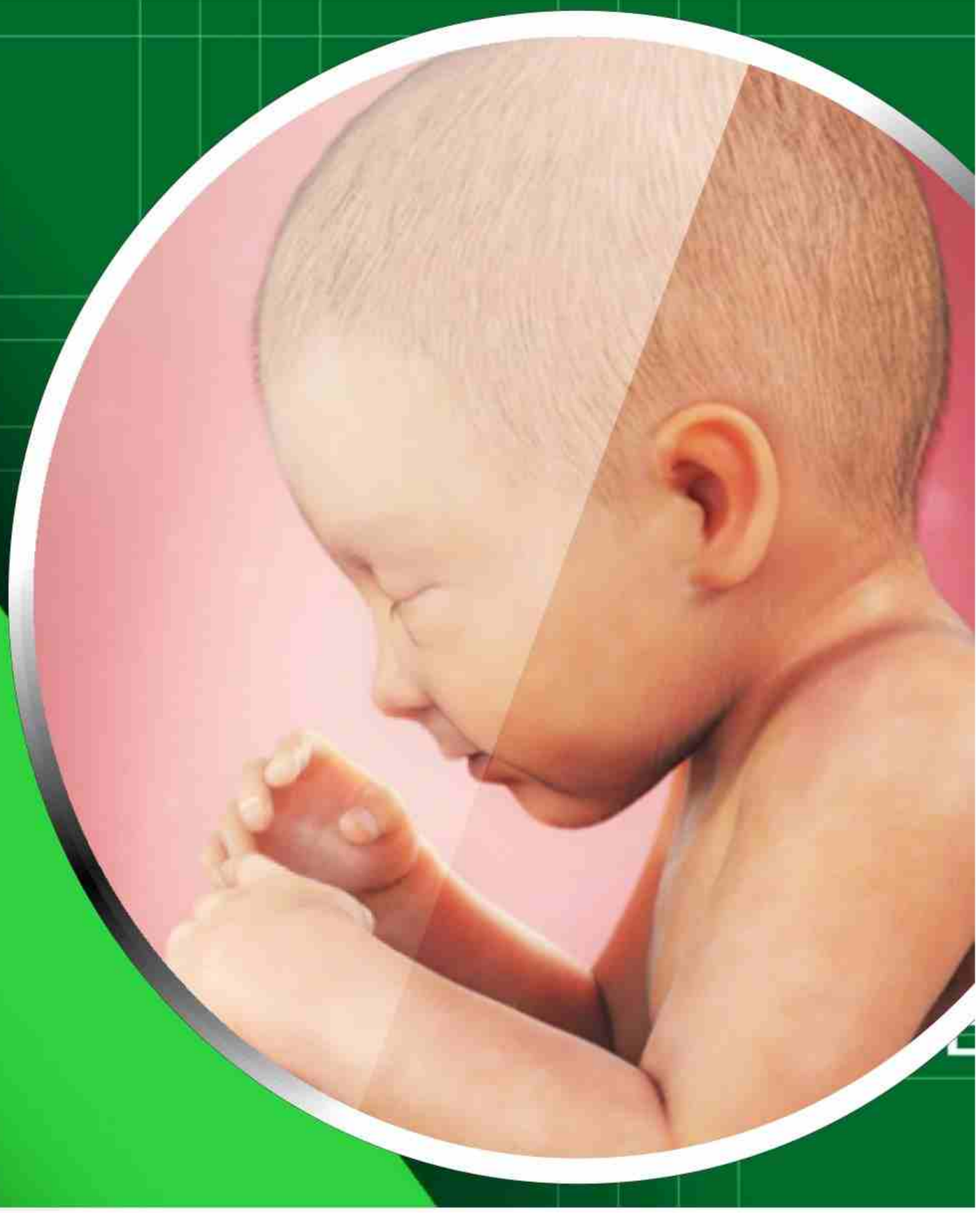
DEVELOPMENT AND AGING

Chapter 21

Major Concept

In this Unit you will learn:

- Human Embryonic Development
- Control of Development
- Pregnancy
- Disorders during embryonic Development
- Aging



Development refers to the process by which an organism grows and matures from a single cell into a complex multicellular organism with specialized tissues and organs. It involves a series of coordinated and sequential events that begin with fertilization and continue throughout the life of an organism. **Development** is a highly regulated process that is influenced by genetic and environmental factors, and it requires the precise coordination of numerous cellular and molecular processes.

In biology, growth and development are two distinct processes. **Growth** refers to an increase in size or number of cells, tissues, or organs, often resulting in an increase in overall mass. On the other hand, development refers to the process by which an organism changes from a simple to a more complex structure, acquiring new structures and functions. Development involves changes in gene expression, cell differentiation, and tissue organization that give rise to the diverse cell types and organs in an organism.

21.1.1 Fertilization and its site

Union of male and female gametes is called fertilization, this union results in the formation of single cell called zygote. Egg release from ovary in the form of secondary oocyte, which is covered with zona pellucida. Fertilization takes place in proximal part of oviduct. This process is facilitated by enzymes on the surface of the sperm cell, which break down the outer membrane of the egg.

Once a sperm cell has successfully penetrated the egg cell, zona pellucida of the egg undergoes changes that prevent any other sperm from entering. Once the sperm cell has entered the egg cell, the two cells fuse, and their nuclei combine to form a single, diploid nucleus. This marks the beginning of the development of a new individual. The zygote then undergoes a series of cell divisions and transformations as it travels down the fallopian tube towards the

uterus, where it will implant into the uterine lining and continue to develop.

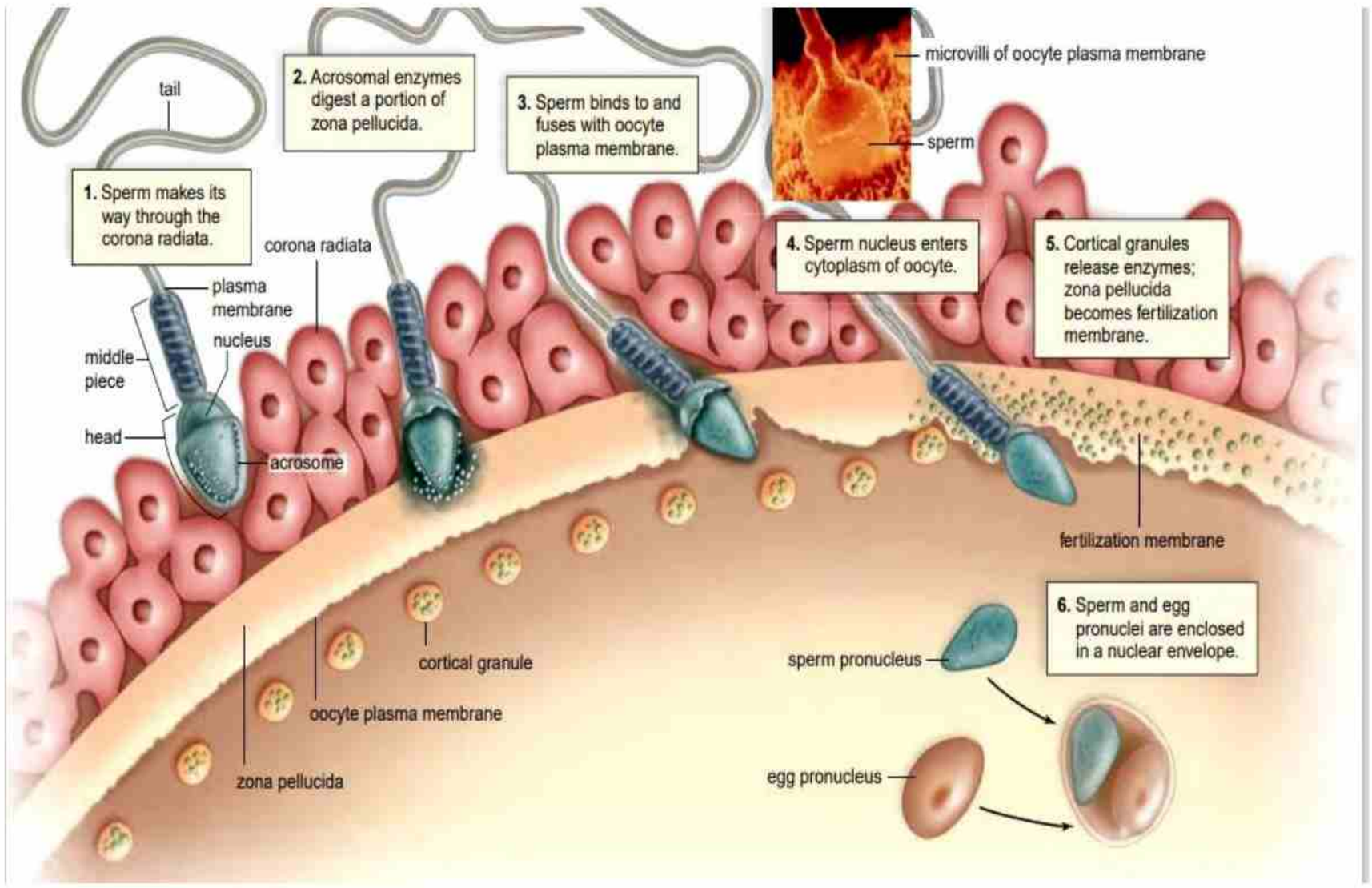


Fig. 21.1 Stages of Sperm entering an egg

21.1.2 Cleavage and egg types

Cleavage is the process of rapid cell division that occurs after fertilization, during which the zygote divides into smaller and smaller cells, each containing a copy of the genetic material from the original cell. The purpose of cleavage is to generate many cells that will eventually form the tissues and organs of the developing embryo. The amount of yolk present in the egg cell can significantly impact the cleavage process. In some animal species, such as birds and reptiles, the egg contains a large amount of yolk, which can make cleavage more difficult.

In eggs with moderate to little yolk, cleavage occurs throughout the whole egg, a pattern called **holoblastic cleavage**. However, in eggs with a large amount of yolk, with a small amount of clear cytoplasm concentrated at one pole called the **blastodisc**. Cleavage in

these eggs restricted to the blastodisc. The yolk is essentially an inert mass. This type of cleavage pattern is called **meroblastic cleavage**.

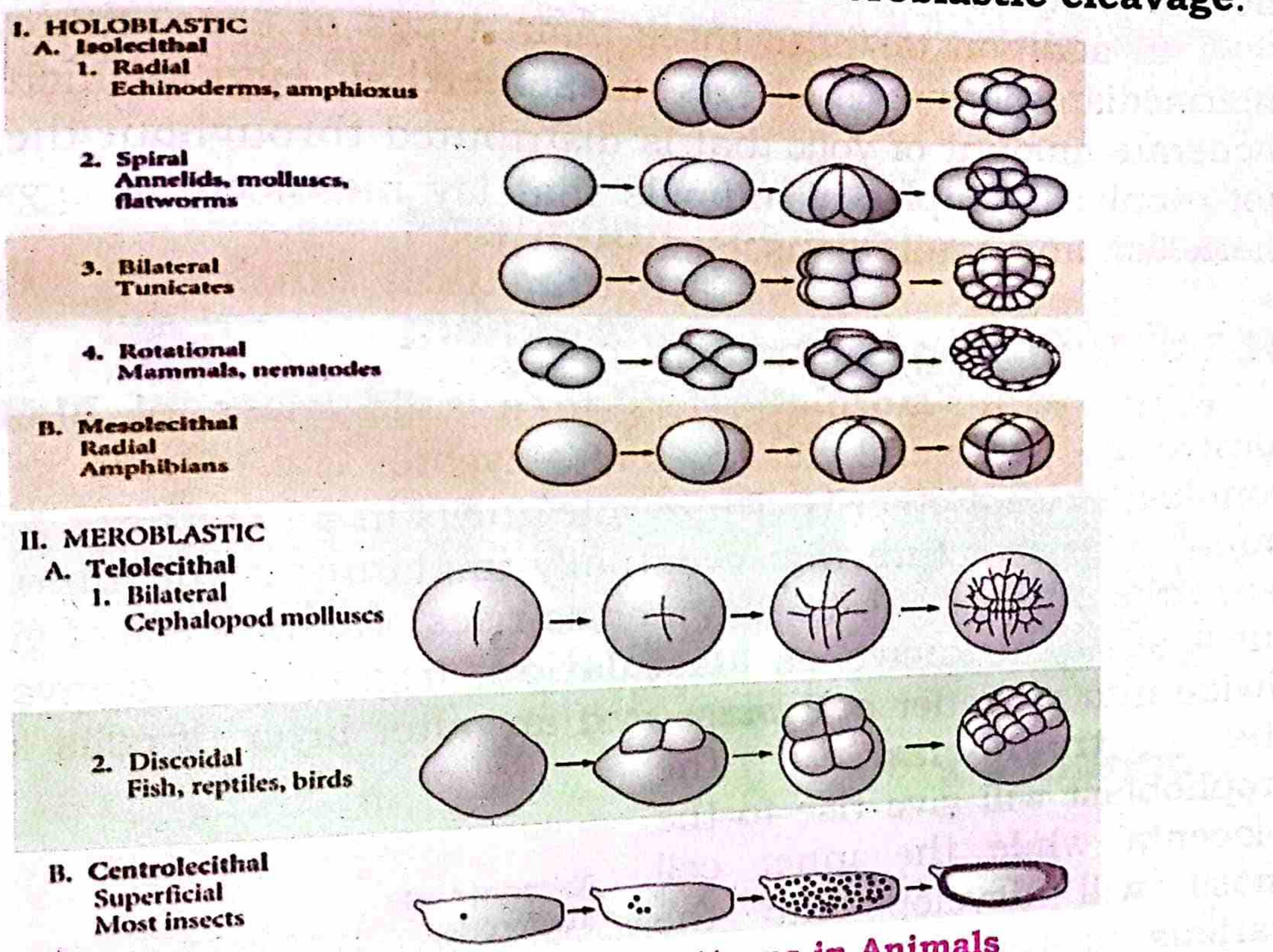


Fig. 21.2 Major Cleavage Patterns in Animals

Eggs can be classified into different types based on the amount and distribution of yolk present in them. The three main types of eggs are:

Telolecithal eggs: This type of eggs having large amount of yolk, which is concentrated at one end of the egg, creating a concentration gradient. Examples of animals that lay telolecithal eggs include birds, reptiles, and monotremes (egg-laying mammals).

Centrolecithal eggs: This type of eggs having large, centrally located yolk surrounded by a thin layer of cytoplasm. In these eggs, the nucleus and other organelles are located at the periphery of the egg, while the yolk is in the center. Examples of animals that lay centrolecithal eggs include insects and crustaceans.

Isolecithal eggs: This type of eggs having small amount of yolk that is evenly distributed throughout the cytoplasm of the egg. These eggs are common in animals that have a placenta, such as mammals, as the developing embryo receives nutrients from the mother rather

than from the yolk. Examples of animals that lay isolecithal eggs include many fish, amphibians, and some invertebrates.

In addition to these three main types of eggs, there are also intermediate forms, such as **mesolecithal eggs**, which have a moderate amount of yolk that is distributed throughout the egg, but not evenly. Examples of animals that lay mesolecithal eggs include many fish and amphibians.

21.1.3 Morula and Blastula

The term "**morula**" refers to a solid mass of **blastomeres** formed by the several cleavages of a zygote. The morula in humans contains at least 60 cells. The zygote grows in a **blastocyst**, a hollow, bubble-like structure that eventually implants in the uterine lining when the number of cells in a morula rises. The process of generating the blastocyst, known as **blastulation**, begins with cleavage. Cells divide into an inner **cell mass** and an outer layer of cells known as the **trophoblast**. The trophoblast will give rise to the placenta while the inner cell mass will develop into the various tissues and organs of the embryo, so inner mass cells are called **embryoblasts**, as division continues cells begin to move apart, so that spaces appear among cells in the center of mass. Cells keep pulling away from the central area, forming a fluid cavity called **segmentation cavity** or **blastocoel**.

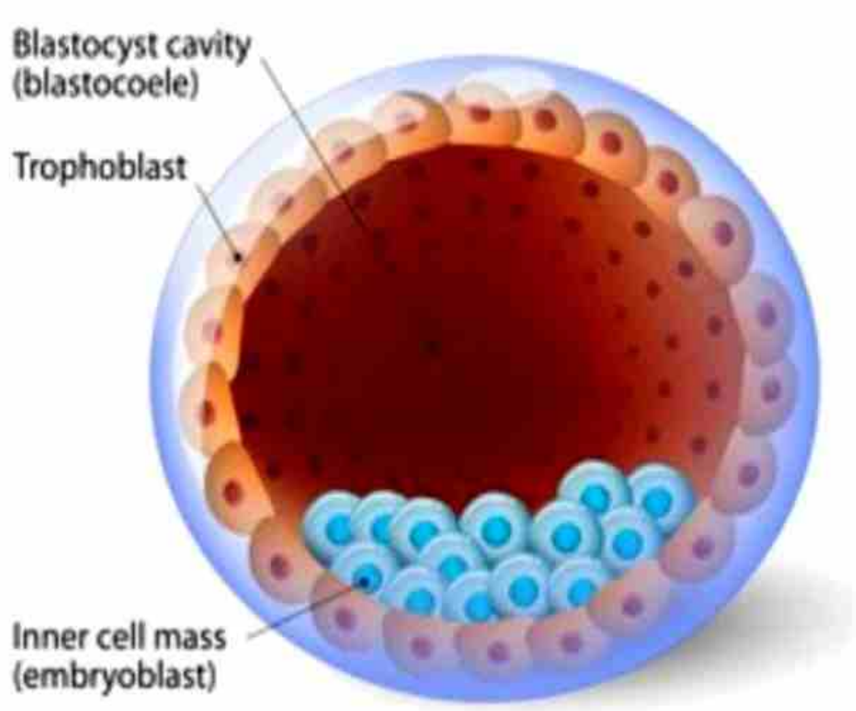


Fig. 21.3 Blastula

21.1.4 Events of Gastrulation

Gastrulation is a vital stage in human embryonic development, and it involves a series of complex cellular movements resulting in the formation of three germ layers: the **endoderm**, **mesoderm**, and **ectoderm**. These layers will develop into various organs and tissues such as the lining of the digestive tract, the heart, and the nervous

system. The process begins with the formation of the **primitive streak**, followed by the invagination of epiblast towards the midline. As the endoderm forms, a third layer of cells, the mesoderm, develops between the endoderm and ectoderm.

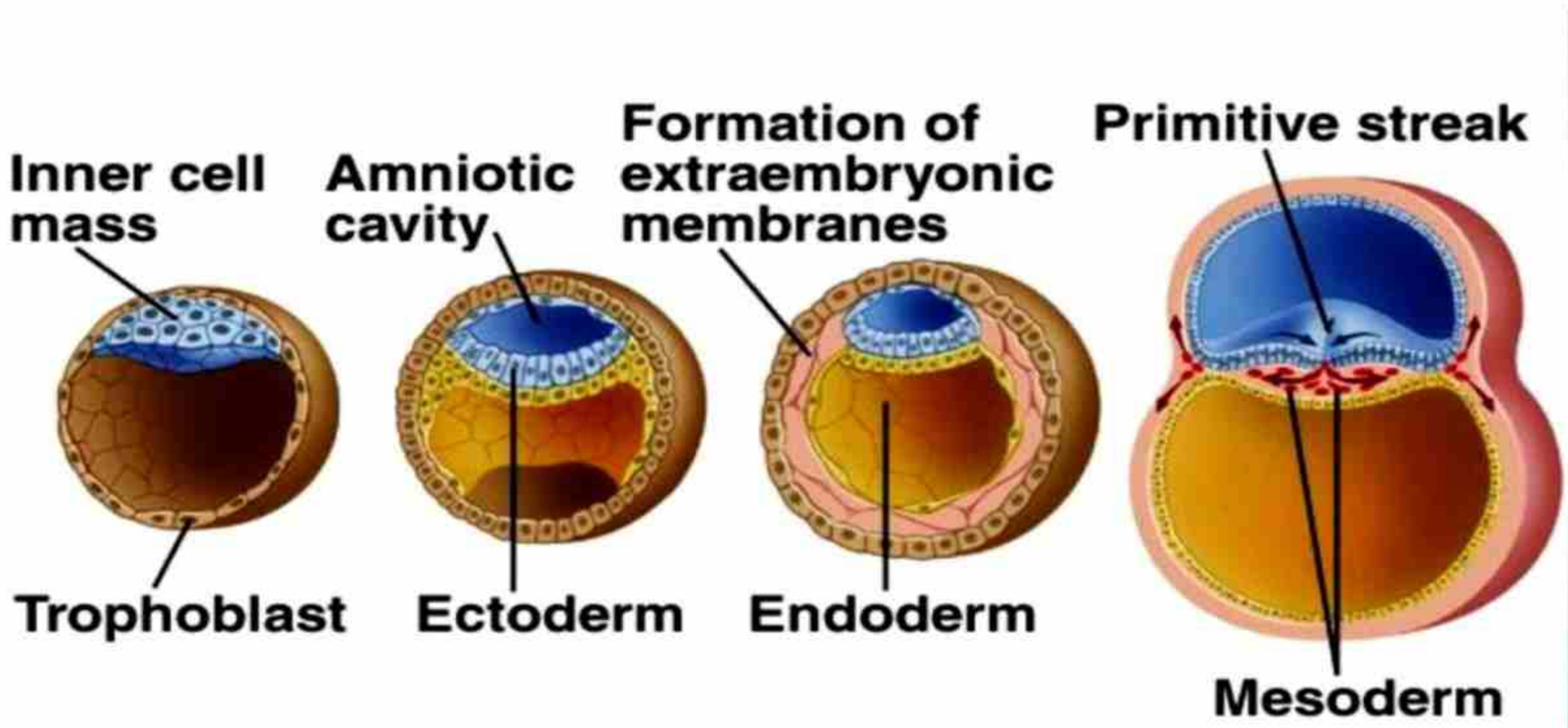


Fig. 21.4 Events of Gastrulation

During gastrulation, the inner cell mass creates **hypoblast cells** that line the **blastocoel**, resulting in the primitive yolk sac and a bi-layered embryonic disc made up of **epiblast** and **hypoblast**,

The epiblast splits into the **amniotic ectoderm** and the **embryonic epiblast**. The embryonic epiblast develops into the embryo (including ectoderm, endoderm, mesoderm, and germ cells), while the extra embryonic endoderm forms the **yolk sac**.

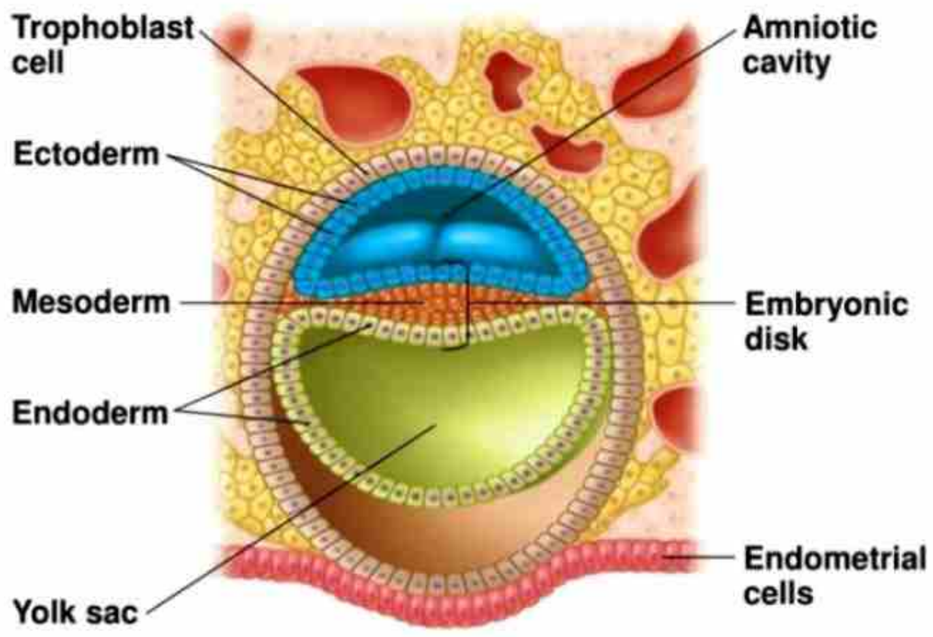


Fig. 21.5 Formation of Germ layers

The trophoblast develops through several stages, eventually becoming the **chorion**, the embryonically derived portion of the

placenta. Trophoblast cells also induce the mother's uterine cells to form the maternal portion of the placenta, **the decidua**. The decidua becomes rich in the blood vessels that will provide oxygen and nutrients to the embryo.

21.1.5 Fate of three germ layers

During human embryonic development, the three germ layers that form during gastrulation give rise to a wide variety of tissues and organs.

Table 21.1 Fate of Three Germ Layers

Germ Layer	Tissues and Organs
Ectoderm	Skin, teeth, eyes, nervous system (brain, spinal cord, nerves)
Mesoderm	Bones, muscles, heart, kidneys, blood vessels, reproductive system, dermis of skin
Endoderm	Lining of digestive tract (including esophagus, stomach, and intestines), lining of respiratory tract, liver, pancreas, bladder, thyroid gland

21.1.6 Events of Neurulation

Neurulation is the process by which the neural plate forms and eventually becomes the neural tube, which will give rise to the brain and spinal cord. During the third week of development, the ectoderm thickens along the midline, forming the **neural plate**. The neural plate then begins to invaginate or fold inwards, forming the **neural grooves** that runs along the midline of the embryo. As the neural plate continues to invaginate, the raised **neural folds** on either side of the neural groove start to elevate and approach each other until they eventually fuse together, forming the **neural tube**. As the neural tube is forming, some of the cells at the edge of the neural plate start to break away and migrate to form the **neural crest**.

The neural crest will eventually give rise to various cell types including cranial and spinal nerves, some components of the skull and face, and pigment cells. As the neural tube forms, it also undergoes **segmentation**, forming distinct regions that will give rise to different parts of the nervous system.

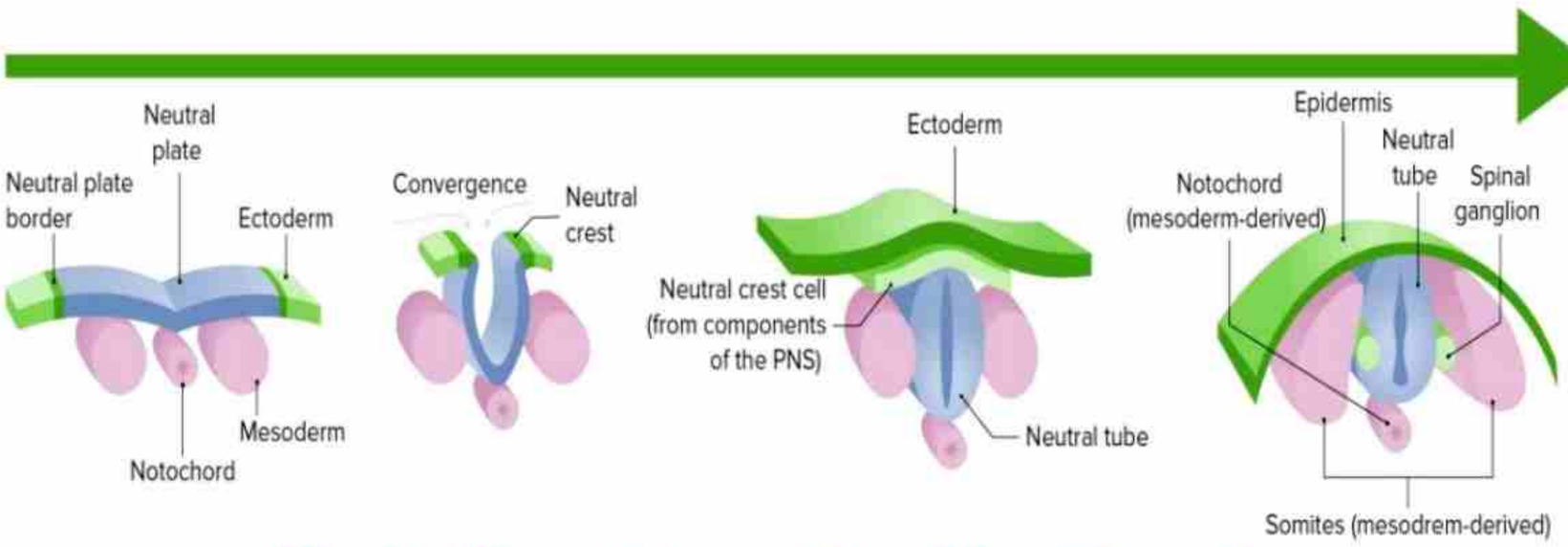


Fig. 21.6 Neural tube and Neural Crest Formation

For example, the anterior end of the neural tube will form the **brain** while the posterior end will form the **spinal cord**. The neural tube eventually closes at both ends, with the cranial (head) end closing first, followed by the caudal (tail) end.

21.1.7 Neural crest and neural crest cells

During embryonic development, the neural crest is a transient, highly migratory population of cells that arises from the neural plate and gives rise to a diverse array of cell types and tissues.

Table 21.2 Structures derived from neural crest cells

Structure	Description
Cranial nerve ganglia	Sensory and autonomic ganglia of the cranial nerves
Adrenal medulla	Chromaffin cells that make up the adrenal medulla, producing epinephrine and norepinephrine
Dorsal root ganglia	Sensory ganglia of the spinal nerves
Melanocytes	Pigment-producing cells responsible for skin, hair, and eye color
Skeletal and connective tissue	Cartilage, bones, and connective tissue of the face and skull, as well as some teeth
Smooth muscle	Smooth muscle cells of the cardiovascular system, including the aortic arch arteries
Schwann cells	Myelin sheath-forming cells around axons in the peripheral nervous system
Enteric nervous system	Nervous system controlling the function of the gastrointestinal tract

21.1.8 Organogenesis

Organogenesis is the process of organ formation in the developing embryo, which begins during the third week of human embryonic development and continues until the end of the eighth week. The three germ layers of the embryo the endoderm, mesoderm, and ectoderm give rise to the various organs and tissues of the body.

21.2 CONTROL OF DEVELOPMENT

The control of development involves the intricate interplay between genetic and environmental factors to determine how a fertilized egg transforms into a complex multicellular organism with distinct tissues and organs. Key processes in this control include pattern formation, where different regions of the embryo become specialized through regulated gene expression and signaling pathways. Another essential aspect is cell differentiation, where undifferentiated cells acquire specific identities through the influence of signaling molecules and transcription factors. Additionally, the environment, including factors like temperature, light, and nutrients, also influences gene expression and cell differentiation, thereby impacting the overall development of the organism.

21.2.1 Role of nucleus in development

During his studies in the late 1920s, Hammerling discovered that *Acetabularia*, a type of marine algae, had a single nucleus located in the base of the cell. He conducted an experiment in 1934 where he successfully transplanted the nucleus of one *Acetabularia* species, *Acetabularia crenulata*, onto the stem of another species, *Acetabularia mediterranea*, which had a different cap shape. The interesting finding was that the cap that grew in

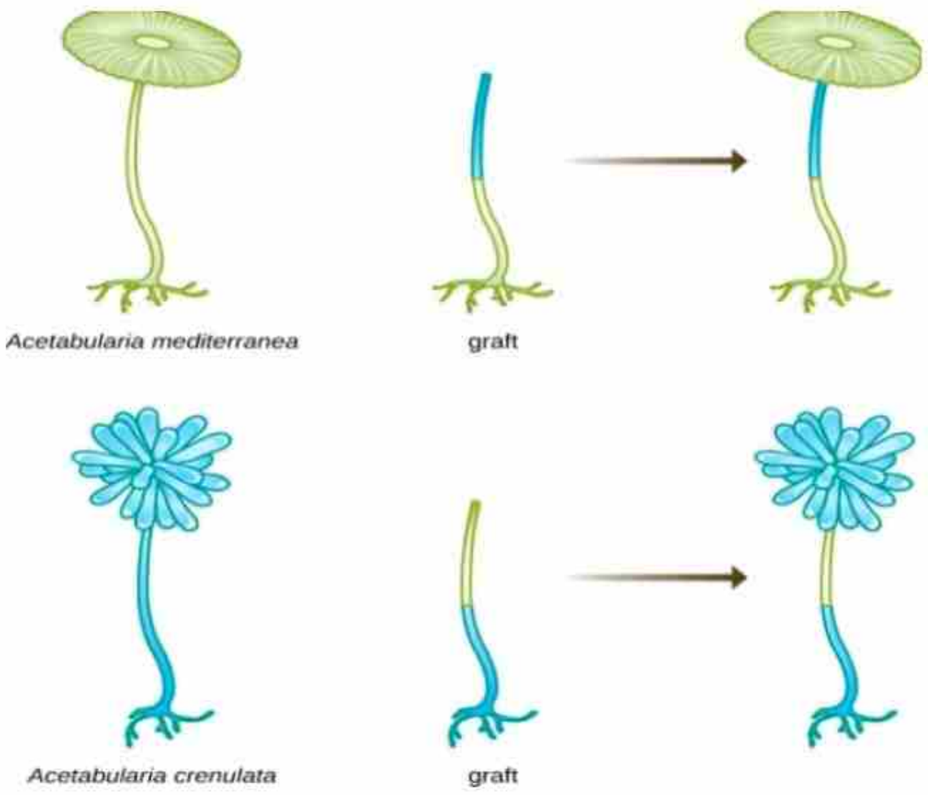


Fig. 21.7 Hammerling's experiments

the transplanted cell resembled that of A. *crenulata*. This indicated that the nucleus influenced the development of the cap by transmitting factors or substances to the cytoplasm. In simpler terms, the experiment showed that the nucleus controls the information that determines the shape of the cap.

21.2.2 Role of cytoplasm in development

The role of cytoplasm in controlling the process of development has been revealed through experiments on frog embryos. Before fertilization, the unfertilized frog egg has a pigmented upper cytoplasmic half and a yolky lower half. After fertilization, a gray crescent forms opposite to the point where the sperm nucleus enters the egg. This gray crescent is created when some pigments in the cytoplasm shift upward, leaving a crescent-shaped area.

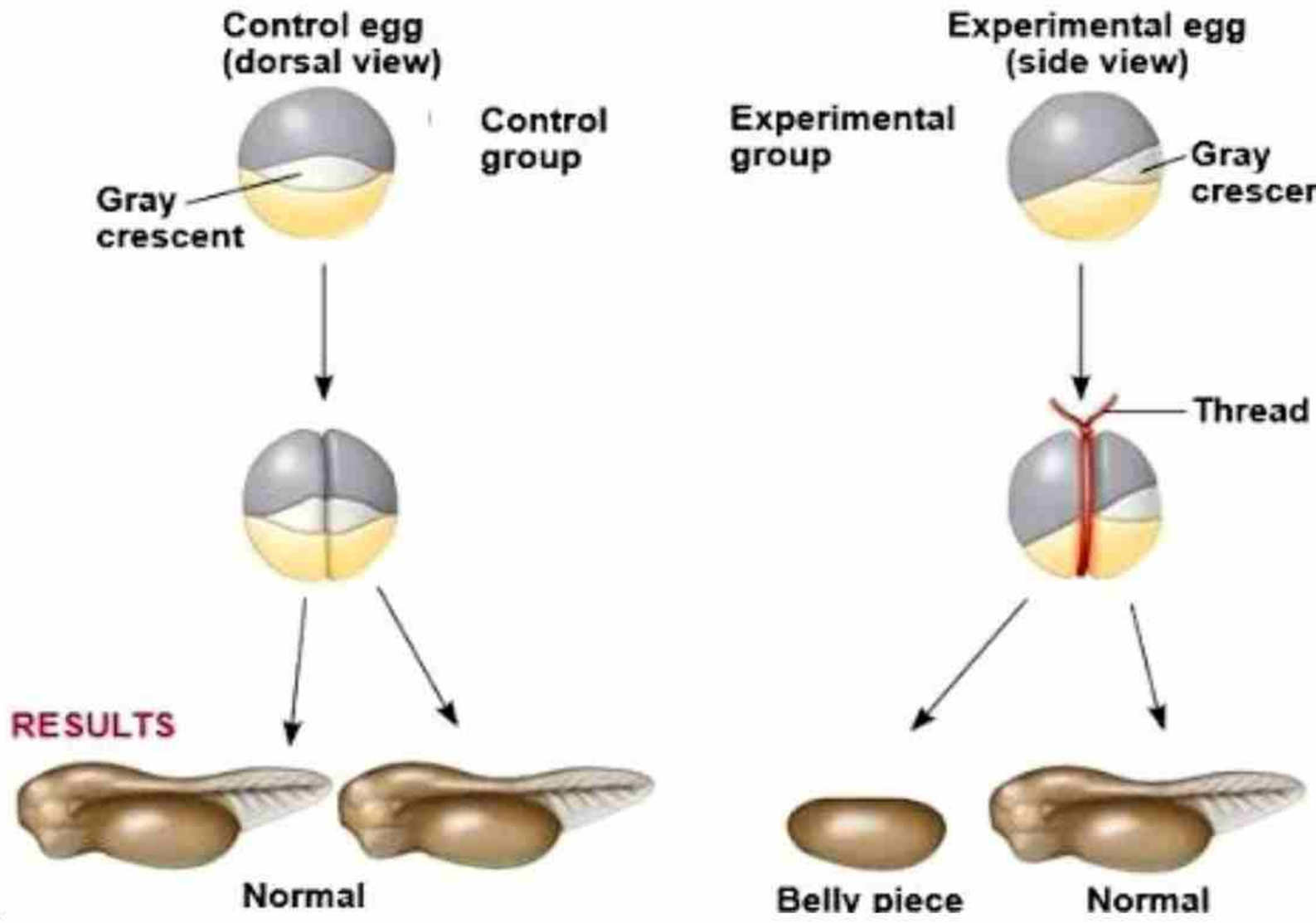


Fig.21.8 Distribution of gene regulating substance

During the first cleavage, the zygote divides vertically, and each daughter cell receives half of the crescent. Interestingly, if these daughter cells are separated carefully, each of them develops into a

normal tadpole larva. In an experiment conducted by Hans Spemann in 1930, he purposely altered the normal plane of the first cleavage. As a result, one of the daughter cells received the entire gray crescent, while the other did not receive any crescent. Both of these daughter cells were separated and allowed to develop. The daughter cell that received the entire gray crescent developed into a complete tadpole larva, while the non-crescent daughter cell failed to develop properly. This experiment highlighted that even though both daughter cells had the same genes, the presence or absence of the gray crescent in the cytoplasm had a significant effect on gene expression and subsequent development.

21.2.3 Embryonic Induction

Induction, the process by which one type of embryonic tissue influences the development of another, is a fundamental aspect of embryonic development. In frog embryos, the primary organizer, situated at the dorsal lip of the blastopore, is essential for proper development. The proximity to the primary organizer determines the fate of cells, with those closest becoming endoderm, those farther away becoming mesoderm, and the farthest becoming ectoderm. This suggests the presence of a molecular gradient that serves as a chemical signal for germ layer differentiation.

Renowned embryologist **Hans Spemann** and his colleague **Hilde Mangold** conducted a groundbreaking experiment in 1924 to study embryonic induction, specifically focusing on the formation of neural tissue. They carefully excised the presumptive nervous system tissue above the notochord and transplanted it to a different region of the embryo, the belly area. Remarkably, the transplanted tissue failed to develop into neural tissue at the new location. This experiment demonstrated the influential capacity of the transplanted tissue, indicating that it induced the surrounding cells to adopt specific fates. The notochord, acting as the primary organizer, played a vital role by releasing signaling molecules that guided neighboring cells to differentiate into neural tissue.

Spemann and Mangold's findings revolutionized our understanding of embryonic induction, revealing that certain tissues

or regions have the ability to direct neighboring cells towards specific developmental paths.

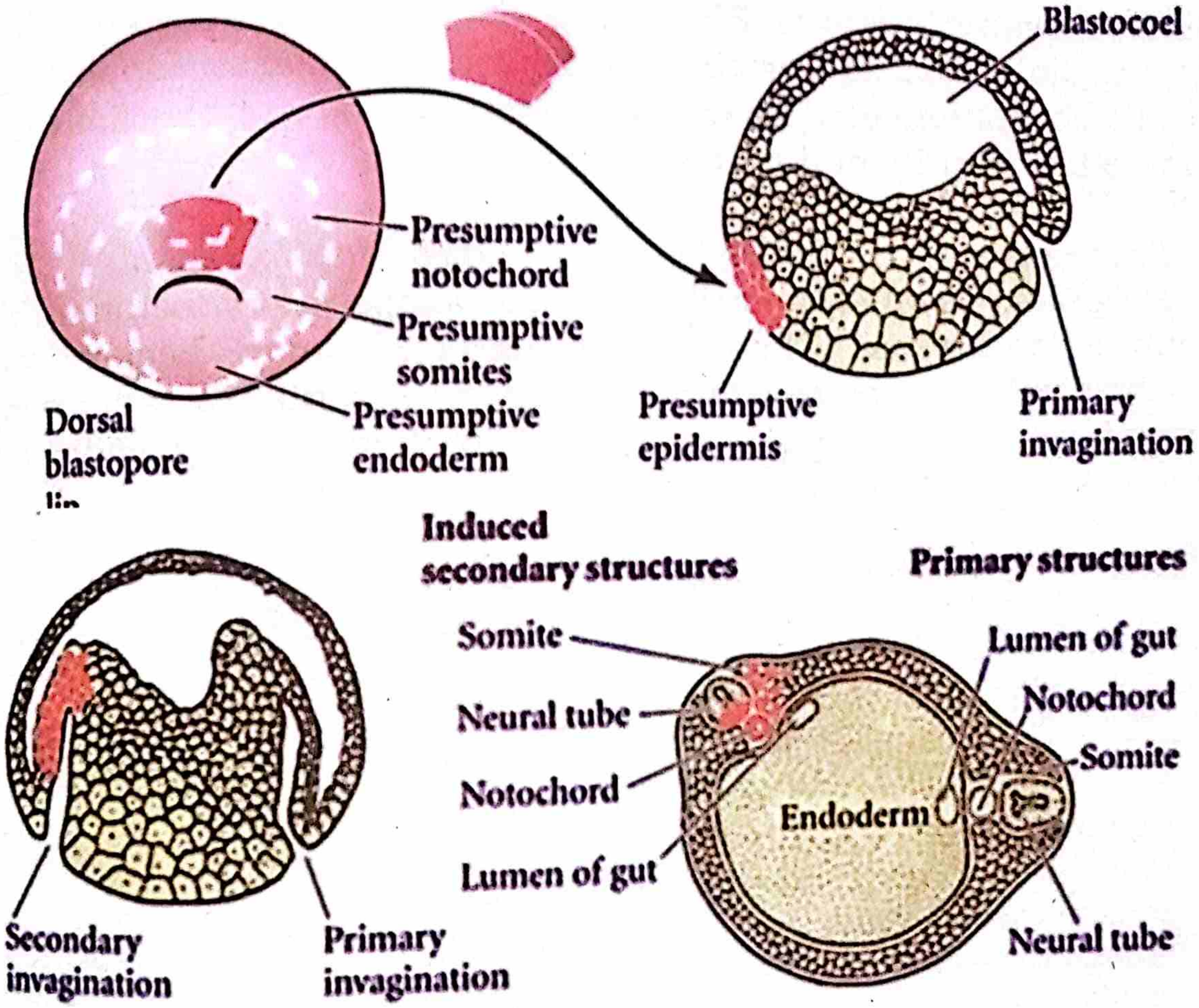


Fig. 21.9 Experiment performed by Hans Spemann and Mangold

21.2.4 Organizers

Organizers are cluster of cells that release diffusible signal molecules, which can induce or direct the differentiation of other cells or tissues.

There are two types of organizers: primary and secondary.

Primary organizers, also known as **embryonic organizers**, are regions that determine the basic body plan of the embryo. In vertebrates, the dorsal lip of the blastopore is considered the primary organizer, as it initiates gastrulation and gives rise to the three germ layers.

Secondary organizers, also known as **regional organizers**, develop later and are responsible for organizing specific regions of the embryo or promoting the differentiation of specific cell types. An example of a secondary organizer is the **ZPA** (zone of polarizing activity) in the developing limb bud of vertebrates. The ZPA releases signals that direct the formation of the anterior-posterior axis of the limb and determine the identity of different digits.

21.3 Pregnancy

Pregnancy is when a fertilized egg develops into a foetus within the mother's uterus. The process of pregnancy begins with fertilization, when a sperm cell penetrates and combines with an egg cell, forming a zygote. The zygote then begins to divide and undergoes several stages of development before it becomes a foetus.

Extra Reading Material

Science & Society: Proper nourishment of the mother during the third trimester

Proper nourishment of the mother during the third trimester of pregnancy is essential for various reasons. Firstly, this is a critical period for the fetus as it undergoes rapid growth and development. Adequate intake of nutrients like protein, carbohydrates, and fats is crucial to support this growth. Insufficient nutrition can lead to complications such as low birth weight, developmental delays, and an increased risk of chronic diseases later in life.

Secondly, the mother's body experiences significant changes during the third trimester to accommodate the growing fetus. These changes require extra energy and nutrients. For instance, blood volume increases, the uterus expands, and breast tissue develops in preparation for lactation. Without proper nourishment, the mother may experience fatigue and lack the necessary resources to support these bodily changes.

Lastly, maintaining proper nutrition during the third trimester can help reduce the risk of delivery complications. Well-nourished women are less likely to experience prolonged labor or require a cesarean delivery.

During pregnancy, the mother's body undergoes numerous physiological changes to support the growing foetus. Hormonal changes occur, leading to increased blood flow to the uterus, changes in metabolism, and growth of the placenta, which connects the foetus to the mother's blood supply. The development of the foetus is divided into three trimesters, each lasting approximately three months.

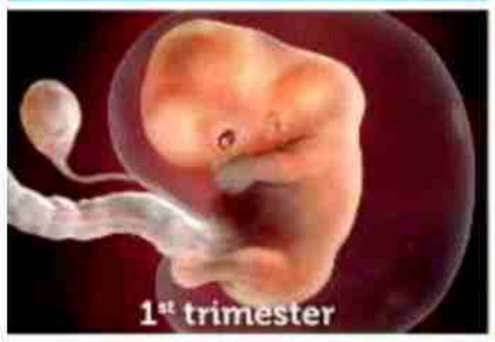
21.3.1. Human development in trimesters

Human development during pregnancy is divided into three trimesters, each lasting about three months. Let's take a brief look at the major milestones that occur during each trimester.

Table 21.3. Summary of Three Trimesters events

Trimester	Time frame	Major Developmental Events
First Trimester	First Month	Fertilization and implantation, formation of the blastocyst, and the beginning of embryonic development
	Second Month	Development of major organs and systems, including the heart, brain, limbs, and digestive system. The embryo becomes a foetus by the end of the second month.
	Third Month	Rapid growth and development of the foetus, including the formation of fingers and toes, eyelids, and external genitalia. The foetus can move its limbs and make facial expressions.
Second	Fourth Month	Continued growth and development, including the formation of hair and nails, and the development of a functioning urinary system. The foetus can hear sounds from outside the womb.
	Fifth Month	Development of taste buds, and the ability to swallow and digest amniotic fluid. The foetus has distinct sleeping and waking patterns, and can respond to light and touch.

Third	Sixth Month	Rapid brain development and the growth of hair and nails. The foetus has a good chance of survival if born prematurely.
	Seventh Month	Continued growth and development of organs, and the development of fat stores under the skin. The foetus can open and close its eyes and respond to external stimuli.
	Eighth Month	Increased weight gain, and continued development of the nervous and respiratory systems. The foetus can recognize its mother's voice and can turn head-down in preparation for birth.
	Ninth Month	Final stages of development, including the shedding of the lanugo hair and the formation of the vernix caseosa. The foetus is fully developed and ready for birth

Trimester	Months pregnant*	Weeks pregnant
	0	0 - 4
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	2	9 - 12
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	3	14 - 17
	4	18 - 21
	5	22 - 25
	6	26 - 27
	6	28 - 30
	7	31 - 34
	8	35 - 38
	9	39 - 42

Fig. 21.10 Pregnancy by Weeks and Months

21.3.2 Twins and Quadruplets

The development of twins and quadruplets occurs when multiple embryos form from a single fertilized egg, or when multiple eggs are fertilized by multiple sperm.

Twins:

Twins are children which develop and are born together. Twins are of two types i.e. **Identical twins**, also known as **monozygotic twins**, occur when a single fertilized egg splits into two embryos. The embryos will have the same genetic material and will develop into two separate feotuses. The timing of the split determines if the twins will share a placenta and amniotic sac or have separate ones. This process occurs randomly and is not influenced by genetics or other external factors. **Fraternal twins**, or **dizygotic twins**, occur when two eggs are fertilized by two separate sperm. These embryos will have different genetic material and can develop into two separate foetuses. Fraternal twins may or may not share a placenta and amniotic sac, depending on when the eggs are fertilized.

The development of **quadruplets** follows a similar pattern to that of twins. Multiple eggs may be fertilized by multiple sperm or a single fertilized egg may split into multiple embryos. Quadruplets may share a placenta and amniotic sac or have separate ones, depending on the timing of embryo formation and implantation.

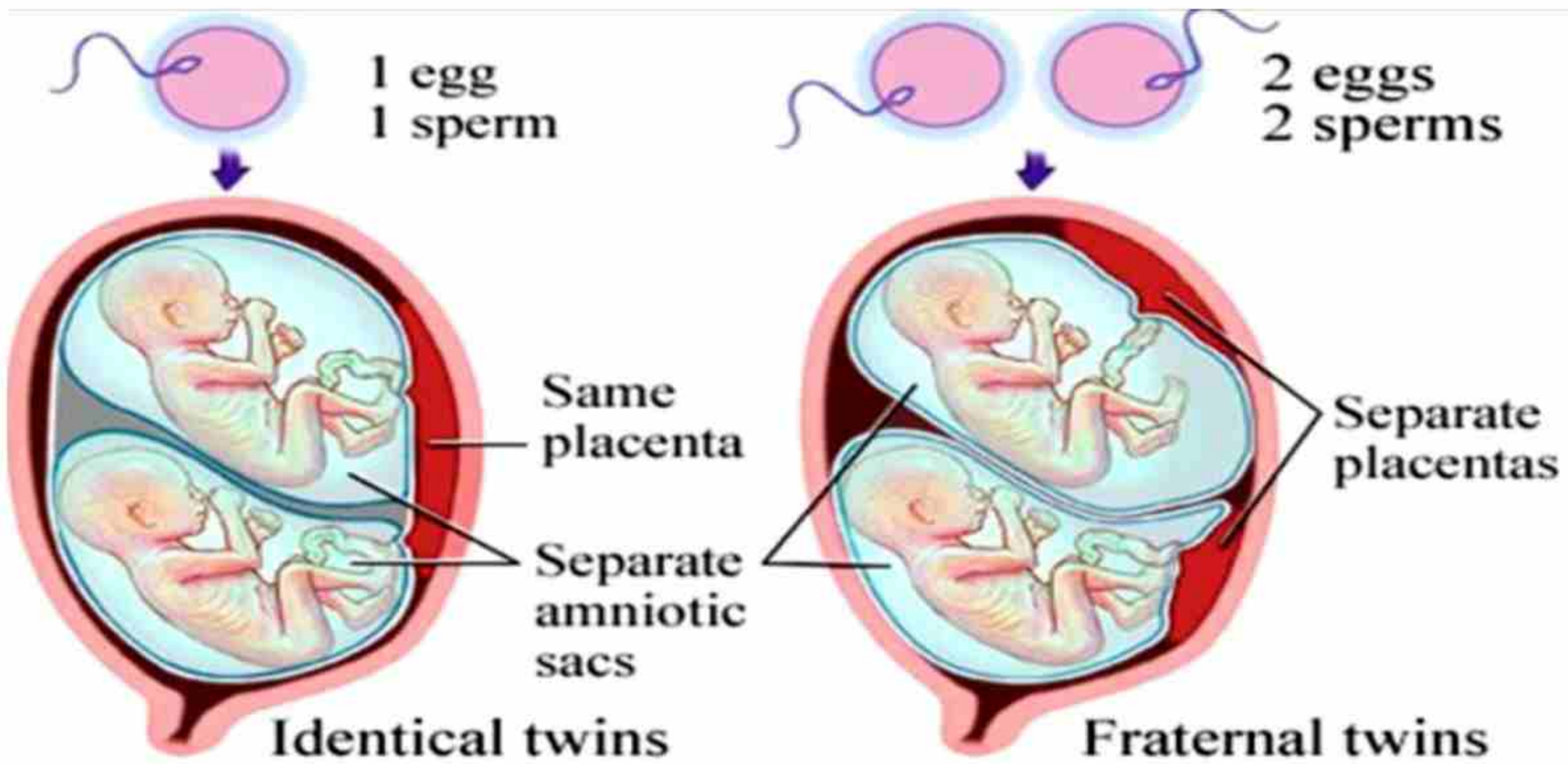

Fig. 21.11 Monozygotic and Dizygotic Twins

21.3.3. Placenta and Umbilical Cord

The placenta is a temporary organ that develops during pregnancy and serves as the interface between the maternal and foetal circulatory systems. It is formed from the chorion, the outermost foetal membrane, and the decidua, the lining of the uterus. The placenta is attached to the uterine wall and connected to the foetus by the umbilical cord.

The placenta has a disc-like shape and is composed of two layers: the **maternal side** and the **foetal side**. The maternal side of the placenta is rough and irregular in shape, while the foetal side is smooth and rounded. The maternal side contains maternal blood vessels that bring oxygen and nutrients to the foetus, while the foetal side contains foetal blood vessels that remove waste products and carbon dioxide from the foetal blood.

Umbilical cord

The umbilical cord (Latin: Funiculus Umbilicalis) is a tube-like structure that connects the developing foetus to the placenta. It has one umbilical vein and two umbilical arteries, which are used by the foetal heart to pump blood to and from the placenta, which exchanges nutrients and waste products with the mother's circulatory system. After birth, the umbilical cord is clamped and cut, leaving a small stump that becomes the belly button.

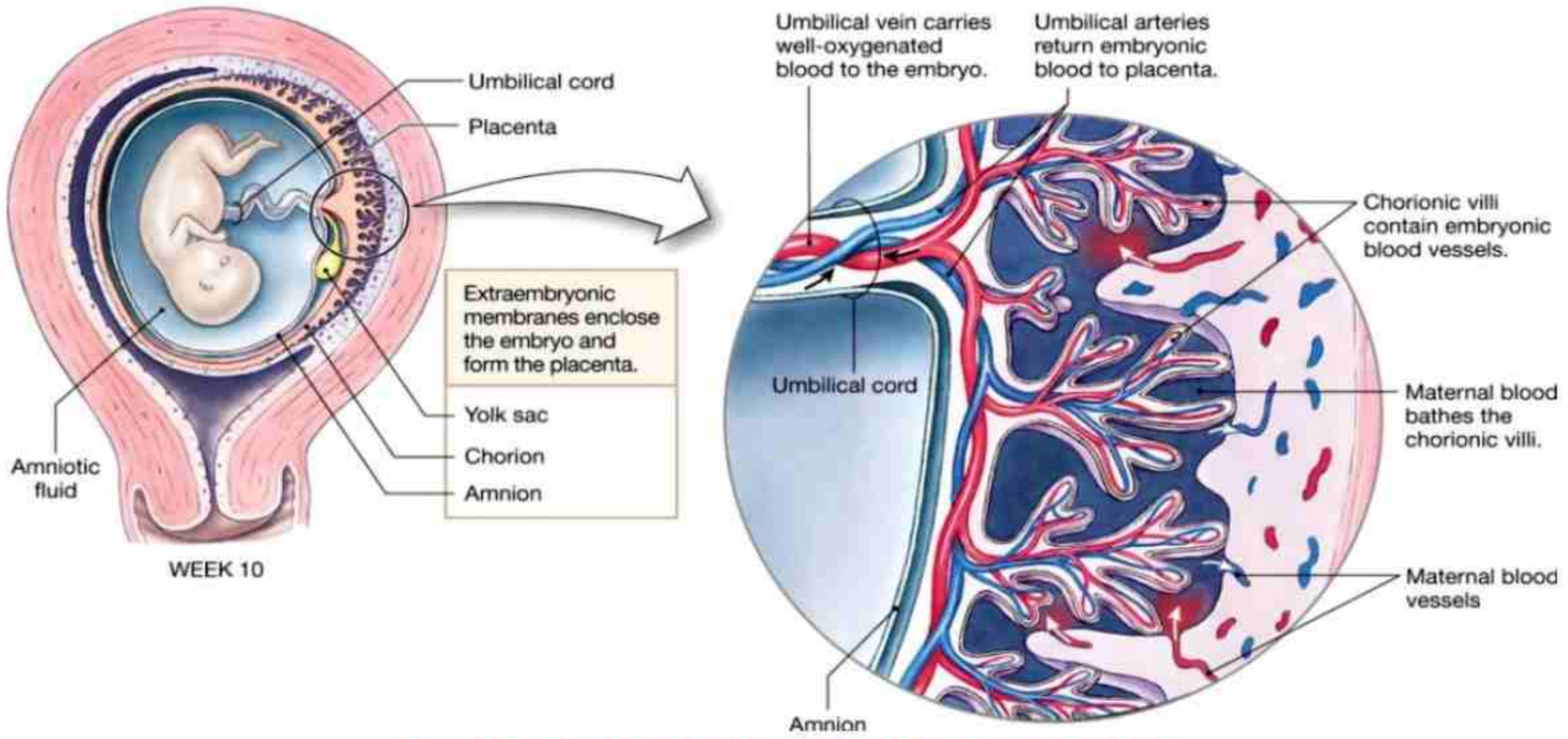

Fig. 21.12 Placenta and Umbilical Cord

21.3.4 Difference between Gestation and Pregnancy

The terms "**gestation**" and "**pregnancy**" are often used interchangeably, but they refer to different concepts. Gestation refers to the period during which an embryo is developing within the uterus. This includes the time from fertilization of the egg by the sperm to the birth of the offspring. In humans, gestation typically lasts around 38-42 weeks, or approximately 9 months.

On the other hand, pregnancy refers specifically to the condition of a female mammal (usually a human) in which she is carrying one or more offspring in her uterus. Pregnancy includes not only the period of gestation, but also the various physiological and hormonal changes that occur in the mother's body during this time. These changes include increased levels of hormones like progesterone and estrogen, as well as physical changes like weight gain and changes in the size and shape of the uterus.

21.4 EMBRYONIC DISORDERS

Disorders during embryonic development refer to a range of medical conditions that can occur during the early stages of human development. These disorders can be caused by genetic abnormalities, environmental factors, or a combination of both, and can have significant impacts on both the developing foetus and the mother.

21.4.1 The maternal-derived abnormalities

Maternal Health Problems:

Certain maternal health problems, such as uncontrolled diabetes or high blood pressure, can also have negative impacts on embryonic development.

Rubella is a viral infection that can be transmitted to the foetus during pregnancy, leading to a range of birth defects, collectively known as **Congenital Rubella Syndrome** (CRS). The infection can cause developmental delays, hearing loss, cataracts, heart defects, and intellectual disabilities in the developing foetus.

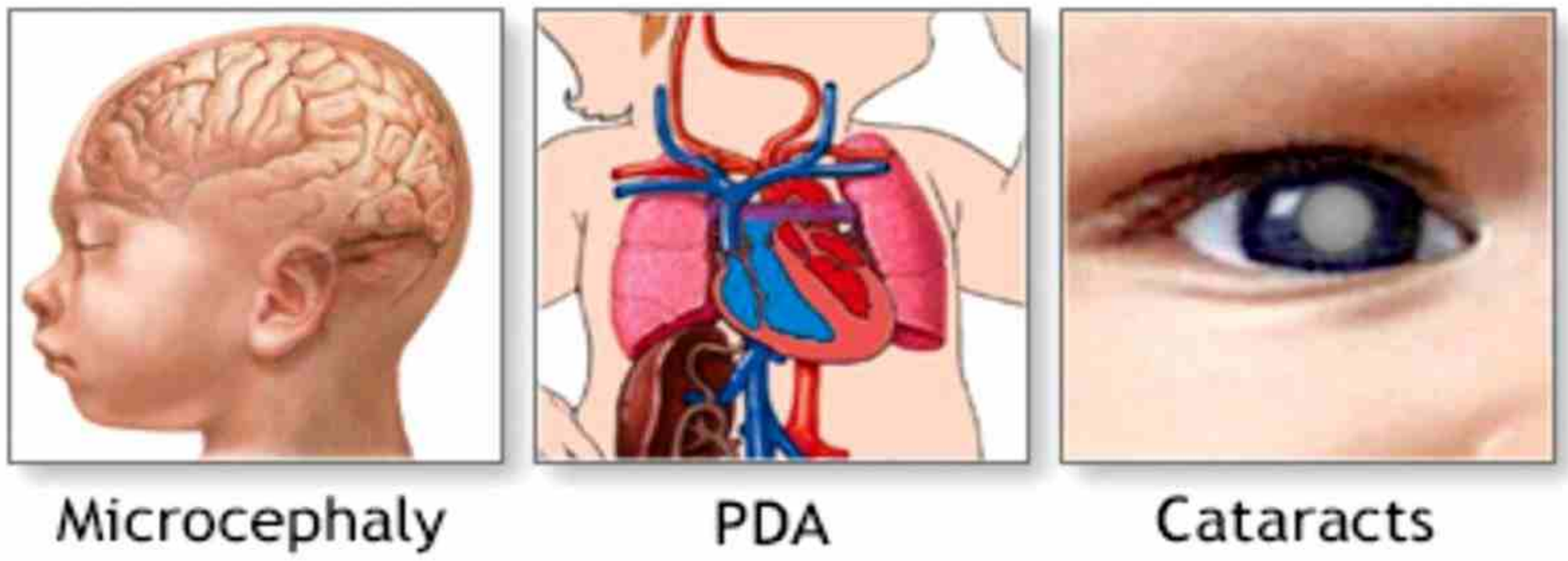

Fig. 21.13 Congenital Rubella Syndrome

Abnormal neural tube development can lead to neural tube defects (**NTDs**) in the developing foetus. NTDs occur due to the failure of the neural tube to close completely during embryonic development, leading to conditions such as spina bifida and anencephaly. These conditions can result in severe disabilities or even be fatal.

Thyroid gland dysfunction can cause developmental abnormalities in the foetus, as thyroid hormones play a crucial role in foetal growth and development. If the mother has an underactive thyroid gland (hypothyroidism) during pregnancy, it can lead to developmental delays, intellectual disability, and other abnormalities in the developing foetus.

Limb development issues can occur due to various maternal health factors and environmental exposures. Certain medications, infections, and genetic conditions can lead to limb abnormalities in the developing foetus, such as missing or extra fingers, shortened limbs, or limb deformities.

Proper prenatal care, including regular check-ups and proper management of maternal health conditions, can help prevent or minimize the risk of these maternal-derived abnormalities in the developing foetus

21.4.2 Genetic abnormalities & Spontaneous abortion

Spontaneous abortion, also known as miscarriage, is a common complication of pregnancy that results in the loss of the

foetus before the 20th week of gestation. It is estimated that up to 20% of all recognized pregnancies end in miscarriage, with the majority occurring during the first trimester. Many of these miscarriages are caused by major genetic abnormalities in the embryo.

Genetic abnormalities in embryos can arise from errors in chromosome number or structure, gene mutations, or epigenetic modifications. These abnormalities can affect various aspects of embryonic development, including cell proliferation, differentiation, and apoptosis. As a result, affected embryos may fail to implant properly, develop abnormal tissues or organs, or have severe developmental defects that are incompatible with life.

Some common genetic abnormalities that can cause spontaneous abortion include:

Chromosomal abnormalities: These are the most common cause of spontaneous abortion, accounting for up to 60% of cases. They include errors in chromosome number (such as trisomy or monosomy) or structure (such as deletions or translocations). Most chromosomal abnormalities are random events that occur during cell division in the egg or sperm, but some can be inherited from a parent.

Gene mutations: Mutations in specific genes can also cause spontaneous abortion. For example, mutations in genes that regulate cell proliferation or differentiation can disrupt normal embryonic development. Inherited mutations in genes such as BRCA1 and BRCA2, which are associated with an increased risk of breast and ovarian cancer, can also increase the risk of miscarriage.

Epigenetic modifications: Epigenetic modifications are changes in gene expression that do not involve alterations to the DNA sequence itself. They can be influenced by environmental factors such as diet and stress, as well as by inherited factors. Abnormal epigenetic modifications can affect gene expression in the developing embryo and increase the risk of miscarriage.

In summary, major genetic abnormalities in the embryo can lead to spontaneous abortion by disrupting normal embryonic development.

While some of these abnormalities are inherited, many are random events that cannot be prevented.

21.4.3 Foetal surgery

Foetal surgery is a medical procedure performed on a foetus in the uterus to correct structural or developmental abnormalities. This type of surgery is typically performed in cases where there is a high risk of foetal death or long-term disability if the issue is not corrected before birth.

One example of foetal surgery is the correction of **spina bifida**, a condition where the neural tube does not close properly during embryonic development, leading to damage to the spinal cord and nerves. In foetal surgery for spina bifida, a surgical team will make a small incision in the mother's abdomen and uterus and repair the opening in the baby's back. This can prevent further damage to the spinal cord and improve the baby's chances of being able to walk and have normal bladder and bowel function.

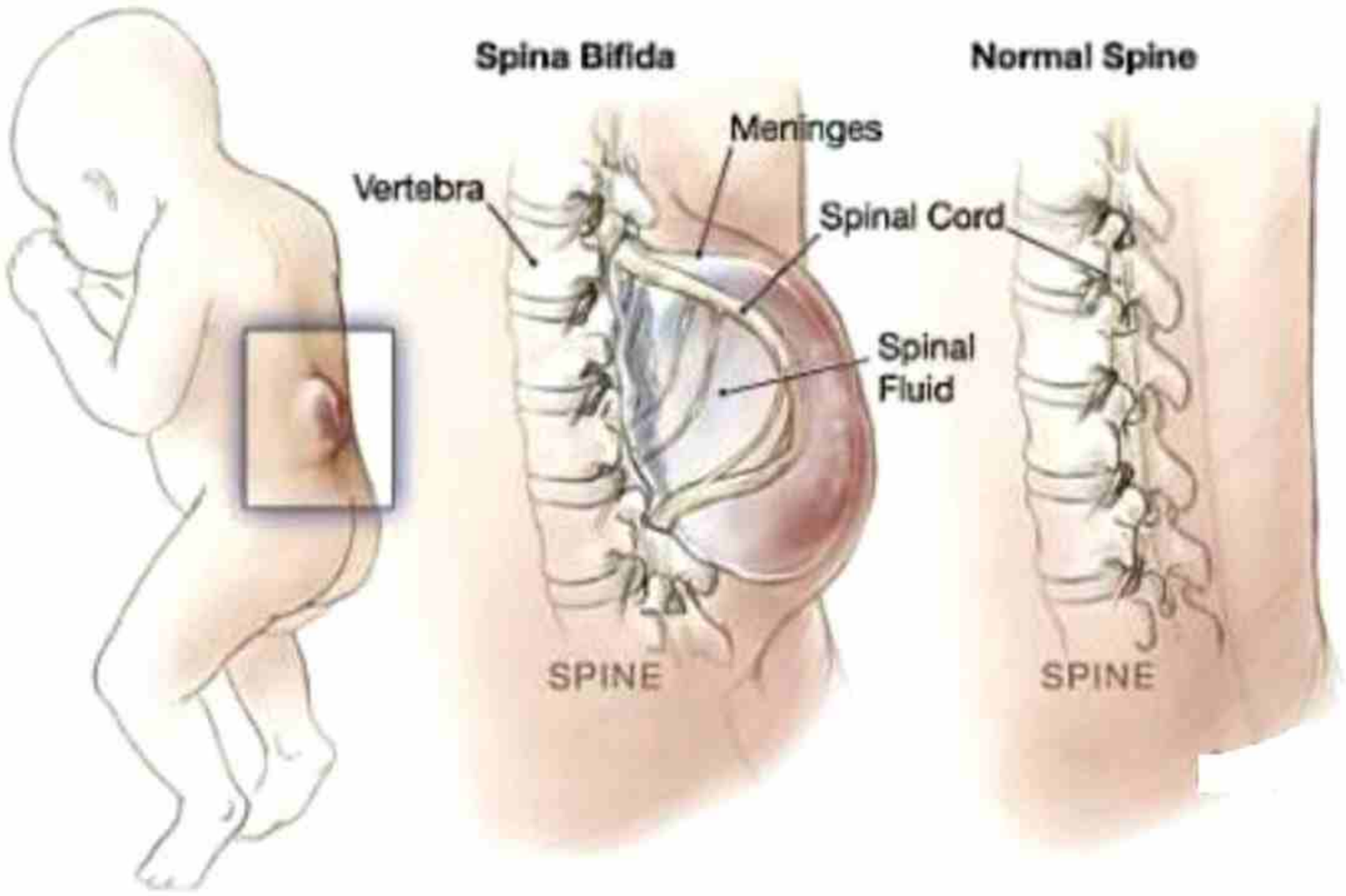

Fig. 21.14 Spina bifida and normal spine

21.5 AGING

Aging refers to the process of natural, gradual and irreversible changes that occur in living organisms over time, resulting in a decline in their physical and mental abilities. It is a biological phenomenon that affects all living organisms and is characterized by a progressive deterioration of physiological functions that eventually leads to death. The aging process is influenced by various factors such as genetics, environmental factors, lifestyle, and disease, and it varies from person to person.

21.5.1 Aging as part of normal development

Aging can be rationalized as a part of normal development because it is a natural and inevitable process that occurs in all living organisms. It is a result of progressive changes that occur in the body over time, including cellular damage, DNA damage, and metabolic changes. These changes lead to a gradual decline in the body's ability to function, resulting in death.

As humans age, they experience a decline in physical and cognitive function, including decreased muscle mass, decreased bone density, reduced sensory function, and decreased immune function. These changes can lead to an increased risk of chronic diseases, such as cardiovascular disease, diabetes, and cancer.

There are several genetic and extrinsic factors that can contribute to the aging process:

21.5.2 Aging: Genetic factors

Aging is a complex process that involves the progressive decline in cellular and physiological functions, leading to an increased vulnerability to age-related diseases.

Research has identified several genetic factors that contribute to the aging process. One of the most well-known genetic factors is the role of telomeres in aging. **Telomeres** are the protective caps at the end of chromosomes that shorten with each cell division. The length of telomeres has been associated with aging, as shorter telomeres are correlated with age-related diseases and decreased lifespan. Genetic variations in the genes that control telomere length have been linked to accelerated aging and increased risk of age-related diseases.

Another genetic factor that contributes to aging is the role of genes involved in DNA repair. As we age, the DNA in our cells becomes damaged, and if not repaired, can lead to mutations and cell death. Genetic variations in genes involved in DNA repair have been linked to increased risk of age-related diseases and decreased lifespan.

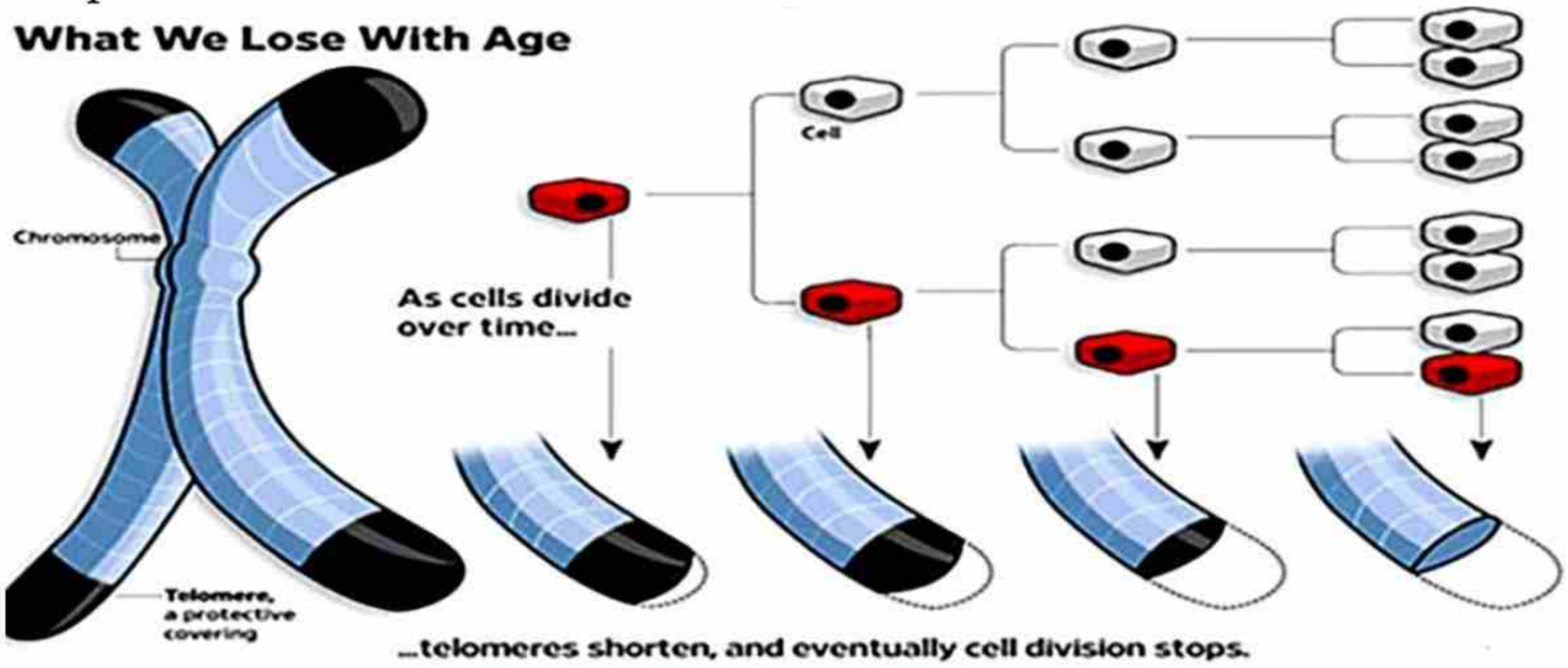

Fig. 21.15 Aging and Telomeres

In addition to telomere length and DNA repair genes, other genetic factors that contribute to aging include mitochondrial function, inflammation, and oxidative stress. Mitochondria are the energy-producing organelles in cells, and their dysfunction has been linked to aging and age-related diseases. Inflammation and oxidative stress are also key factors in aging, and genetic variations in genes that regulate these processes can influence an individual's rate of aging.

21.5.3 Extrinsic Factors

In addition to genetics, aging is also influenced by various **extrinsic** or **external factors**. These factors can include environmental, lifestyle, and social factors that can impact an individual's rate of aging.

Environmental factors such as pollution, radiation, and exposure to toxins can contribute to aging by causing damage to cellular components such as DNA, proteins, and lipids. For example, exposure to UV radiation from the sun can cause DNA damage, which can lead to mutations and cellular aging. Similarly, exposure

to air pollution has been linked to accelerated aging and increased risk of age-related diseases such as respiratory and cardiovascular disease.

Lifestyle factors such as diet, exercise, and sleep can also influence the aging process. A diet high in processed foods, sugar, and saturated fats can lead to chronic inflammation, oxidative stress, and metabolic dysfunction, which can accelerate aging and increase the risk of age-related diseases such as diabetes and heart disease. On the other hand, a diet rich in fruits, vegetables, whole grains, and lean proteins can promote cellular health and slow down the aging process.

Table 21.4 Aging Factors

Aging Factors	Description
Intrinsic	➢ Telomere length and DNA repair genes ➢ Mitochondrial dysfunction ➢ Inflammation and oxidative stress
Extrinsic	➢ Environmental factors (pollution, radiation, exposure to toxins ➢ Lifestyle factors (diet, exercise, sleep) ➢ Social factors (social support, education, socioeconomic status)

21.5.4 Primary aging

Primary aging refers to the natural, inevitable changes that occur as a person ages, and are not typically associated with disease or injury. Graying and thinning of hair occurs as melanin production decreases, while pigmented patches of skin result from an uneven distribution of melanin. Slow movements and fading vision are due to a decrease in the efficiency of nerve impulses and the gradual loss of muscle mass. Impaired hearing is often due to a gradual decline in the function of the inner ear.

Reduced ability to adapt to stress occurs due to a decrease in the body's ability to produce and regulate hormones such as cortisol. Finally, decreased resistance to infections is due to a weakened immune system caused by a decline in the function of the thymus

gland, which produces T-cells. These changes are a natural part of the aging process and occur in most people to varying degrees.

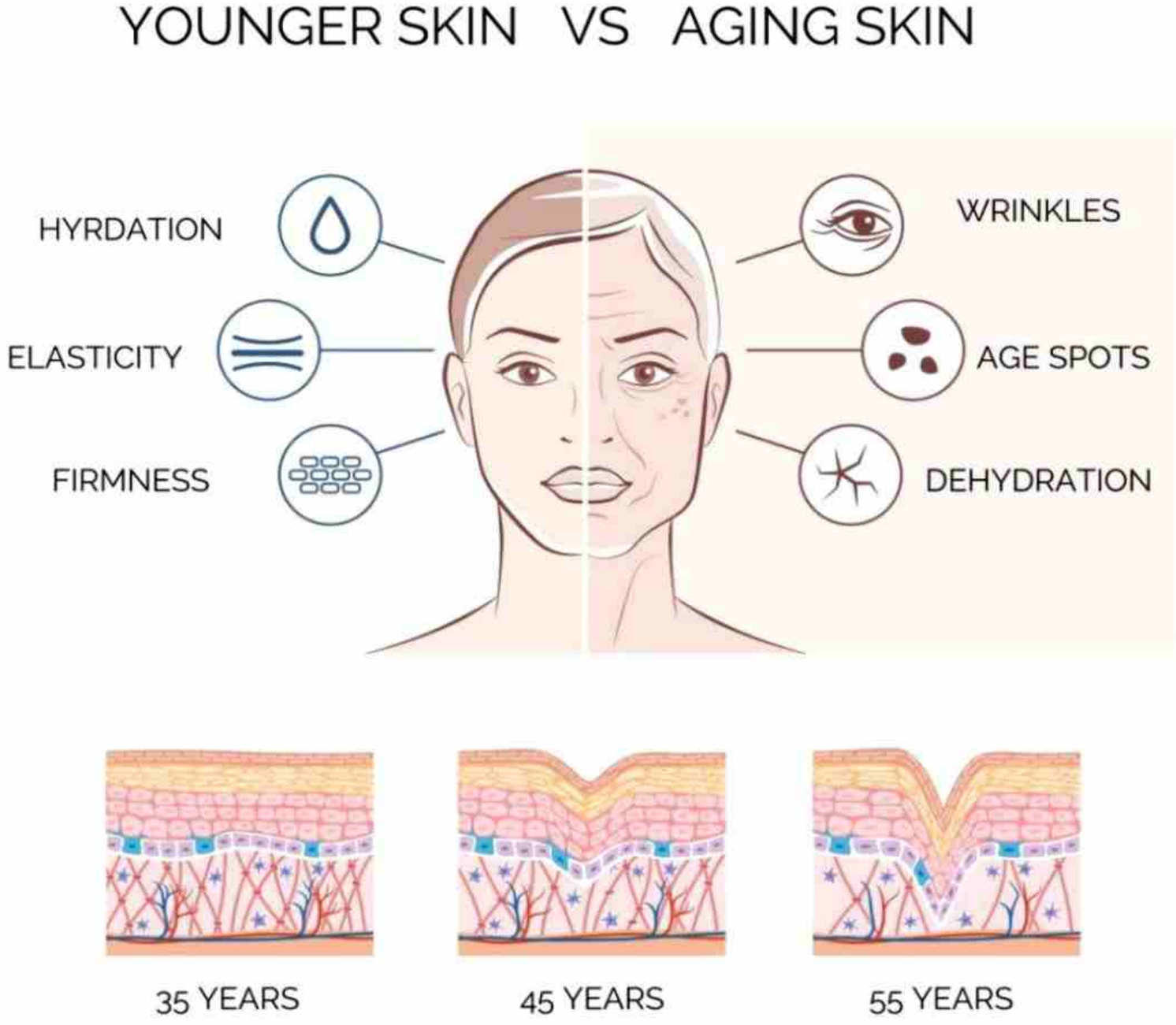

Fig. 21.16 Aging and Skin

21.5.5 Secondary aging

Secondary aging refers to body changes resulting from environmental and lifestyle factors such as disease, disuse, and abuse. These changes can accelerate the natural aging process and lead to a decline in physical and cognitive functions. Disease can be a major factor in secondary aging. Chronic conditions such as diabetes, cardiovascular disease, and cancer can have a significant impact on the body and accelerate the aging process. Infections, particularly those that are recurrent, can also contribute to secondary aging.

Lack of exercise can also accelerate aging. The muscles, bones, and joints require regular use to maintain their strength and flexibility. Without regular exercise, these structures can weaken and become more prone to injury. Abuse of substances such as smoking, alcohol, and drugs can also lead to secondary aging. Smoking is a major contributor to premature aging. It causes damage to the skin and respiratory system, and can increase the risk of heart disease, cancer, and stroke. Obesity and malnutrition can also have a significant impact on the body, leading to a range of health problems and accelerating the aging process.

Exposure to environmental factors such as ultra-violet light can also accelerate aging. Sun damage to the skin is a common example of this, leading to the development of wrinkles and age spots. Pollution, radiation, and other toxins in the environment can also contribute to secondary aging.

21.5.4 Changes that occur at the system level during aging

Cardiovascular system:

Reduced heart function, stiffening of blood vessels, and decreased blood flow to tissues.

Respiratory system: Decreased lung function and reduced oxygen supply to tissues.

Digestive system: Decreased production of digestive enzymes and reduced nutrient absorption.

Urinary system: Reduced kidney function and increased risk of urinary tract infections.

Musculoskeletal system: Reduced muscle mass, strength, and bone density, and increased risk of fractures.

21.5.5 Changes that occur at the cellular level during aging include:

DNA damage: Accumulation of DNA damage can lead to mutations and cellular dysfunction.

Telomere shortening: Telomeres, the protective caps at the ends of chromosomes, shorten with each cell division, leading to cellular senescence.

Mitochondrial dysfunction: Mitochondria, the energy-producing organelles in cells, become less efficient and generate more harmful byproducts as they age.

Oxidative stress: Accumulation of reactive oxygen species (ROS) can damage cellular components and contribute to aging-related diseases.

Inflammation: Chronic inflammation is a hallmark of aging and can contribute to age-related diseases such as cardiovascular disease, diabetes, and cancer

21.5.6 Age-related diseases & Medical science

Here is a list of age-related diseases along with their brief descriptions and common medical interventions:

Table 21.5 Age-related diseases & Medical science

Disease	Description	Medical Interventions
Cardiovascular disease	A group of conditions that affect the heart and blood vessels	Medications, lifestyle changes, surgical procedures
Alzheimer's disease	A progressive brain disorder that affects memory and cognitive function	Medications, cognitive/behavioral therapies, lifestyle changes
Osteoporosis	A condition that causes bone loss and increases the risk of fractures	Medications, calcium/vitamin D supplements, weight-bearing exercises
Arthritis	A group of conditions that cause joint pain, stiffness, and swelling	Medications, physical therapy, joint replacement surgery
Age-related macular degeneration	A progressive eye disease that can cause vision loss	Medications, laser therapy, surgical procedures
Type 2 diabetes	A chronic condition that affects how the body processes blood sugar	Medications, lifestyle changes, insulin therapy

SUMMARY

- Human embryonic development involves a series of stages that result in the formation of a foetus.
- The process of development is regulated by a combination of genetic, environmental, and epigenetic factors.
- During pregnancy, the mother undergoes significant physiological changes to support the developing foetus.
- The three trimesters of pregnancy are characterized by different stages of foetal development and maternal adaptations.
- Abnormalities in embryonic development can result in birth defects, genetic disorders, or miscarriage.
- Aging is a complex process that is influenced by both genetic and environmental factors.
- Age-related changes can occur in tissues, organs, and systems throughout the body, leading to a decline in function and increased risk for disease.
- The study of aging involves multiple disciplines, including genetics, physiology, and psychology.
- Genetic factors play a significant role in determining lifespan and the risk for age-related diseases.
- Environmental factors, such as diet, exercise, and exposure to toxins, can influence the aging process and disease risk.
- Interventions aimed at slowing or reversing aging include lifestyle modifications, pharmaceuticals, and gene therapies.
- The use of these interventions raises ethical, social, and economic issues related to access, safety, and societal values.
- The study of human embryonic development, pregnancy, disorders, and aging is important for understanding human health and disease.
- Studying human development and aging requires a multidisciplinary approach that draws on knowledge from genetics, developmental biology, physiology, psychology, and other fields.

EXERCISE

1. Encircle the correct choice

i) The genetic material of a fertilized egg is a combination of
(a) The mother's DNA only
(b) The father's DNA only
(c) Both the mother's and father's DNA
(d) None of the above

ii) Human embryonic development occurs in the
(a) Uterus (b) Fallopian tube
(c) Cervix (d) Vagina

iii) The process of cell differentiation involves:
(a) The formation of gametes
(b) The formation of zygotes
(c) The specialization of cells for different functions
(d) The replication of DNA

iv) The implantation of the embryo in the uterus occurs at
(a) 1 week after fertilization (b) 2 weeks after fertilization
(c) 4 weeks after fertilization (d) 8 weeks after fertilization

v) Aging is characterized by:
(a) The accumulation of genetic mutations
(b) The breakdown of cellular processes
(c) The cessation of mitosis
(d) The reduction in DNA replication

vi) The inner cell mass of a blastocyst gives rise to:
(a) The placenta (b) The embryo
(c) The umbilical cord (d) The amniotic fluid

vii) The process of fertilization occurs in the
(a) Uterus (b) Fallopian tube
(c) Cervix (d) Vagina Answer

viii) The stages of embryonic development are
(a) Cleavage, implantation, gastrulation, and organogenesis
(b) Fertilization, implantation, gastrulation, and organogenesis
(c) Cleavage, fertilization, gastrulation, and organogenesis
(d) Cleavage, fertilization, implantation, and organogenesis

ix) The placenta is responsible for
(a) Providing oxygen and nutrients to the developing embryo
(b) Removing waste products from the developing embryo
(c) Producing hormones that maintain the pregnancy
(d) All of the above

x) The formation of the neural tube occurs during
(a) Cleavage (b) Gastrulation
(c) Organogenesis (d) Implantation

2. Write short answer of the following:

i) Why cleavage in birds and reptiles called meroblastic?
ii) Why morula is named so?
iii) How embryonic tissues influence other embryonic tissues?
iv) Define organizers and differentiate between primary and secondary induction.
v) Differentiate between blastula and gastrula.
vi) Why monozygotic twins having same sex?

3. Write detailed answers to the following questions.

i) Explain blastula/blastocyst with emphasis on segmentation cavity.
ii) List the tissues and organs formed from the three germ layers.
iii) Through experimental narration, describe the role of the nucleus and cytoplasm in controlling development.
iv) Describe the events of development in humans in terms of first, second and third trimesters.
v) Describe the maternal derived abnormalities (rubella, abnormal neural tube, thyroid gland and limb development).