryo.

### Anatomy of the Male Reproductive System

#### Scrotum

The scrotum is a sac-like organ made of skin and muscles that houses the testes. It is located inferior to the penis in the pubic region. The scrotum is made up of 2 side-by-side pouches with a testis located in each pouch. The smooth muscles that make up the scrotum allow it to regulate the distance between the testes and the rest of the body. When the testes become too warm to support spermatogenesis, the scrotum relaxes to move the testes away from the body’s heat. Conversely, the scrotum contracts to move the testes closer to the body’s core heat when temperatures drop below the ideal range for spermatogenesis.

#### Testes

The 2 testes, also known as testicles, are the male gonads responsible for the production of sperm and testosterone. The testes are ellipsoid glandular organs around 1.5 to 2 inches long and an inch in diameter. Each testis is found inside its own pouch on one side of the scrotum and is connected to the abdomen by a spermatic cord and cremaster muscle. The cremaster muscles contract and relax along with the scrotum to regulate the temperature of the testes. The inside of the testes is divided into small compartments known as lobules. Each lobule contains a section of seminiferous tubule lined with epithelial cells. These epithelial cells contain many stem cells that divide and form sperm cells through the process of spermatogenesis.

#### Epididymis

The epididymis is a sperm storage area that wraps around the superior and posterior edge of the testes. The epididymis is made up of several feet of long, thin tubules that are tightly coiled into a small mass. Sperm produced in the testes moves into the epididymis to mature before being passed on through the male reproductive organs. The length of the epididymis delays the release of the sperm and allows them time to mature.

#### Spermatic Cords and Ductus Deferens

Within the scrotum, a pair of spermatic cords connects the testes to the abdominal cavity. The spermatic cords contain the ductus deferens along with nerves, veins, arteries, and lymphatic vessels that support the function of the testes.

The ductus deferens, also known as the vas deferens, is a muscular tube that carries sperm superiorly from the epididymis into the abdominal cavity to the ejaculatory duct. The ductus deferens is wider in diameter than the epididymis and uses its internal space to store mature sperm. The smooth muscles of the walls of the ductus deferens are used to move sperm towards the ejaculatory duct through peristalsis.

#### Seminal Vesicles

The seminal vesicles are a pair of lumpy exocrine glands that store and produce some of the liquid portion of semen. The seminal vesicles are about 2 inches in length and located posterior to the urinary bladder and anterior to the rectum. The liquid produced by the seminal vesicles contains proteins and mucus and has an alkaline pH to help sperm survive in the acidic environment of the vagina. The liquid also contains fructose to feed sperm cells so that they survive long enough to fertilize the oocyte.

#### Ejaculatory Duct

The ductus deferens passes through the prostate and joins with the urethra at a structure known as the ejaculatory duct. The ejaculatory duct contains the ducts from the seminal vesicles as well. During ejaculation, the ejaculatory duct opens and expels sperm and the secretions from the seminal vesicles into the urethra.

#### Urethra

Semen passes from the ejaculatory duct to the exterior of the body via the urethra, an 8 to 10-inch-long muscular tube. The urethra passes through the prostate and ends at the external urethral orifice located at the tip of the penis. Urine exiting the body from the urinary bladder also passes through the urethra.

#### Prostate

The prostate is a walnut-sized exocrine gland that borders the inferior end of the urinary bladder and surrounds the urethra. The prostate produces a large portion of the fluid that makes up semen. This fluid is milky white in colour and contains enzymes, proteins, and other chemicals to support and protect sperm during ejaculation. The prostate also contains smooth muscle tissue that can constrict to prevent the flow of urine or semen.

Unfortunately, the prostate is also particularly susceptible to cancer. Thankfully, DNA health testing can tell you whether you’re at higher genetic risk of developing prostate cancer due to your BRCA1 and BRCA2 genes.

#### Cowper’s Glands

The Cowper’s glands, also known as the bulbourethral glands, are a pair of pea-sized exocrine glands located inferior to the prostate and anterior to the anus. The Cowper’s glands secrete a thin alkaline fluid into the urethra that lubricates the urethra and neutralizes acid from urine remaining in the urethra after urination. This fluid enters the urethra during sexual arousal prior to ejaculation to prepare the urethra for the flow of semen.

#### Penis

The penis is the male external sexual organ located superior to the scrotum and inferior to the umbilicus. The penis is roughly cylindrical in shape and contains the urethra and the external opening of the urethra. Large pockets of erectile tissue in the penis allow it to fill with blood and become erect. The erection of the penis causes it to increase in size and become turgid. The function of the penis is to deliver semen into the vagina during sexual intercourse. In addition to its reproductive function, the penis also allows for the excretion of urine through the urethra to the exterior of the body.

#### Semen

Semen is the fluid produced by males for sexual reproduction and is ejaculated out of the body during sexual intercourse. Semen contains sperm, the male reproductive gametes, along with many chemicals suspended in a liquid medium. The chemical composition of semen gives it a thick, sticky consistency and a slightly alkaline ph. These traits help semen to support reproduction by helping sperm to remain within the vagina after intercourse and to neutralize the acidic environment of the vagina. In healthy adult males, semen contains around 100 million sperm cells per millilitre. These sperm cells fertilize oocytes inside the female fallopian tubes.

## The Female Reproductive System

The female reproductive system includes the ovaries, fallopian tubes, uterus, vagina, vulva, mammary glands and breasts. These organs are involved in the production and transportation of gametes and the production of sex hormones. The female reproductive system also facilitates the fertilization of ova by sperm and supports the development of offspring during pregnancy and infancy.

### Physiology

#### The Reproductive Cycle

The female reproductive cycle is the process of producing an ovum and readying the uterus to receive a fertilized ovum to begin pregnancy. If an ovum is produced but not fertilized and implanted in the uterine wall, the reproductive cycle resets itself through menstruation. The entire reproductive cycle takes about 28 days on average, but may be as short as 24 days or as long as 36 days for some women.

#### Oogenesis and Ovulation

Under the influence of follicle stimulating hormone (FSH), and luteinizing hormone (LH), the ovaries produce a mature ovum in a process known as ovulation. By about 14 days into the reproductive cycle, an oocyte reaches maturity and is released as an ovum. Although the ovaries begin to mature many oocytes each month, usually only one ovum per cycle is released.

#### Fertilization

Once the mature ovum is released from the ovary, the fimbriae catch the egg and direct it down the fallopian tube to the uterus. It takes about a week for the ovum to travel to the uterus. If sperm can reach and penetrate the ovum, the ovum becomes a fertilized zygote containing a full complement of DNA. After a two-week period of rapid cell division known as the germinal period of development, the zygote forms an embryo. The embryo will then implant itself into the uterine wall and develop there during pregnancy.

#### Menstruation

While the ovum matures and travels through the fallopian tube, the endometrium grows and develops in preparation for the embryo. If the ovum is not fertilized in time or if it fails to implant into the endometrium, the arteries of the uterus constrict to cut off blood flow to the endometrium. The lack of blood flow causes cell death in the endometrium and the eventual shedding of tissue in a process known as menstruation. In a normal menstrual cycle, this shedding begins around day 28 and continues into the first few days of the new reproductive cycle.

#### Pregnancy

If the ovum is fertilized by a sperm cell, the fertilized embryo will implant itself into the endometrium and begin to form an amniotic cavity, umbilical cord, and placenta. For the first 8 weeks, the embryo will develop almost all the tissues and organs present in the adult before entering the foetal period of development during weeks 9 through 38. During the foetal period, the foetus grows larger and more complex until it is ready to be born.

#### Lactation

Lactation is the production and release of milk to feed an infant. The production of milk begins prior to birth under the control of the hormone prolactin. Prolactin is produced in response to the suckling of an infant on the nipple, so milk is produced if active breastfeeding occurs. As soon as an infant is weaned, prolactin and milk production end soon after. The release of milk by the nipples is known as the “milk-let-down reflex” and is controlled by the hormone oxytocin. Oxytocin is also produced in response to infant suckling so that milk is only released when an infant is actively feeding.

### Anatomy

#### Ovaries

The ovaries are a pair of small glands about the size and shape of almonds, located on the left and right sides of the pelvic body cavity lateral to the superior portion of the uterus. Ovaries produce female sex hormones such as oestrogen and progesterone as well as ova (commonly called “eggs”), the female gametes.

Ova are produced from oocyte cells that slowly develop throughout a woman’s early life and reach maturity after puberty. Each month during ovulation, a mature ovum is released. The ovum travels from the ovary to the fallopian tube, where it may be fertilized before reaching the uterus.

#### Fallopian Tubes

The fallopian tubes are a pair of muscular tubes that extend from the left and right superior corners of the uterus to the edge of the ovaries. The fallopian tubes end in a funnel-shaped structure called the infundibulum, which is covered with small finger-like projections called fimbriae. The fimbriae swipe over the outside of the ovaries to pick up released ova and carry them into the infundibulum for transport to the uterus. The inside of each fallopian tube is covered in cilia that work with the smooth muscle of the tube to carry the ovum to the uterus.

#### Uterus

The uterus is a hollow, muscular, pear-shaped organ located posterior and superior to the urinary bladder. Connected to the two fallopian tubes on its superior end and to the vagina (via the cervix) on its inferior end, the uterus is also known as the womb, as it surrounds and supports the developing foetus during pregnancy.

The inner lining of the uterus, known as the endometrium, provides support to the embryo during early development. The visceral muscles of the uterus contract during childbirth to push the foetus through the birth canal.

#### Vagina

The vagina is an elastic, muscular tube that connects the cervix of the uterus to the exterior of the body. It is located inferior to the uterus and posterior to the urinary bladder. The vagina functions as the receptacle for the penis during sexual intercourse and carries sperm to the uterus and fallopian tubes. It also serves as the birth canal by stretching to allow delivery of the foetus during childbirth. During menstruation, the menstrual flow exits the body via the vagina.

#### Vulva

The vulva is the collective name for the external female genitalia located in the pubic region of the body. The vulva surrounds the external ends of the urethral opening and the vagina and includes the mons pubis, labia majora, labia minora, and clitoris.

The mons pubis, or pubic mound, is a raised layer of adipose tissue between the skin and the pubic bone that provides cushioning to the vulva. The inferior portion of the mons pubis splits into left and right halves called the labia majora. The mons pubis and labia majora are covered with pubic hairs. Inside of the labia majora are smaller, hairless folds of skin called the labia minora that surround the vaginal and urethral openings. On the superior end of the labia minora is a small mass of erectile tissue known as the clitoris that contains many nerve endings for sensing sexual pleasure.

#### Breasts and Mammary Glands

The breasts are specialized organs of the female body that contain mammary glands, milk ducts, and adipose tissue. The two breasts are located on the left and right sides of the thoracic region of the body. In the centre of each breast is a highly pigmented nipple that releases milk when stimulated. The areola, a thickened, highly pigmented band of skin that surrounds the nipple, protects the underlying tissues during breastfeeding. The mammary glands are a special type of sudoriferous glands that have been modified to produce milk to feed infants. Within each breast, 15 to 20 clusters of mammary glands become active during pregnancy and remain active until milk is no longer needed. The milk passes through milk ducts on its way to the nipple, where it exits the body.

# The Nervous System

The nervous system consists of the brain, spinal cord, sensory organs, and all the nerves that connect these organs with the rest of the body. Together, these organs are responsible for the control of the body and communication among its parts.

The nervous system has 3 main functions: **sensory**, **integration**, and **motor**.

* **Sensory:** The sensory function of the nervous system involves collecting information from sensory receptors that monitor the body’s internal and external conditions. These signals are then passed on to the central nervous system (CNS) for further processing by afferent neurons (and nerves).
* **Integration:** The process of integration is the processing of the many sensory signals that are passed into the CNS at any given time. These signals are evaluated, compared, used for decision making, discarded or committed to memory as deemed appropriate. Integration takes place in the gray matter of the brain and spinal cord and is performed by interneurons. Many interneurons work together to form complex networks that provide this processing power.
* **Motor:** Once the networks of interneurons in the CNS evaluate sensory information and decide on an action, they stimulate efferent neurons. Efferent neurons (also called motor neurons) carry signals from the gray matter of the CNS through the nerves of the peripheral nervous system to effector cells. The effector may be smooth, cardiac, or skeletal muscle tissue or glandular tissue. The effector then releases a hormone or moves a part of the body to respond to the stimulus.

The brain and spinal cord form the control centre known as the **central nervous system (CNS)**, where information is evaluated and decisions made. The sensory nerves and sense organs of the **peripheral nervous system (PNS)** monitor conditions inside and outside of the body and send this information to the CNS. Efferent nerves in the PNS carry signals from the control centre to the muscles, glands, and organs to regulate their functions.

The majority of the nervous system is tissue made up of two classes of cells: **neurons** and **neuroglia**.

(I have added a diagram of nerve cell.)

### Neurons

Neurons, also known as nerve cells, communicate within the body by transmitting electrochemical signals. Neurons look quite different from other cells in the body due to the many long cellular processes that extend from their central cell body. The **cell body** is the roughly round part of a neuron that contains the nucleus, mitochondria, and most of the cellular organelles. Small tree-like structures called **dendrites** extend from the cell body to pick up stimuli from the environment, other neurons, or sensory receptor cells. Long transmitting processes called **axons** extend from the cell body to send signals onward to other neurons or effector cells in the body.

There are 3 basic classes of neurons:

* **Afferent neurons:** Also known as sensory neurons, afferent neurons transmit sensory signals to the central nervous system from receptors in the body.
* **Efferent neurons:** Also known as motor neurons, efferent neurons transmit signals from the central nervous system to effectors in the body such as muscles and glands.
* **Interneurons:** Interneurons form complex networks within the central nervous system to integrate the information received from afferent neurons and to direct the function of the body through efferent neurons.

### Neuroglia

Neuroglia, also known as glial cells, act as the “helper” cells of the nervous system. Each neuron in the body is surrounded by anywhere from 6 to 60 neuroglia that protect, feed, and insulate the neuron. Because neurons are extremely specialized cells that are essential to body function and almost never reproduce, neuroglia are vital to maintaining a functional nervous system.

### Brain

The brain, a soft, wrinkled organ that weighs about 3 pounds, is located inside the cranial cavity, where the bones of the skull surround and protect it. The approximately 100 billion neurons of the brain form the main control centre of the body.

The brain and spinal cord together form the central nervous system (CNS), where information is processed and responses originate. The brain, the seat of higher mental functions such as consciousness, memory, planning, and voluntary actions, also controls lower body functions such as the maintenance of respiration.

### Spinal Cord

The spinal cord is a long, thin mass of bundled neurons that carries information through the vertebral cavity of the spine beginning at the medulla oblongata of the brain on its superior end and continuing inferiorly to the lumbar region of the spine. In the lumbar region, the spinal cord separates into a bundle of individual nerves called the **cauda equina** (due to its resemblance to a horse’s tail) that continues inferiorly to the sacrum and coccyx. The white matter of the spinal cord functions as the main conduit of nerve signals to the body from the brain. The grey matter of the spinal cord integrates reflexes to stimuli.

### Nerves

Nerves are bundles of axons in the peripheral nervous system (PNS) that act as information highways to carry signals between the brain and spinal cord and the rest of the body. Each axon is wrapped in a connective tissue sheath called the **endoneurium**. Individual axons of the nerve are bundled into groups of axons called **fascicles**, wrapped in a sheath of connective tissue called the **perineurium**.

Finally, many fascicles are wrapped together in another layer of connective tissue called the **epineurium** to form a whole nerve. The wrapping of nerves with connective tissue helps to protect the axons and to increase the speed of their communication within the body.

* **Afferent, Efferent, and Mixed Nerves:** Some of the nerves in the body are specialized for carrying information in only one direction, like a one-way street. Nerves that carry information from sensory receptors to the central nervous system only are called **afferent nerves**. Other neurons, known as **efferent nerves**, carry signals only from the central nervous system to effectors such as muscles and glands. Finally, some nerves are **mixed nerves** that contain both afferent and efferent axons. Mixed nerves function like 2-way streets where afferent axons act as lanes heading toward the central nervous system and efferent axons act as lanes heading away from the central nervous system.

### Cranial Nerves

Extending from the inferior side of the brain are 12 pairs of cranial nerves. Each cranial nerve pair is identified by a Roman numeral 1 to 12 based upon its location along the anterior-posterior axis of the brain. Each nerve also has a descriptive name (e.g. olfactory, optic, etc.) that identifies its function or location.

The cranial nerves provide a direct connection to the brain for the special sense organs, muscles of the head, neck, and shoulders, the heart, and the GI tract.

### Spinal Nerves

Extending from the left and right sides of the spinal cord are 31 pairs of spinal nerves. The spinal nerves are mixed nerves that carry both sensory and motor signals between the spinal cord and specific regions of the body. The 31 spinal nerves are split into 5 groups named for the 5 regions of the vertebral column. Thus, there are 8 pairs of cervical nerves, 12 pairs of thoracic nerves, 5 pairs of lumbar nerves, 5 pairs of sacral nerves, and 1 pair of coccygeal nerves. Each spinal nerve exits from the spinal cord through the intervertebral foramen between a pair of vertebrae or between the C1 vertebra and the occipital bone of the skull.

### Meninges

The meninges are the protective coverings of the central nervous system (CNS). They consist of three layers: the dura mater, arachnoid mater, and pia mater.

* **Dura mater:** The dura mater, which means “tough mother,” is the thickest, toughest, and most superficial layer of meninges. Made of dense irregular connective tissue, it contains many tough collagen fibres and blood vessels. Dura mater protects the CNS from external damage, contains the cerebrospinal fluid that surrounds the CNS, and provides blood to the nervous tissue of the CNS.
* **Arachnoid mater:** The arachnoid mater, which means “spider-like mother,” is much thinner and more delicate than the dura mater. It lines the inside of the dura mater and contains many thin fibres that connect it to the underlying pia mater. These fibres cross a fluid-filled space called the subarachnoid space between the arachnoid mater and the pia mater.
* **Pia mater:** The pia mater, which means “tender mother,” is a thin and delicate layer of tissue that rests on the outside of the brain and spinal cord. Containing many blood vessels that feed the nervous tissue of the CNS, the pia mater penetrates the valleys of the sulci and fissures of the brain as it covers the entire surface of the CNS.

### Cerebrospinal Fluid

The space surrounding the organs of the CNS is filled with a clear fluid known as cerebrospinal fluid (CSF). CSF is formed from blood plasma by special structures called **choroid plexuses**. The choroid plexuses contain many capillaries lined with epithelial tissue that filters blood plasma and allows the filtered fluid to enter the space around the brain.

Newly created CSF flows through the inside of the brain in hollow spaces called **ventricles** and through a small cavity in the middle of the spinal cord called the **central canal**. CSF also flows through the subarachnoid space around the outside of the brain and spinal cord. CSF is constantly produced at the choroid plexuses and is reabsorbed into the bloodstream at structures called **arachnoid villi**.

Cerebrospinal fluid provides several vital functions to the central nervous system:

* CSF absorbs shocks between the brain and skull and between the spinal cord and vertebrae. This shock absorption protects the CNS from blows or sudden changes in velocity, such as during a car accident.
* The brain and spinal cord float within the CSF, reducing their apparent weight through buoyancy. The brain is a very large but soft organ that requires a high volume of blood to function effectively. The reduced weight in cerebrospinal fluid allows the blood vessels of the brain to remain open and helps protect the nervous tissue from becoming crushed under its own weight.
* CSF helps to maintain chemical homeostasis within the central nervous system. It contains ions, nutrients, oxygen, and albumins that support the chemical and osmotic balance of nervous tissue. CSF also removes waste products that form as by-products of cellular metabolism within nervous tissue.

### Divisions of the Nervous System

The nervous system is split into four divisions:

* **Central Nervous System (CNS):** The brain and spinal cord together form the central nervous system, or CNS. The CNS acts as the control centre of the body by providing its processing, memory, and regulation systems. The CNS takes in all the conscious and subconscious sensory information from the body’s sensory receptors to stay aware of the body’s internal and external conditions. Using this sensory information, it makes decisions about both conscious and subconscious actions to take to maintain the body’s homeostasis and ensure its survival. The CNS is also responsible for the higher functions of the nervous system such as language, creativity, expression, emotions, and personality. The brain is the seat of consciousness and determines who we are as individuals.
* **Peripheral Nervous System (PNS):** The peripheral nervous system (PNS) includes all the parts of the nervous system outside of the brain and spinal cord. These parts include all the cranial and spinal nerves, ganglia, and sensory receptors.
* **Somatic Nervous System (SNS):** The somatic nervous system (SNS) is a division of the PNS that includes all the voluntary efferent neurons. The SNS is the only consciously controlled part of the PNS and is responsible for stimulating skeletal muscles in the body.
* **Autonomic Nervous System (ANS):** The autonomic nervous system (ANS) is a division of the PNS that includes all the involuntary efferent neurons. The ANS controls subconscious effectors such as visceral muscle tissue, cardiac muscle tissue, and glandular tissue.

There are 2 divisions of the autonomic nervous system in the body: the **sympathetic** and **parasympathetic** divisions.

* **Sympathetic:** The sympathetic division forms the body’s “fight or flight” response to stress, danger, excitement, exercise, emotions, and embarrassment. The sympathetic division increases respiration and heart rate, releases adrenaline and other stress hormones, and decreases digestion to cope with these situations.
* **Parasympathetic:** The parasympathetic division forms the body’s “rest and digest” response when the body is relaxed, resting, or feeding. The parasympathetic works to undo the work of the sympathetic division after a stressful situation. Among other functions, the parasympathetic division works to decrease respiration and heart rate, increase digestion, and permit the elimination of wastes.

#### Enteric Nervous System

The enteric nervous system (ENS) is the division of the ANS that is responsible for regulating digestion and the function of the digestive organs. The ENS receives signals from the central nervous system through both the sympathetic and parasympathetic divisions of the autonomic nervous system to help regulate its functions.

However, the ENS mostly works independently of the CNS and continues to function without any outside input. For this reason, the ENS is often called the “brain of the gut” or the body’s “second brain.” The ENS is an immense system—almost as many neurons exist in the ENS as in the spinal cord.

# The Muscular System

The muscular system is responsible for the movement of the human body. Attached to the bones of the skeletal system are about 700 named muscles that make up roughly half of a person’s body weight. Each of these muscles is a discrete organ constructed of skeletal muscle tissue, blood vessels, tendons, and nerves. Muscle tissue is also found inside of the heart, digestive organs, and blood vessels. In these organs, muscles serve to move substances throughout the body.

There are three types of muscle tissue: **Visceral**, **cardiac**, and **skeletal**.

### Visceral Muscle

Visceral muscle is found inside of organs like the stomach, intestines, and blood vessels. The weakest of all muscle tissues, visceral muscle makes organs contract to move substances through the organ. Because visceral muscle is controlled by the unconscious part of the brain, it is known as **involuntary muscle**—it cannot be directly controlled by the conscious mind. The term “smooth muscle” is often used to describe visceral muscle because it has a very smooth, uniform appearance when viewed under a microscope. This smooth appearance starkly contrasts with the banded appearance of cardiac and skeletal muscles.

### Cardiac Muscle

Found only in the heart, cardiac muscle is responsible for pumping blood throughout the body. Cardiac muscle tissue cannot be controlled consciously, so it is an involuntary muscle. While hormones and signals from the brain adjust the rate of contraction, cardiac muscle stimulates itself to contract. The natural pacemaker of the heart is made of cardiac muscle tissue that stimulates other cardiac muscle cells to contract. Because of its self-stimulation, cardiac muscle is considered to be **auto rhythmic** or **intrinsically controlled**.

The cells of cardiac muscle tissue are **striated**—that is, they appear to have light and dark stripes when viewed under a light microscope. The arrangement of protein fibres inside of the cells causes these light and dark bands. Striations indicate that a muscle cell is very strong, unlike visceral muscles.

The cells of cardiac muscle are branched X or Y shaped cells tightly connected by special junctions called **intercalated disks**. Intercalated disks are made up of finger like projections from two neighbouring cells that interlock and provide a strong bond between the cells. The branched structure and intercalated disks allow the muscle cells to resist high blood pressures and the strain of pumping blood throughout a lifetime. These features also help to spread electrochemical signals quickly from cell to cell so that the heart can beat as a unit.

### Skeletal Muscle

Skeletal muscle is the only voluntary muscle tissue in the human body—it is controlled consciously. Every physical action that a person consciously performs (e.g. speaking, walking, or writing) requires skeletal muscle. The function of skeletal muscle is to contract to move parts of the body closer to the bone that the muscle is attached to. Most skeletal muscles are attached to two bones across a joint, so the muscle serves to move parts of those bones closer to each other.

Skeletal muscle cells form when many smaller progenitor cells lump themselves together to form long, straight, multinucleated fibres. Striated just like cardiac muscle, these skeletal muscle fibres are very strong. Skeletal muscle derives its name from the fact that these muscles always connect to the skeleton in at least one place.

Most skeletal muscles are attached to two bones through **tendons**. Tendons are tough bands of dense regular connective tissue whose strong collagen fibres firmly attach muscles to bones. Tendons are under extreme stress when muscles pull on them, so they are very strong and are woven into the coverings of both muscles and bones.

Muscles move by shortening their length, pulling on tendons, and moving bones closer to each other. One of the bones is pulled towards the other bone, which remains stationary. The place on the stationary bone that is connected via tendons to the muscle is called the **origin**. The place on the moving bone that is connected to the muscle via tendons is called the **insertion**. The **belly** of the muscle is the fleshy part of the muscle in between the tendons that does the actual contraction.

#### Muscle Contraction

Muscles contract when stimulated by signals from their motor neurons. Motor neurons contact muscle cells at a point called the **Neuromuscular Junction (NMJ)**. Motor neurons release neurotransmitter chemicals at the NMJ that bond to a special part of the sarcolemma known as the **motor end plate**. The motor end plate contains many ion channels that open in response to neurotransmitters and allow positive ions to enter the muscle fibre. The positive ions form an electrochemical gradient to form inside of the cell, which spreads throughout the sarcolemma and the T-tubules by opening even more ion channels.

When the positive ions reach the sarcoplasmic reticulum, Ca2+ ions are released and allowed to flow into the myofibrils. Ca2+ ions bind to **troponin**, which causes the troponin molecule to change shape and move nearby molecules of **tropomyosin**. Tropomyosin is moved away from myosin binding sites on actin molecules, allowing actin and myosin to bind together.

ATP molecules power myosin proteins in the thick filaments to bend and pull on actin molecules in the thin filaments. Myosin proteins act like oars on a boat, pulling the thin filaments closer to the centre of a sarcomere. As the thin filaments are pulled together, the sarcomere shortens and contracts. Myofibrils of muscle fibres are made of many sarcomeres in a row, so that when all the sarcomeres contract, the muscle cells shortens with a great force relative to its size.

Muscles continue contraction if they are stimulated by a neurotransmitter. When a motor neuron stops the release of the neurotransmitter, the process of contraction reverses itself. Calcium returns to the sarcoplasmic reticulum; troponin and tropomyosin return to their resting positions; and actin and myosin are prevented from binding. Sarcomeres return to their elongated resting state once the force of myosin pulling on actin has stopped.

The strength of a muscle’s contraction can be controlled by two factors: the number of motor units involved in contraction and the amount of stimulus from the nervous system. A single nerve impulse of a motor neuron will cause a motor unit to contract briefly before relaxing. This small contraction is known as a **twitch contraction**. If the motor neuron provides several signals within a short period of time, the strength and duration of the muscle contraction increases. This phenomenon is known as **temporal summation**. If the motor neuron provides many nerve impulses in rapid succession, the muscle may enter the state of **tetanus**, or complete and lasting contraction. A muscle will remain in tetanus until the nerve signal rate slows or until the muscle becomes too fatigued to maintain the tetanus.

Not all muscle contractions produce movement. **Isometric contractions** are light contractions that increase the tension in the muscle without exerting enough force to move a body part. When people tense their bodies due to stress, they are performing an isometric contraction. Holding an object still and maintaining posture are also the result of isometric contractions. A contraction that does produce movement is an **isotonic contraction**. Isotonic contractions are required to develop muscle mass through weight lifting.

**Muscle tone** is a natural condition in which a skeletal muscle stays partially contracted at all times. Muscle tone provides a slight tension on the muscle to prevent damage to the muscle and joints from sudden movements, and helps to maintain the body’s posture. All muscles maintain some amount of muscle tone at all times, unless the muscle has been disconnected from the central nervous system due to nerve damage.

#### Muscle Energy

Muscles get their energy from different sources depending on the situation that the muscle is working in. Muscles use **aerobic respiration** when we call on them to produce a low to moderate level of force.

Aerobic respiration requires oxygen to produce about 36-38 ATP molecules from a molecule of glucose. Aerobic respiration is very efficient, and can continue if a muscle receives adequate amounts of oxygen and glucose to keep contracting. When we use muscles to produce a high level of force, they become so tightly contracted that oxygen carrying blood cannot enter the muscle. This condition causes the muscle to create energy using **lactic acid fermentation**, a form of anaerobic respiration. Anaerobic respiration is much less efficient than aerobic respiration—only 2 ATP are produced for each molecule of glucose. Muscles quickly tire as they burn through their energy reserves under anaerobic respiration.

To keep muscles working for a longer period, muscle fibres contain several important energy molecules. **Myoglobin**, a red pigment found in muscles, contains iron and stores oxygen in a manner similar to haemoglobin in the blood. The oxygen from myoglobin allows muscles to continue aerobic respiration in the absence of oxygen. Another chemical that helps to keep muscles working is **creatine phosphate**. Muscles use energy in the form of ATP, converting ATP to ADP to release its energy.

Creatine phosphate donates its phosphate group to ADP to turn it back into ATP in order to provide extra energy to the muscle. Finally, muscle fibres contain energy-storing **glycogen**, a large macromolecule made of many linked glucoses. Active muscles break glucoses off glycogen molecules to provide an internal fuel supply.

When muscles run out of energy during either aerobic or anaerobic respiration, the muscle quickly tires and loses its ability to contract. This condition is known as **muscle fatigue**. A fatigued muscle contains very little or no oxygen, glucose or ATP, but instead has many waste products from respiration, like lactic acid and ADP.

The body must take in extra oxygen after exertion to replace the oxygen that was stored in myoglobin in the muscle fibre as well as to power the aerobic respiration that will rebuild the energy supplies inside of the cell. **Oxygen debt** (or recovery oxygen uptake) is the name for the extra oxygen that the body must take in to restore the muscle cells to their resting state. This explains why you feel out of breath for a few minutes after a strenuous activity—your body is trying to restore itself to its normal state.

# The Integumentary System

The integumentary system consists of the skin, hair, nails, glands, and nerves. Its main function is to act as a barrier to protect the body from the outside world. It also functions to retain body fluids, protect against disease, eliminate waste products, and regulate body temperature.

The skin is only a few millimetres thick yet is by far the largest organ in the body. The average person’s skin weighs 10 pounds and has a surface area of almost 20 square feet. Skin forms the body’s outer covering and forms a barrier to protect the body from chemicals, disease, UV light, and physical damage. Hair and nails extend from the skin to reinforce the skin and protect it from environmental damage. The exocrine glands of the integumentary system produce sweat, oil, and wax to cool, protect, and moisturize the skin’s surface.

### Anatomy of the Integumentary System

#### Epidermis

The epidermis is the most superficial layer of the skin that covers almost the entire body surface. The epidermis rests upon and protects the deeper and thicker dermis layer of the skin. Structurally, the epidermis is only about a tenth of a millimetre thick but is made of 40 to 50 rows of stacked squamous epithelial cells. The epidermis is an avascular region of the body, meaning that it does not contain any blood or blood vessels. The cells of the epidermis receive all their nutrients via diffusion of fluids from the dermis.

The epidermis is made of several specialized types of cells.

* Almost 90% of the epidermis is made of cells known as **keratinocytes**. Keratinocytes develop from stem cells at the base of the epidermis and begin to produce and store the protein keratin. Keratin makes the keratinocytes very tough, scaly and water-resistant.
* At about 8% of epidermal cells, **melanocytes** form the second most numerous cell type in the epidermis. Melanocytes produce the pigment melanin to protect the skin from ultraviolet radiation and sunburn.
* **Langerhans cells** are the third most common cells in the epidermis and make up just over 1% of all epidermal cells. Langerhans cells’ role is to detect and fight pathogens that attempt to enter the body through the skin.
* Finally, **Merkel cells** make up less than 1% of all epidermal cells but have the important function of sensing touch. Merkel cells form a disk along the deepest edge of the epidermis where they connect to nerve endings in the dermis to sense light touch.

In most of the body, the epidermis is arranged into 4 distinct layers. In the palmar surface of the hands and plantar surface of the feet, the skin is thicker than in the rest of the body and there is a fifth layer of epidermis.

* The deepest region of the epidermis is the **stratum Basale**, which contains the stem cells that reproduce to form all the other cells of the epidermis. The cells of the stratum Basale include cuboidal keratinocytes, melanocytes, and Merkel cells.
* Superficial to stratum Basale is the **stratum spinosum** layer where Langerhans cells are found along with many rows of spiny keratinocytes. The spines found here are cellular projections called desmosomes that form between keratinocytes to hold them together and resist friction.
* Just superficial to the stratum spinosum is the **stratum granulosum**, where keratinocytes begin to produce waxy lamellar granules to waterproof the skin. The keratinocytes in the stratum granulosum are so far removed from the dermis that they begin to die from lack of nutrients.
* In the thick skin of the hands and feet, there is a layer of skin superficial to the stratum granulosum known as the **stratum lucidum**. The stratum lucidum is made of several rows of clear, dead keratinocytes that protect the underlying layers.
* The outermost layer of skin is the **stratum corneum**. The stratum corneum is made of many rows of flattened, dead keratinocytes that protect the underlying layers. Dead keratinocytes are constantly being shed from the surface of the stratum corneum and being replaced by cells arriving from the deeper layers.

#### Dermis

The dermis is the deep layer of the skin found under the epidermis. The dermis is mostly made of dense irregular connective tissue along with nervous tissue, blood, and blood vessels. The dermis is much thicker than the epidermis and gives the skin its strength and elasticity. Within the dermis there are two distinct regions: the papillary layer and the reticular layer.

* The **papillary layer** is the superficial layer of the dermis that borders on the epidermis. The papillary layer contains many finger-like extensions called dermal papillae that protrude superficially towards the epidermis. The dermal papillae increase the surface area of the dermis and contain many nerves and blood vessels that are projected toward the surface of the skin. Blood flowing through the dermal papillae provide nutrients and oxygen for the cells of the epidermis. The nerves of the dermal papillae are used to feel touch, pain, and temperature through the cells of the epidermis.
* The deeper layer of the dermis, the **reticular layer**, is the thicker and tougher part of the dermis. The reticular layer is made of dense irregular connective tissue that contains many tough collagen and stretchy elastin fibres running in all directions to provide strength and elasticity to the skin. The reticular layer also contains blood vessels to support the skin cells and nerve tissue to sense pressure and pain in the skin.

#### Hypodermis

Deep to the dermis is a layer of loose connective tissues known as the hypodermis, subcutis, or subcutaneous tissue. The hypodermis serves as the flexible connection between the skin and the underlying muscles and bones as well as a fat storage area. Areolar connective tissue in the hypodermis contains elastin and collagen fibres loosely arranged to allow the skin to stretch and move independently of its underlying structures. Fatty adipose tissue in the hypodermis stores energy in the form of triglycerides. Adipose also helps to insulate the body by trapping body heat produced by the underlying muscles.

#### Hair

Hair is an accessory organ of the skin made of columns of tightly packed dead keratinocytes found in most regions of the body. The few hairless parts of the body include the palmar surface of the hands, plantar surface of the feet, lips, labia minora, and glans penis. Hair helps to protect the body from UV radiation by preventing sunlight from striking the skin. Hair also insulates the body by trapping warm air around the skin.

The structure of hair can be broken down into 3 major parts: the **follicle**, **root**, and **shaft**.

* The **hair follicle** is a depression of epidermal cells deep into the dermis. Stem cells in the follicle reproduce to form the keratinocytes that eventually form the hair while melanocytes produce pigment that gives the hair its colour.
* Within the follicle is the **hair root**, the portion of the hair below the skin’s surface. As the follicle produces new hair, the cells in the root push up to the surface until they exit the skin.
* The **hair shaft** consists of the part of the hair that is found outside of the skin.

The hair shaft and root are made of 3 distinct layers of cells: the **cuticle**, **cortex**, and **medulla**.

* The **cuticle** is the outermost layer made of keratinocytes. The keratinocytes of the cuticle are stacked on top of each other like shingles so that the outer tip of each cell points away from the body.
* Under the cuticle are the cells of the **cortex** that form most of the hair’s width. The spindle-shaped and tightly packed cortex cells contain pigments that give the hair its colour.
* The innermost layer of the hair, the **medulla**, is not present in all hairs. When present, the medulla usually contains highly pigmented cells full of keratin. When the medulla is absent, the cortex continues through the middle of the hair.

#### Nails

Nails are accessory organs of the skin made of sheets of hardened keratinocytes and found on the distal ends of the fingers and toes. Fingernails and toenails reinforce and protect the end of the digits and are used for scraping and manipulating small objects. There are 3 main parts of a nail: the **root**, **body**, and **free edge**.

* The **nail root** is the portion of the nail found under the surface of the skin.
* The **nail body** is the visible external portion of the nail.
* The **free edge** is the distal end portion of the nail that has grown beyond the end of the finger or toe.

Nails grow from a deep layer of epidermal tissue known as the **nail matrix**, which surrounds the nail root. The stem cells of the nail matrix reproduce to form keratinocytes, which in turn produce keratin protein and pack into tough sheets of hardened cells.

The sheets of keratinocytes form the hard nail root that slowly grows out of the skin and forms the nail body as it reaches the skin’s surface. The cells of the nail root and nail body are pushed toward the distal end of the finger or toe by new cells being formed in the nail matrix. Under the nail body is a layer of epidermis and dermis known as the **nail bed**. The nail bed is pink in colour due to the presence of capillaries that support the cells of the nail body. The proximal end of the nail near the root forms a whitish crescent shape known as the **lunula** where a small amount of nail matrix is visible through the nail body. Around the proximal and lateral edges of the nail is the **eponychium**, a layer of epithelium that overlaps and covers the edge of the nail body. The eponychium helps to seal the edges of the nail to prevent infection of the underlying tissues.

#### Sudoriferous Glands

Sudoriferous glands are exocrine glands found in the dermis of the skin and commonly known as sweat glands. There are 2 major types of sudoriferous glands: **eccrine sweat glands** and **apocrine sweat glands**.

* **Eccrine sweat glands** are found in almost every region of the skin and produce a secretion of water and sodium chloride. Eccrine sweat is delivered via a duct to the surface of the skin and is used to lower the body’s temperature through evaporative cooling.
* **Apocrine sweat glands** are found in mainly in the axillary and pubic regions of the body. The ducts of apocrine sweat glands extend into the follicles of hairs so that the sweat produced by these glands exits the body along the surface of the hair shaft. Apocrine sweat glands are inactive until puberty, at which point they produce a thick, oily liquid that is consumed by bacteria living on the skin. The digestion of apocrine sweat by bacteria produces body odour.

#### Sebaceous Glands

Sebaceous glands are exocrine glands found in the dermis of the skin that produce an oily secretion known as **sebum**. Sebaceous glands are found in every part of the skin except for the thick skin of the palms of the hands and soles of the feet. Sebum is produced in the sebaceous glands and carried through ducts to the surface of the skin or to hair follicles. Sebum acts to waterproof and increase the elasticity of the skin. Sebum also lubricates and protects the cuticles of hairs as they pass through the follicles to the exterior of the body.

#### Ceruminous Glands

Ceruminous glands are special exocrine glands found only in the dermis of the ear canals. Ceruminous glands produce a waxy secretion known as **cerumen** to protect the ear canals and lubricate the eardrum. Cerumen protects the ears by trapping foreign material such as dust and airborne pathogens that enter the ear canal. Cerumen is made continuously and slowly pushes older cerumen outward toward the exterior of the ear canal where it falls out of the ear or is manually removed.

## Essay Question 7

**Please place answers on a separate answer sheet.**

1. Name the layers of the skin and their function in detail.

# The Face

The human skull contains 22 bones. 8 bones make up the cranium and the other 14 form the lower front of the skull, these are known as the **facial bones**.

Those bones are:

* Inferior nasal concha (2)
* Lacrimal bones (2)
* Mandible
* Maxilla (2)
* Nasal bones (2)
* Palatine bones (2)
* Vomer
* Zygomatic bones (2)

The facial skeleton serves to protect the brain; house and protect the sense organs of smell, sight, and taste; and provide a frame on which the soft tissues of the face can act to facilitate eating, facial expression, breathing, and speech.

The fourteen bones at the front of your skull hold your eyes in place and form your facial features. Your **mandible**, or jawbone, is the largest, strongest bone in your face. It holds your lower teeth in place and you move it to chew your food.

Apart from your mandible and your vomer, all your facial bones are arranged in pairs. That's why your face is symmetrical. For example, your two **zygomatic bones** form your cheekbones and the outside of your eye sockets on either side of your face.

## The Muscles of The Face

The facial muscles are a group of striated skeletal muscles supplied by the facial nerve (cranial nerve VII) that, among other things, control facial expression. These muscles are also called **mimetic muscles**.

The facial muscles are just under the skin (subcutaneous) muscles that control facial expression. They generally originate from the surface of the skull bone (rarely the fascia), and insert on the skin of the face. When they contract, the skin moves. These muscles also cause wrinkles at right angles to the muscles’ action line.

The facial muscles are supplied by the **facial nerve (cranial nerve VII)**, with each nerve serving one side of the face. In contrast, the nearby masticatory muscles are supplied by the **mandibular nerve**, a branch of the trigeminal nerve (cranial nerve V).

The facial muscles include:

* Occipitofrontalis muscle
* Temporoparietalis muscle
* Procerus muscle
* Nasalis muscle
* Depressor septi nasi muscle
* Orbicularis oculi muscle
* Corrugator supercilii muscle
* Depressor supercilii muscle
* Auricular muscles (anterior, superior and posterior)
* Orbicularis oris muscle
* Depressor anguli oris muscle
* Risorius
* Zygomaticus major muscle
* Zygomaticus minor muscle
* Levator labii superioris
* Levator labii superioris alaeque nasi muscle
* Depressor labii inferioris muscle
* Levator anguli oris
* Buccinator muscle
* Mentalis

### 20 Muscles of the Face & their Functions

Since the mouth is the part of the face that has maximum movement and function, most of the muscle groups are positioned around this.

1. **Orbicularis Oris Muscle of the Face:** This facial muscle is positioned around the mouth, encircling it.
   * **Function:** The Orbicularis oris muscle of the face helps to close the mouth and also, when this muscle contracts, the mouth puckers.
2. **Depressor Labii Inferioris Muscle of Face:** This muscle of the face is located beneath the lower lip (mandible) underneath the mental foramen.
   * **Function:** The Depressor labii inferioris muscle of the face helps to depress or lower the lower lip or bottom lip.
3. **Levator Labii Superioris Muscle:** This muscle is located above the upper lip and is located above the infraorbital foramen.
   * **Function:** This muscle helps to elevate the upper lip.
4. **Buccinator Muscle:** This muscle forms the muscular base of the cheek, the wall of the oral cavity and the anterior part of the cheek. The interval between maxilla and mandible is occupied by this muscle.
   * **Function:** This facial muscle helps to hold food inside the mouth in proper position and aids in chewing. Flattening the cheeks and pulling the angle of the mouth backwards is supported by this muscle.
5. **Mentalis Muscle of the Face:** The furrow between the lower lip and chin is formed by this muscle of the face. In other words, it can be said that this facial muscle is located at the tip of the chin.
6. **Risorius Muscle of the Face:** This muscle is also called the laughing muscle. It forms the depression of the cheek, in the angle of the mouth.
   * **Function:** Risorius helps one to smile.
7. **Levator Anguli Oris Muscle:** Right underneath the infraorbital foramen in an angle of the mouth, is the Levator anguli oris muscle that fills the opening.
8. **Zygomaticus Major and Minor Muscles of the Face:** In an angular position, beneath the cheekbones is the Zygomaticus major muscle and Zygomaticus minor muscle that form the cheeks. They create the zygomatic arch.
   * **Function:** The Zygomaticus major muscle of the face helps in lifting the corners of the lips when one smiles. Usually the Zygomaticus major muscle is a single muscle strand. It is thought that differentiation in this muscle structure causes dimple in the cheeks of some people. The Zygomaticus minor muscle on the other hand helps in creating a sad facial expression by drawing the upper lip backwards.
9. **Nasalis Muscle:** On both sides of the nasal cartilage, the Nasalis muscle is located.
   * **Function:** This facial muscle compresses the nasal cartilage and thus aids in “flaring” of the nostrils to prevent water from getting inside the nose when underwater.
10. **Procerus Muscle:** This pyramid shaped muscle of the face is located in the lower part of the forehead, between the eyebrows, covering a part of the nasal bone.
    * **Function:** The Procerus muscle of the face helps in bringing or pulling down the skin between the eyebrows to express anger.
11. **Orbicularis Oculi Muscle of the Face:** This facial muscle is what encircles the eyelids.
    * **Function:** It helps to close the eyes.
12. **Depressor Supercilii Muscle:** The Depressor Supercilii Muscle is also a muscle of the eyes. Some people say that it relates to the Orbicularis Oculi Muscle.
    * **Function:** It helps in the movement of the eyebrows.
13. **Corrugator Supercilii Muscle:** This pyramid shaped small and narrow muscle is located beneath the Frontalis muscle, at the end of the eyebrow and above the Orbicularis Oculi Muscle.
    * **Function:** This is the muscle of the face that causes the wrinkles in forehead. Corrugator supercilii muscle also helps in expressing anger or expression of suffering and is another frowning muscle.
14. **Occipitofrontalis Muscle of Face:** The Occipitofrontalis muscle is also known as the Epicranius muscle and it covers some parts of the skulls. Located near the occipital bone and frontal belly, as well as occipital belly, this facial muscle helps in facial expression.
15. **Temporoparietalis Muscle:** This muscle is located on both sides of the skull, above the ears.
    * **Function:** It helps in ear elevation.
16. **Auricular Muscle:** There are three distinct types of the Auricular muscle. These are –
    * **Anterior Auricular Muscle** – It is a fan shaped and thin muscle. It is also the smallest of the three Auricular muscles. This muscle has pale and indistinct fibres.
    * **Posterior auricular muscle** – This muscle consists of 2 to 3 fleshy fibres.
    * **Superior Auricular Muscle** – This too is a fan shaped and thin muscle, but the largest of the three Auricular muscles.
17. **Outer Ear:** It is the external part of the ear. It helps in gathering sound energy.
18. **Depressor Septi Nasi Muscle of the Face:** This small muscle lies between the muscular structure of upper lip and mucous membrane.
    * **Function:** It works as an antagonist of other nasal muscles.

These are the main muscles of the face and they all serve either distinct functions or help in the function or action of the other muscles.

# Facial Nerve

The facial nerve is one of the twelve pairs of cranial nerves in the peripheral nervous system. It is the seventh cranial nerve, and so is often referred to as **cranial nerve VII** or simply **CN VII**. Nerve signals from the cranial nerve play important roles in sensing taste as well as controlling the muscles of the face, salivary glands, and lacrimal glands.

The facial nerve is the seventh cranial nerve to exit the brain when counting from anterior to posterior.

It arises from the pons region of the brainstem, posterior to the abducens nerve (CN VI) and anterior to the vestibulocochlear nerve (CN VIII). The facial nerve travels from the pons through the facial canal in the temporal bone to exit the skull at the stylomastoid foramen.

As the facial nerve passes through the temporal bone, several smaller nerves branch off from the main nerve, including the **greater (superficial) petrosal nerve** and the **chorda tympani**.

* Nerve fibres from the **greater (superficial) petrosal nerve** stimulate the lacrimal glands to produce tears and moisten the eyes.
* The **chorda tympani** stimulate the submandibular and sublingual salivary glands to produce saliva. It also carries taste information from the anterior two-thirds of the tongue to the brain.

After passing through the stylomastoid foramen, the facial nerve emerges just inferior to the ear and splits into several superficial branches.

* The **posterior auricular nerve** splits from the facial nerve just beyond the stylomastoid foramen and innervates the muscles posterior to the ear, including the auricularis posterior and the occipitalis.
* Two small nerves next branch off to innervate the **digastric** and **stylohyoid** muscles.
* Finally, the **temporofacial** and **cervicofacial** branches separate to innervate the muscles of the upper and lower face, respectively.

The **temporofacial nerve** divides into the temporal, zygomatic, and infraorbital branches to reach the frontalis and orbicularis oculi muscles, among others. Fibres from the **cervicofacial branch** split into the buccal, mandibular, and cervical nerves to innervate the nasalis, zygomaticus major, buccinator, orbicularis oris, platysma, and other muscles surrounding the nose and mouth.

Like all nerves, the facial nerve is made of thousands of individual neurons bundled together with connective tissue and blood vessels. The outside of the nerve is covered in a layer of connective tissue known as the **epineurium** that protects the soft neurons within and holds the nerve together as a cohesive mass.

Within the epineurium, small arterioles and venules provide blood flow to many small bundles of neurons known as **fascicles**. Each fascicle is wrapped in yet another layer of connective tissue known as the **perineurium**. Within each fascicle are several individual neurons wrapped in individual layers of connective tissue known as **endoneurium**.

The facial nerve is considered a **mixed nerve** because it contains both afferent (sensory) and efferent (motor) neurons. Afferent neurons of the facial nerve carry taste sensations from the taste buds of the anterior tongue to the primary gustatory centre of the cerebrum.

The efferent division of the facial nerve contains both somatic (voluntary) motor neurons and autonomic (involuntary) motor neurons. Somatic motor neurons carry nerve signals to the skeletal muscles of the face to control facial expressions, while autonomic motor neurons carry signals to the lacrimal and salivary glands.

## Essay question 8

**Please answer on a separate answer sheet.**

1. Name all the bones of the face where there are two of each and explain why they come as a pair.
2. Choose 3 muscles of the face and explain their function.
3. What is the largest bone in the face?
4. Which nerve in the face assists with the production of tears and lubrication of the eye?