جامعة اليرموك
YARMOUK UNIVERSITY

MSS Module

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Muscle Development

Muscle Development

- ***By the end of this session you should be able to:***

1. Discuss the timeline of normal development of the muscular system and its embryological abnormalities

Gastrulation

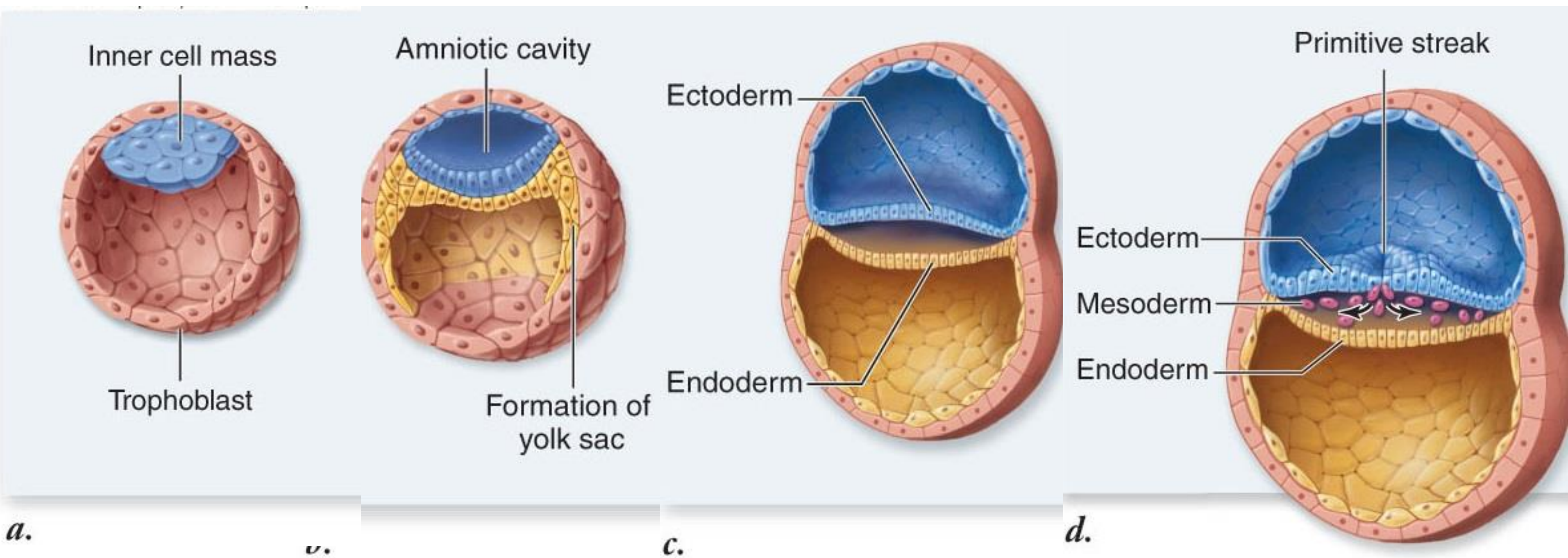
At gastrulation the ***two layered epiblast*** is converted into the three primary embryonic germ layers:

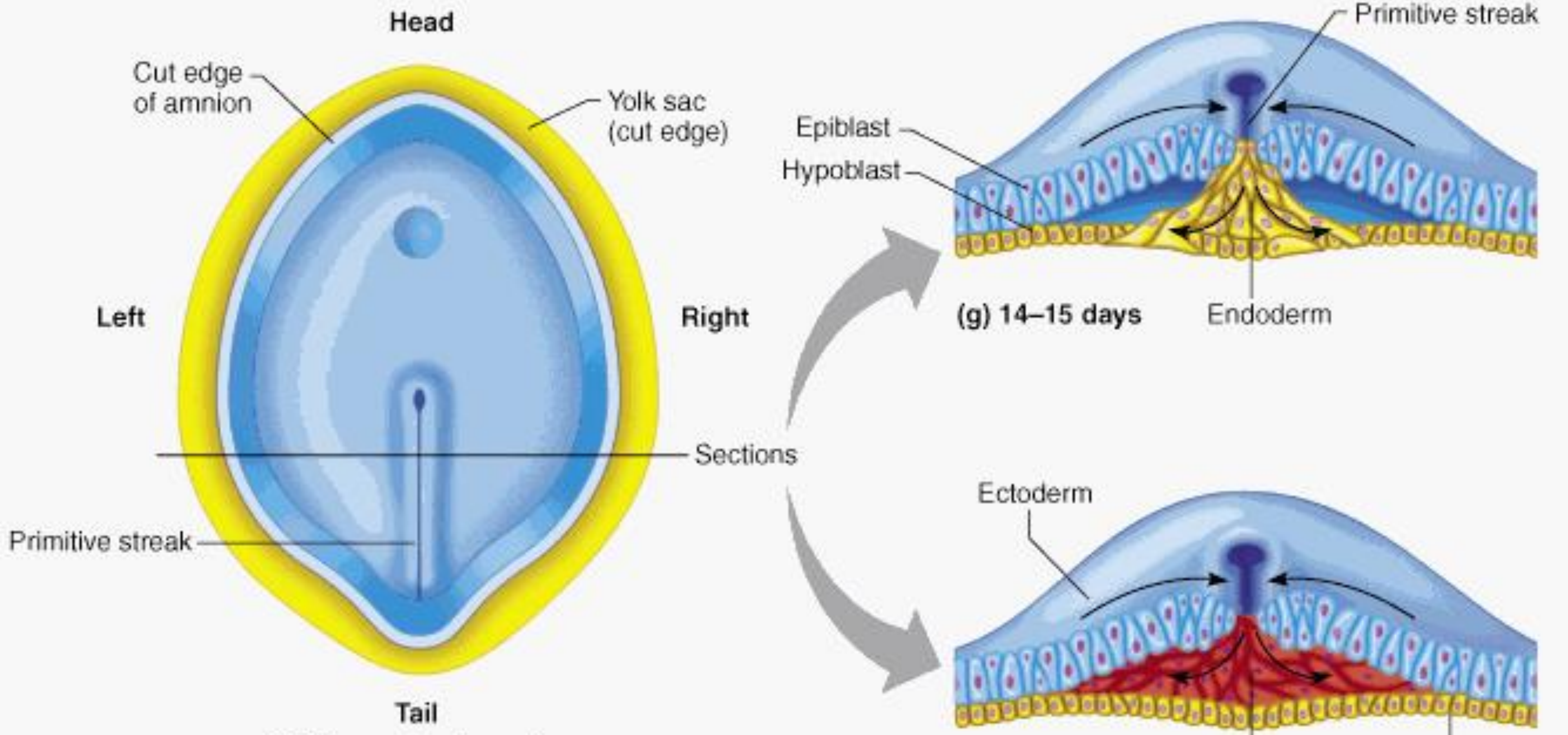
1. ***Ectoderm:*** outside, surrounds other layers later in development, generates **skin** and **nervous tissue**

Gastrulation

2. ***Mesoderm:*** middle layer, generates most of the **muscle, blood** and **connective tissues** of the body and placenta

3. ***Endoderm:*** eventually most interior of embryo, generates the **epithelial lining** and associated **glands** of the **gut**, **lung**, and **urogenital tracts**


Inner cell mass
Trophoblast
Amniotic cavity
Formation of yolk sac
Ectoderm
Endoderm
Primitive streak
Ectoderm
Mesoderm
Endoderm
a.
c.
d.



(f) Bilayered embryonic disc, superior view

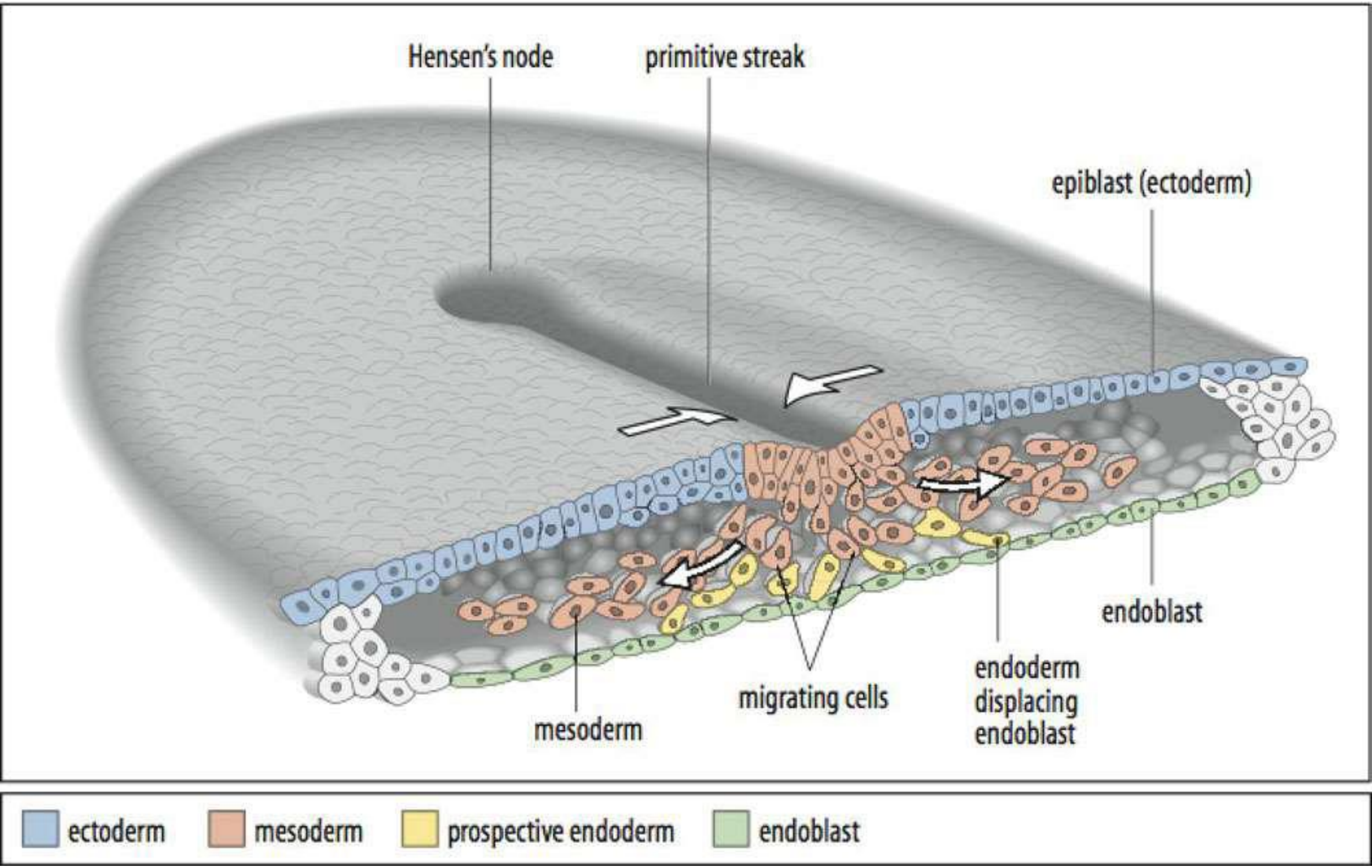
(g) 14–15 days

(h) 16 days

Mechanism of Gastrulation

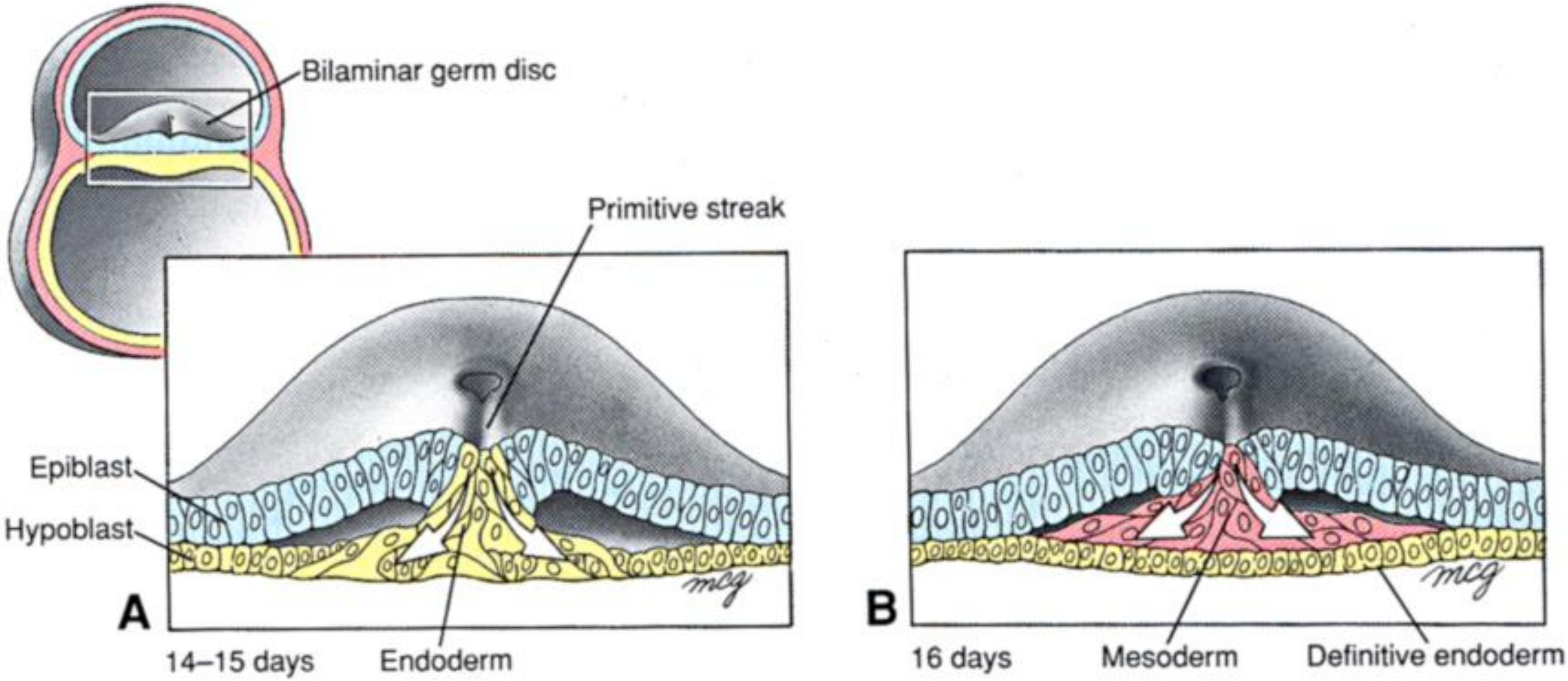
- The ***epiblast***, through the process of gastrulation, is the source of ***all of the germ layers***, and cells in these layers will give rise to all of the tissues and organs in the embryo.

- Cells of the epiblast migrate toward the primitive streak. Upon arrival in the region of the streak, they become flask-shaped, detach from the epiblast, and slip beneath it. This inward movement is known as ***invagination***


Hensen's node
primitive streak
epiblast (ectoderm)
endoblast
endoderm
displacing
endoblast
migrating cells
mesoderm
ectoderm
mesoderm
prospective endoderm
endoblast

Mechanism of Gastrulation

- Once the cells have invaginated, some *displace* the *hypoblast*, *creating* the embryonic *endoderm*, and others come to lie *between* the *epiblast* and newly created *endoderm* to *form mesoderm*. Cells remaining in the epiblast then form ectoderm.



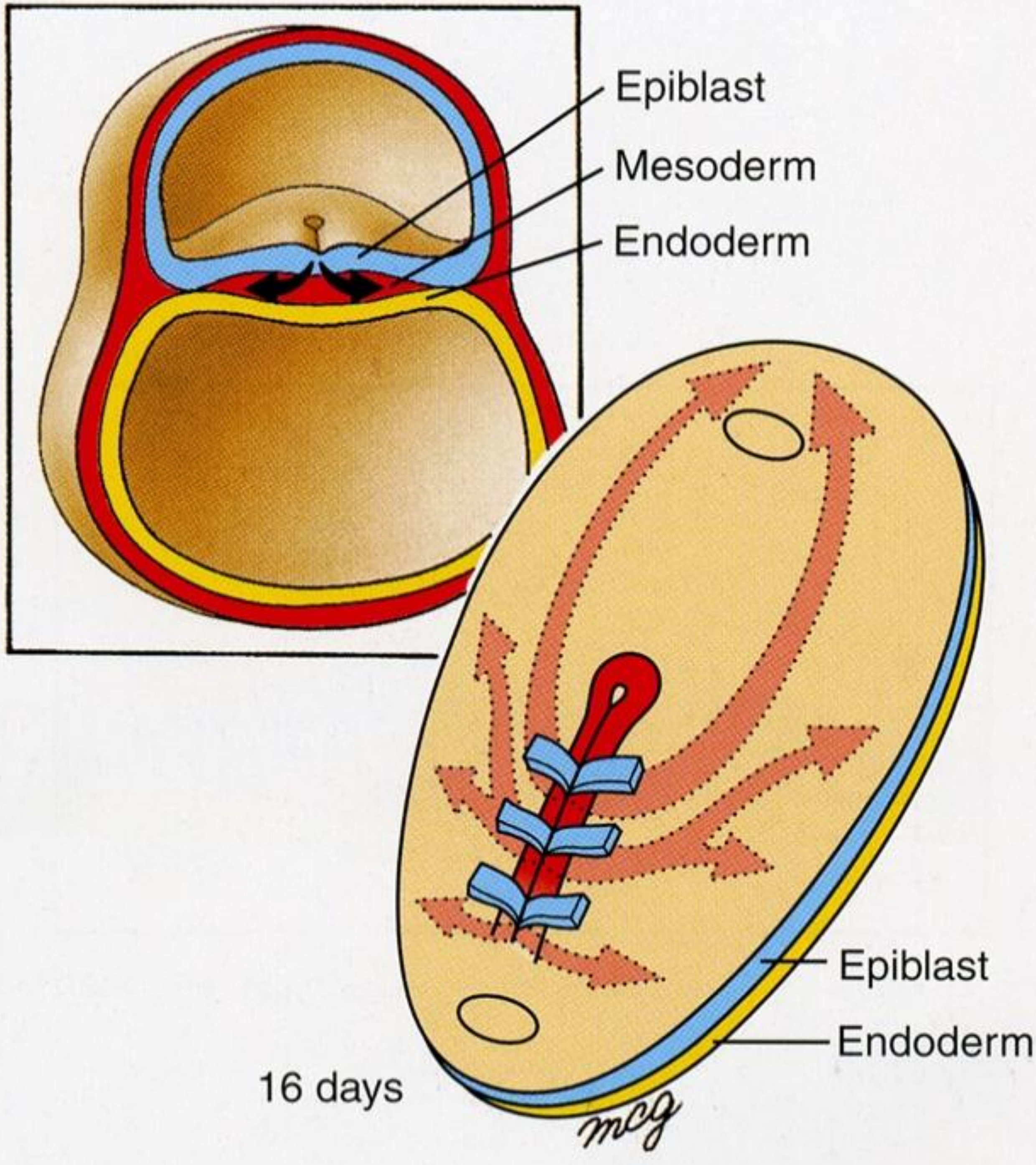
Bilaminar germ disc
Primitive streak
Epiblast
Hypoblast
A
14–15 days
Endoderm
mcg
B
16 days
Mesoderm
Definitive endoderm
mcg

Mechanism of Gastrulation

- The ***mesoderm spreads*** then ***cranially*** and ***caudally*** to fill between the ectoderm and endoderm whole through ***except*** at the regions of the ***oropharyngeal*** and ***cloacal membranes***

- ***There are three sites in the embryo, where it is still bilaminar and not trilaminar. These are:***

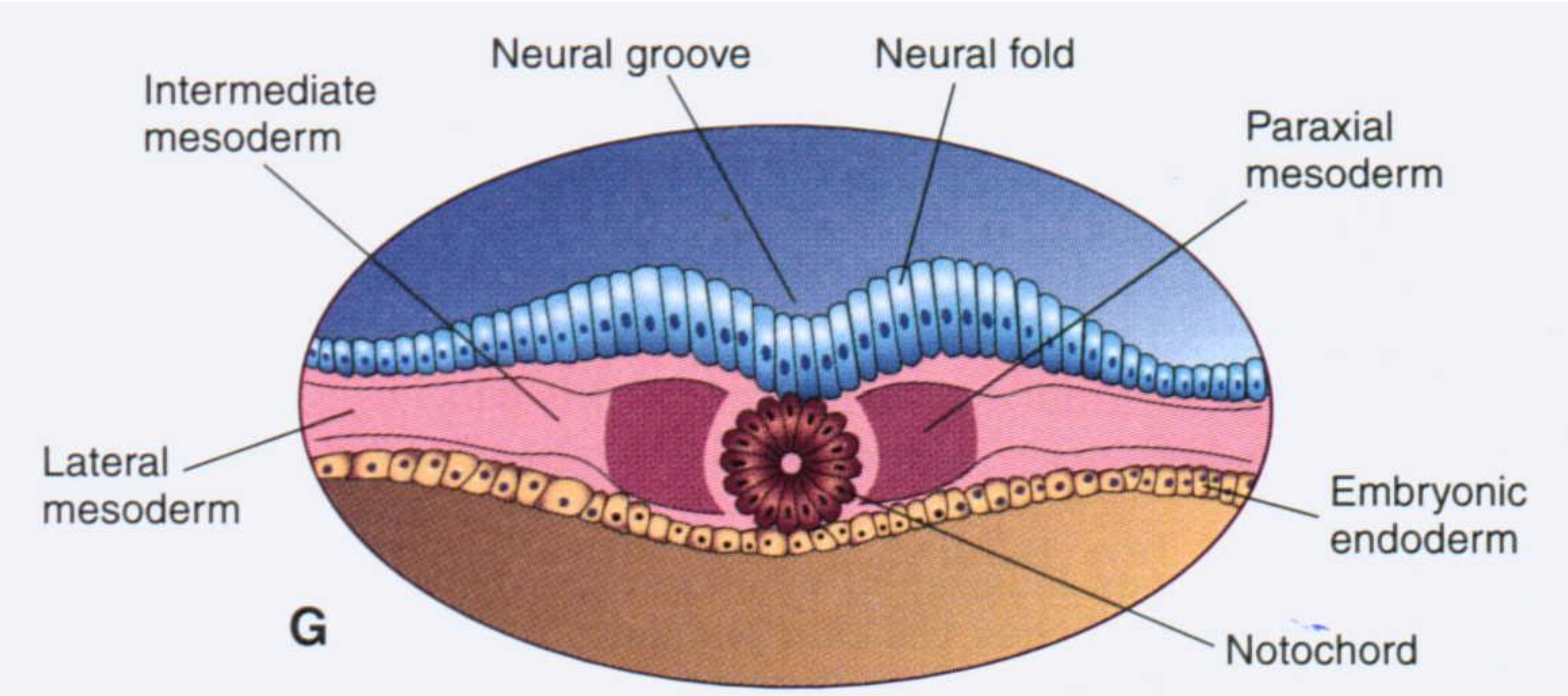
1. The oropharyngeal membrane cranially
2. The clocoal membrane caudally
3. The notochord in the median plane


Epiblast
Mesoderm
Endoderm
Epiblast
Endoderm
16 days
mcg

Mesodermal Differentiation

- At the end of week 3, the intra-embryonic mesenchyme differentiates into three loose aggregate pairs of mesenchyme on each side of the neural tube (Paraxial, Intermediate, Lateral)

1. ***Paraxial mesoderm*** differentiates into the future ***dermatome*** (dorsal surface), ***myotome*** (middle layer), and ***sclerotome*** (ventral layer), forming ***dermis***, ***muscle***, and ***connective tissue*** respectively.



6 weeks from conception

Mesodermal Differentiation

2. ***Intermediate mesoderm***, will form the future urogenital system.

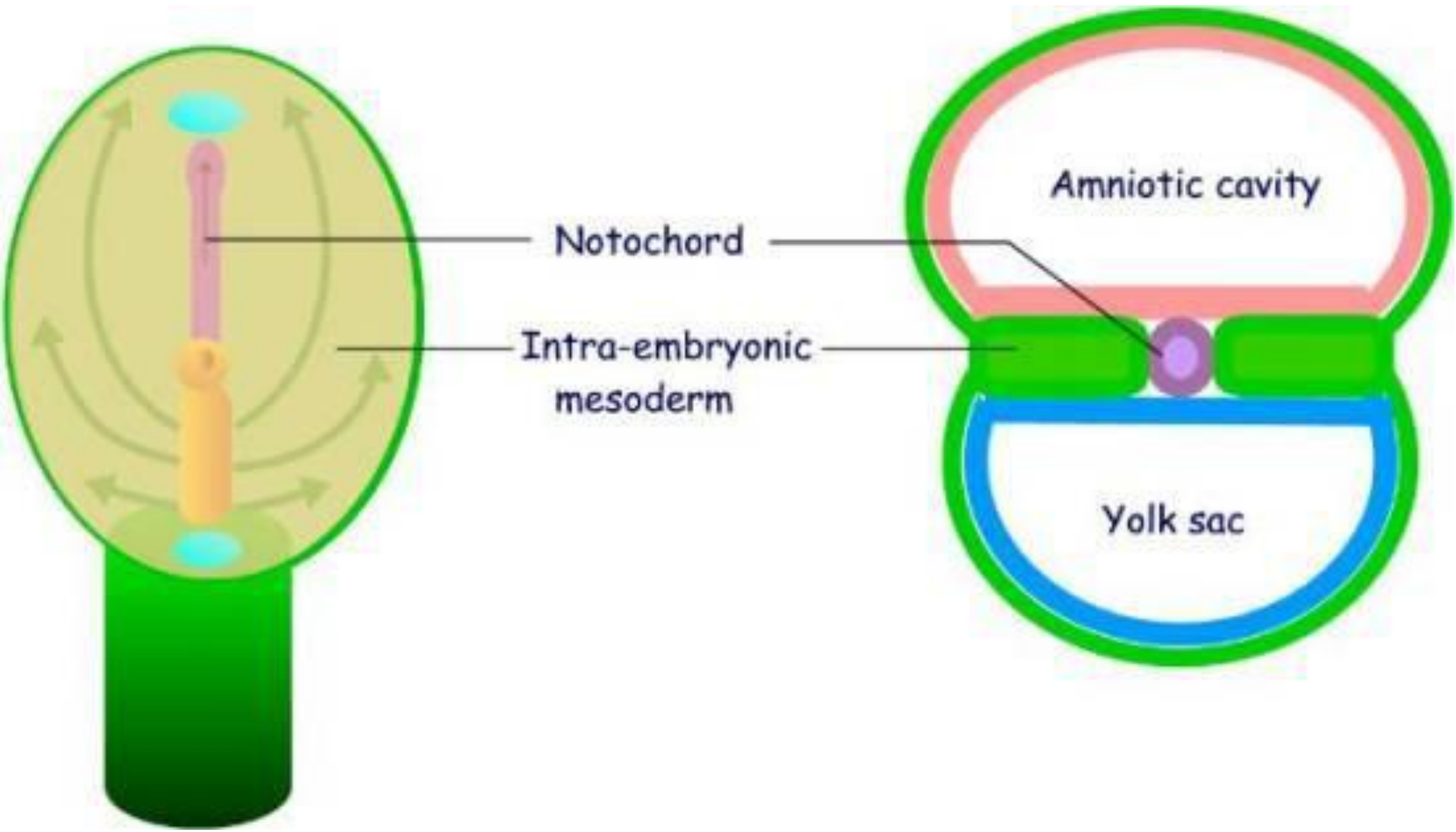
3. ***Lateral mesoderm*** will develop into future body cavities and parts of the body wall.

Notochord Development

- Solid cord of mesoderm cells, between the ectoderm and the endoderm
- Formed by the **18th day**
- Midline, in cranio-caudal axis of the embryo
- First sign of skeletal formation

Notochord Development

- The notochord acts as a temporary axial skeleton for the embryo, it is replaced later by part of the vertebral column (intervertebral disc) which completes the axial skeleton.


Amniotic cavity
Notochord
Intra-embryonic
mesoderm
Yolk sac

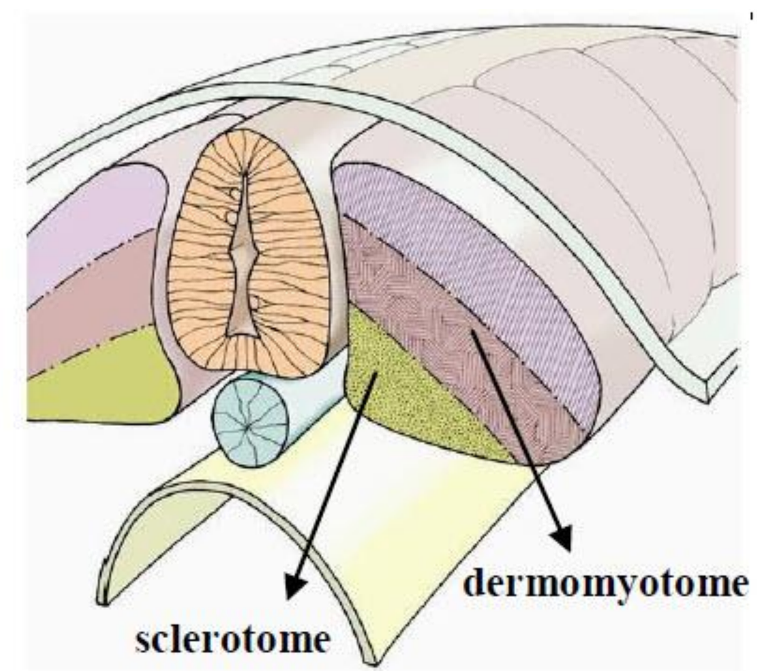
Notochordal Canal

- A small central canal is formed inside the notochordal process starting as a forward extension from the primitive pit and the passing anteriorly, then losses its floor and ***connects*** the ***amniotic cavity*** to the ***yolk sac***.

Somites

- **Axial structures**

Somites are arranged in pairs alongside the neural tube(***light orange***) and notochord (***blue***). Each somite is composed of a dermatome (***light purple***), myotome (***light brown***), and sclerotome (***dark yellow***). The ectoderm lies above and the endoderm below.



Germ Layer Development

- **Day 20**: paraxial mesoderm form somites
  - Begins in cervical region, spread cranially and caudally
    - Cervical is most advanced part of body.
  - In the 20th day, the 1st pair (most cephalic) of somites appear, 3 additional pairs of somites are formed each day from the 21st to the 30th day. The rate of formation of somites then becomes slower till finally 42 -44 pairs of somites are formed by the end of the 5th week

Germ Layer Development

- In other words, by the end of the 1st month (30 days) about 30 to 31 pairs of somites are formed.

- They can be counted and are used to roughly estimate the age of the embryo.

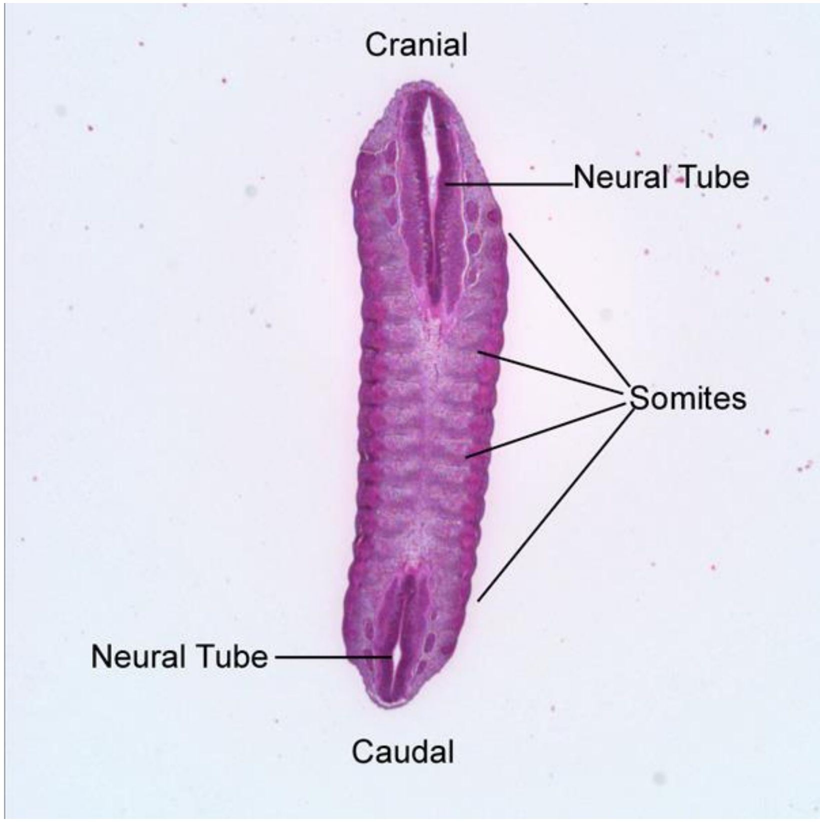
- 5 - 7 coccygeal pairs disappear leaving 37 pairs of somites.

Mesodermal Development

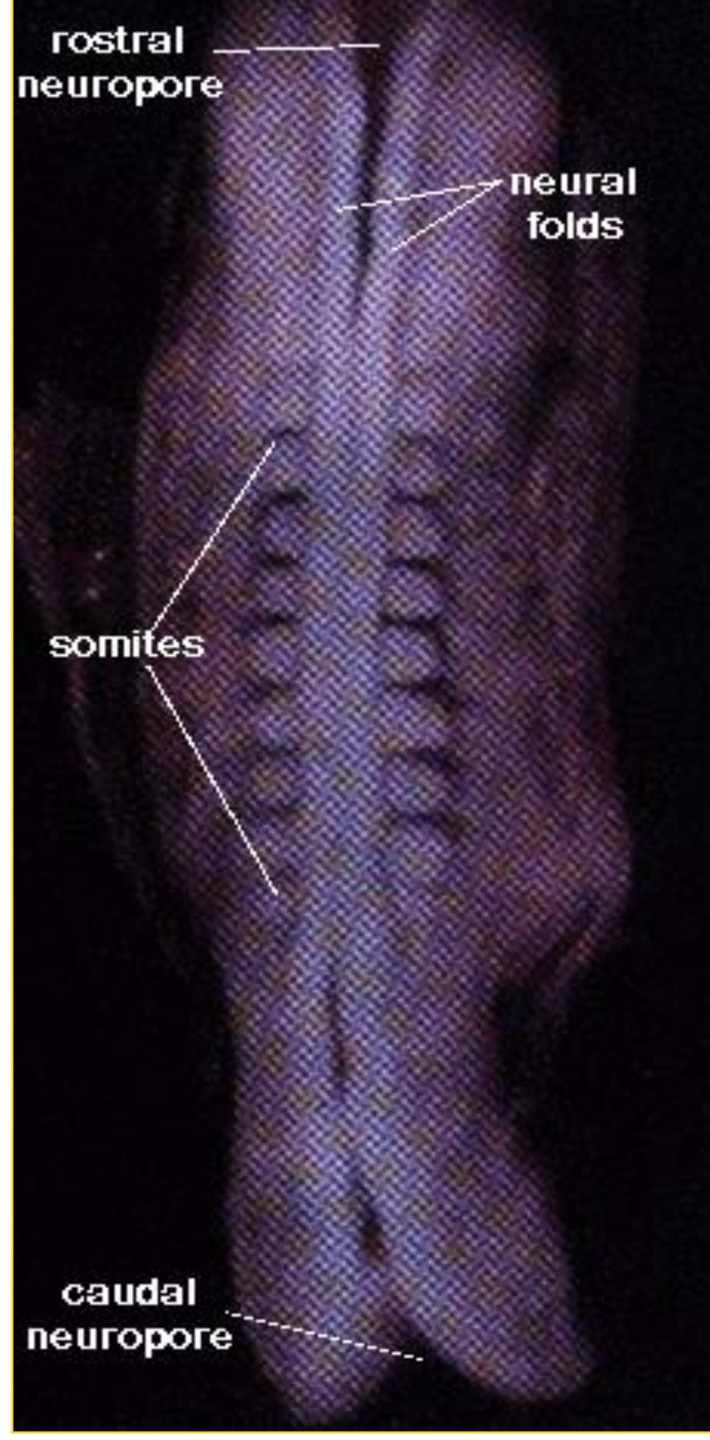
- All muscles develop from ***MESODERM EXCEPT:***
- Muscles of iris (eyeball)
- Myoepithelial cells of ***ECTODERM*** (Mammary & sweat glands)
- All skeletal muscles develop from myotomes of paraxial mesoderm EXCEPT: some head & neck muscles from ***mesoderm of pharyngeal arches***

Somites

- Cellular pairs
  - Ventromedial becomes Sclerotome (BONE)
  - Dorsolateral becomes Dermomyotome
    - Dermis, Dermatome
    - Myoblasts, Myotome

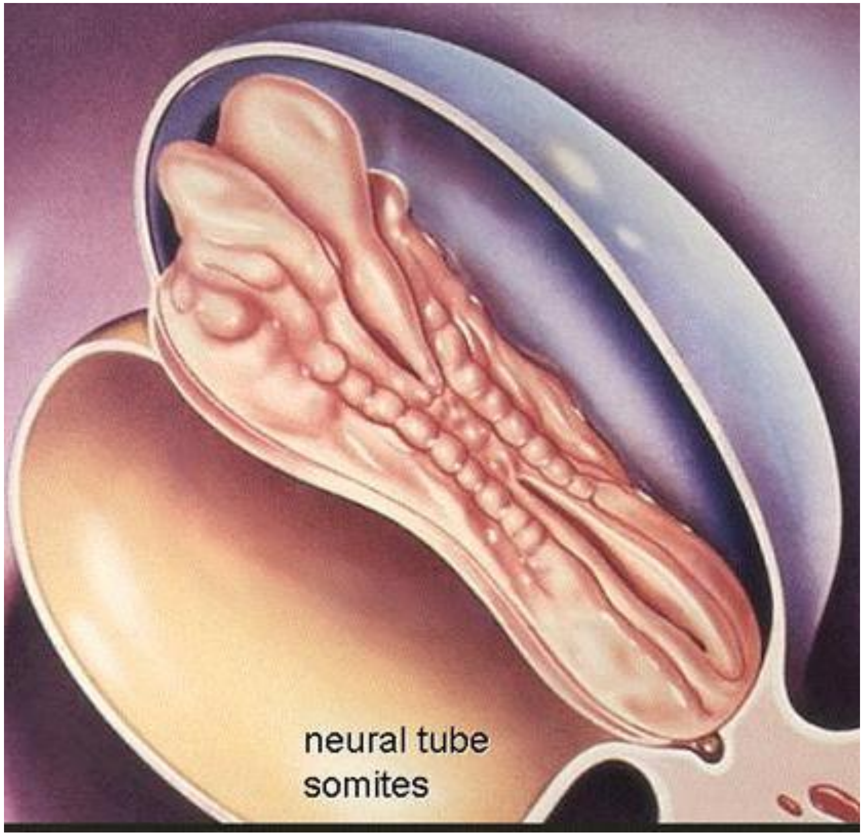


Dorsal View of an Embryo at about 23 days (8 somite stage)



Somites

- Somites, early on, become associated with a particular spinal nerve.
- When many of the somite cells migrate to new locations in the embryo, they retain this neural link.
- Basis for:
  - referred pain
  - patterns of cutaneous innervation
  - nerve supply to muscles



4th weeks

- Major changes in body of embryo
- Two pharyngeal arches are visible and two develop
  - Mandibular arch (first) gives rise to the lower jaw, extension of this gives rise to the upper jaw
  - Second arch is the hyoid arch
- Upper limb buds are recognizable
  - Pouches for arms

5th week

- Enlargement of head caused by brain development

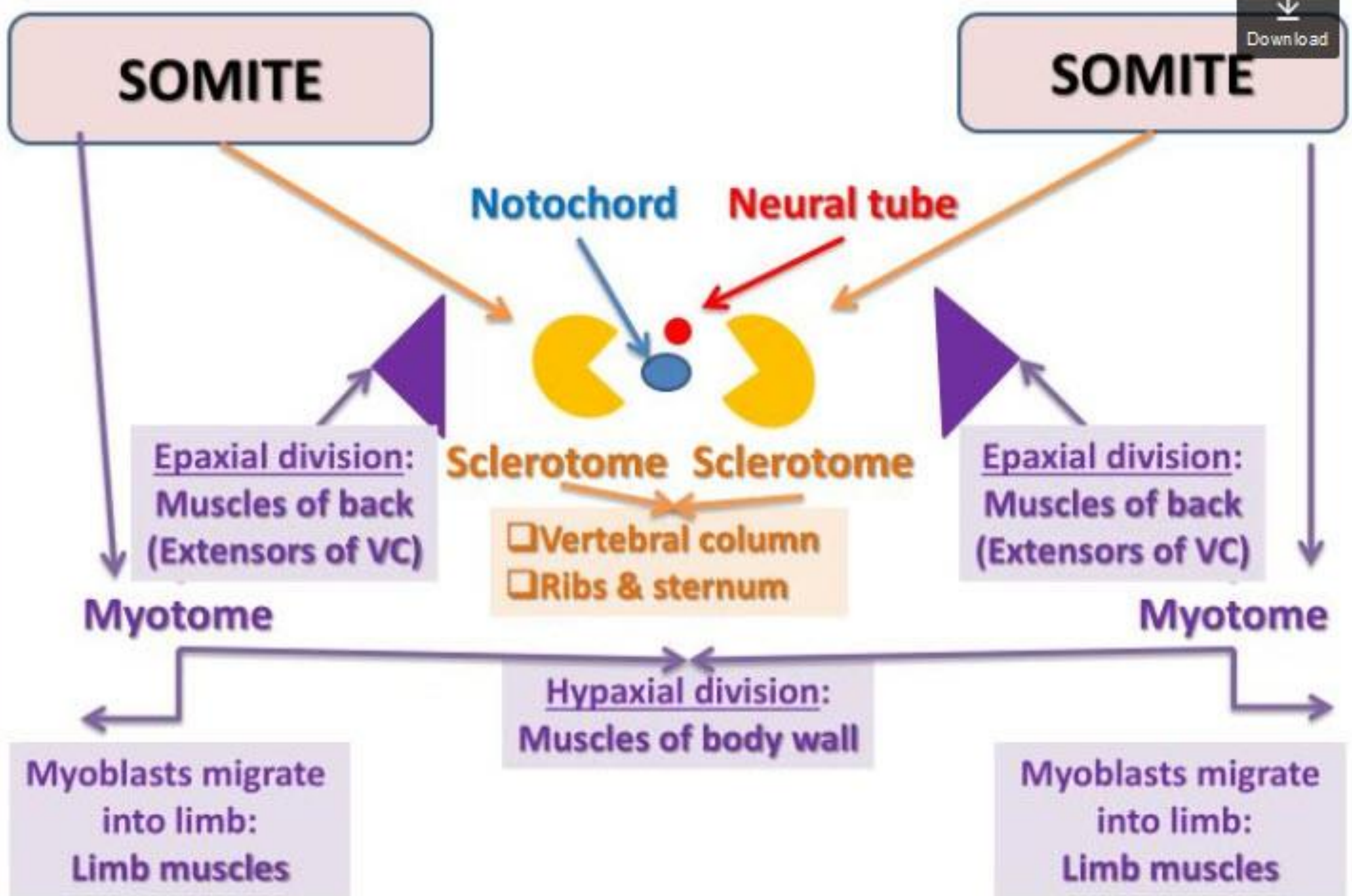
- Articular Cartilage Development

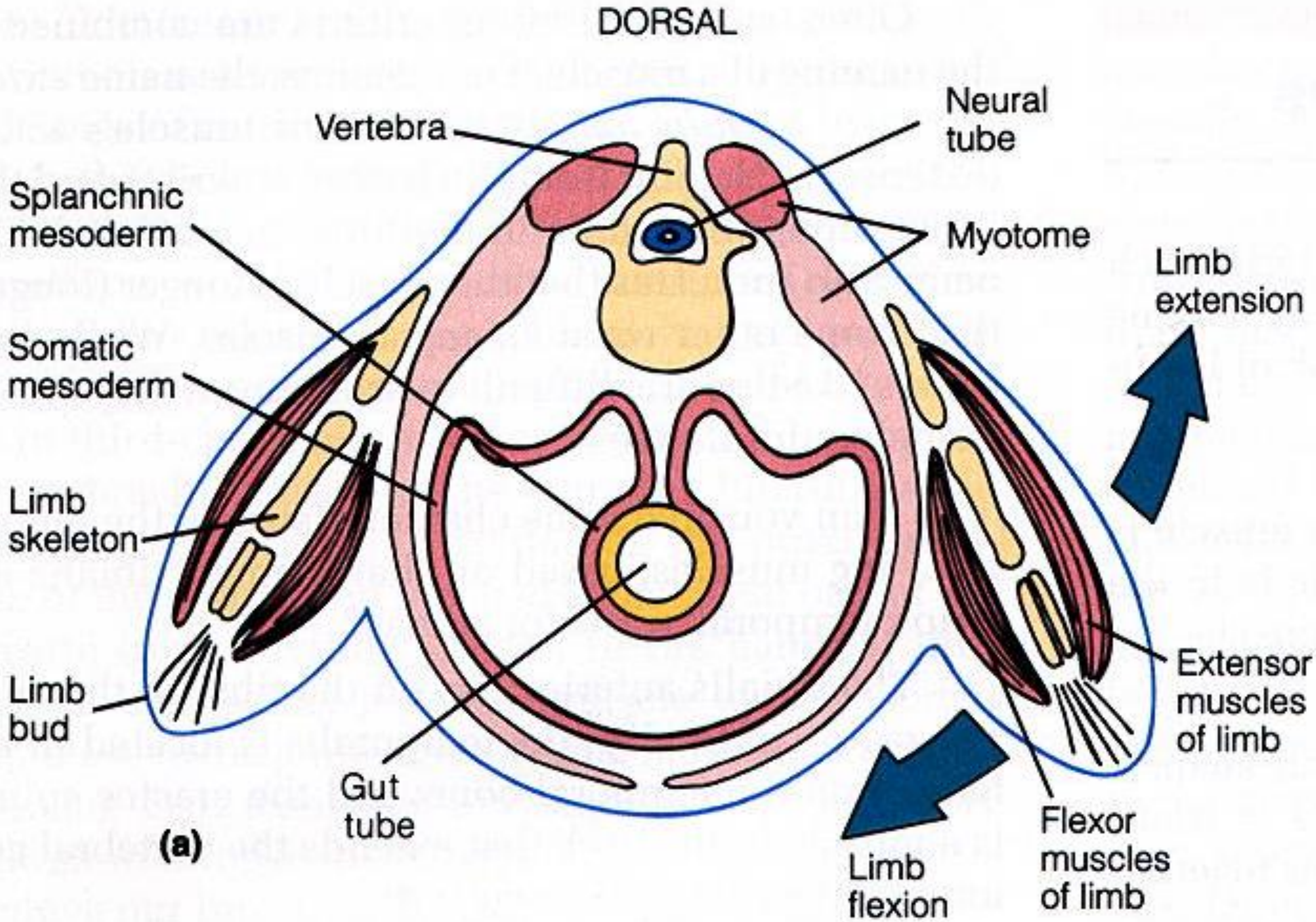
Derivatives of Muscle Precursors

- By the end of the 5th week prospective muscle cells (***Myotomes***) are collected into two parts:

- **Epimere** (small dorsal portion) – innervated by the **dorsal primary ramus** forming the **extensor muscles** of the vertebral column

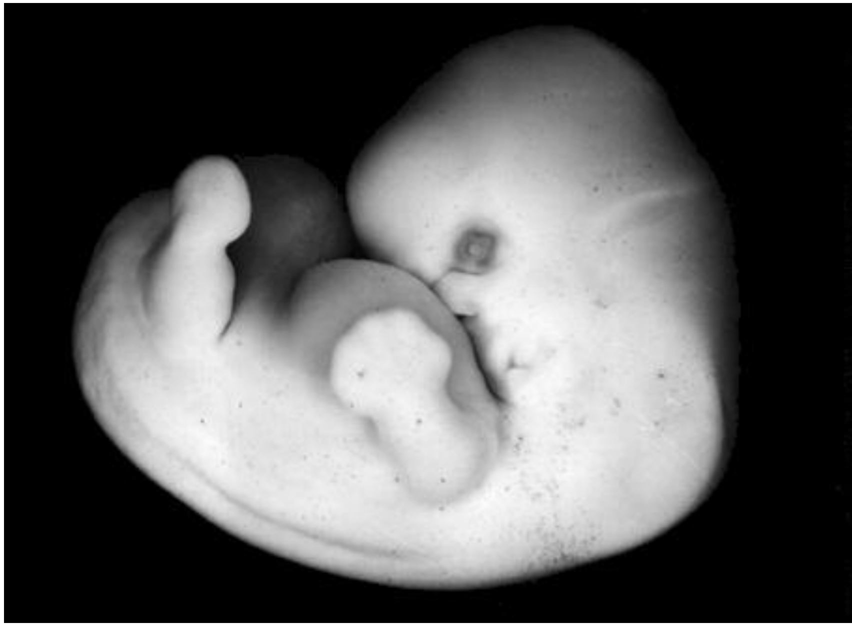
- **Hypomere (**larger ventral part) – innervated by the **ventral primary ramus** giving rise to muscles of the **limbs** and **body wall**


SOMITE
SOMITE
Notochord
Neural tube
Sclerotome
Sclerotome
Epaxial division:
Muscles of back
(Extensors of VC)
Epaxial division:
Muscles of back
(Extensors of VC)
Vertebral column
Ribs & sternum
Myotome
Myotome
Hypaxial division:
Muscles of body wall
Myoblasts migrate
into limb:
Limb muscles
Myoblasts migrate
into limb:
Limb muscles


DORSAL
Vertebra
Neural tube
Splanchnic mesoderm
Myotome
Limb extension
Somatic mesoderm
Limb skeleton
Limb bud
Gut tube
Extensor muscles of limb
Flexor muscles of limb
Limb flexion
(a)

6^{th} week

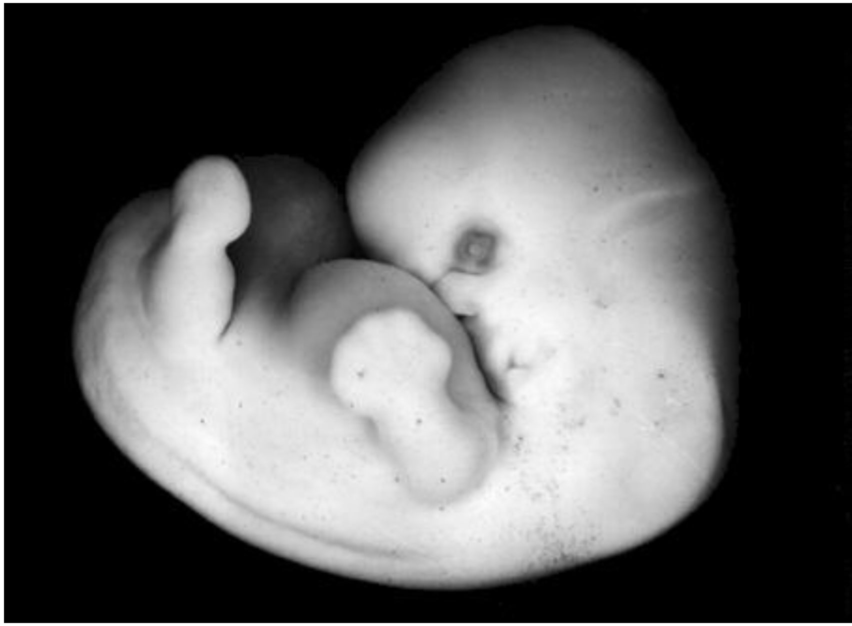
- Upper limbs begin to show differentiation into the elbows and large hand plates develop
- Primordia of the digits develop within the hand plates
- Beginning of the development of the lower limbs (***Usually lagging by 2 days***)



6th week

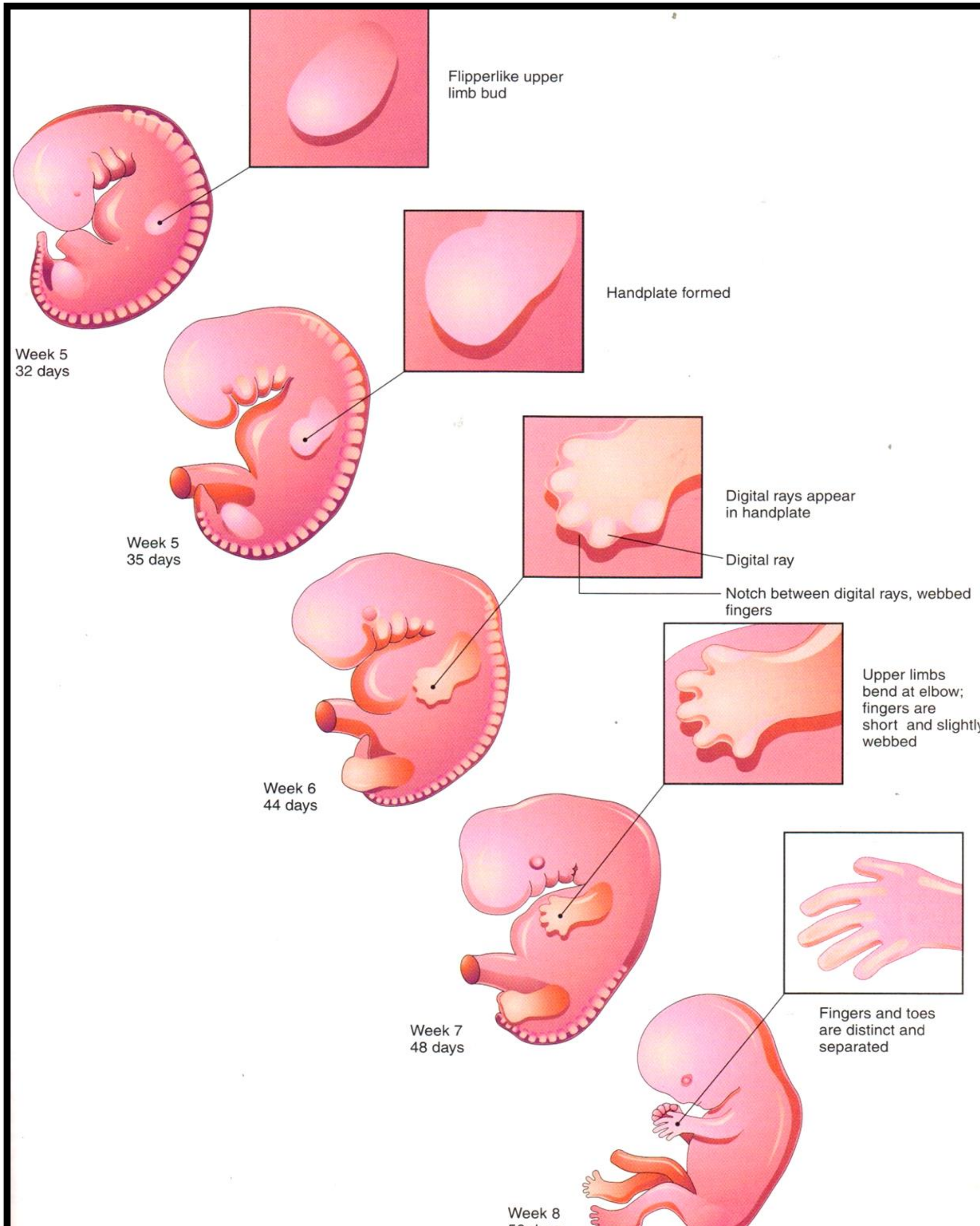
- Trunk and neck begin to straighten

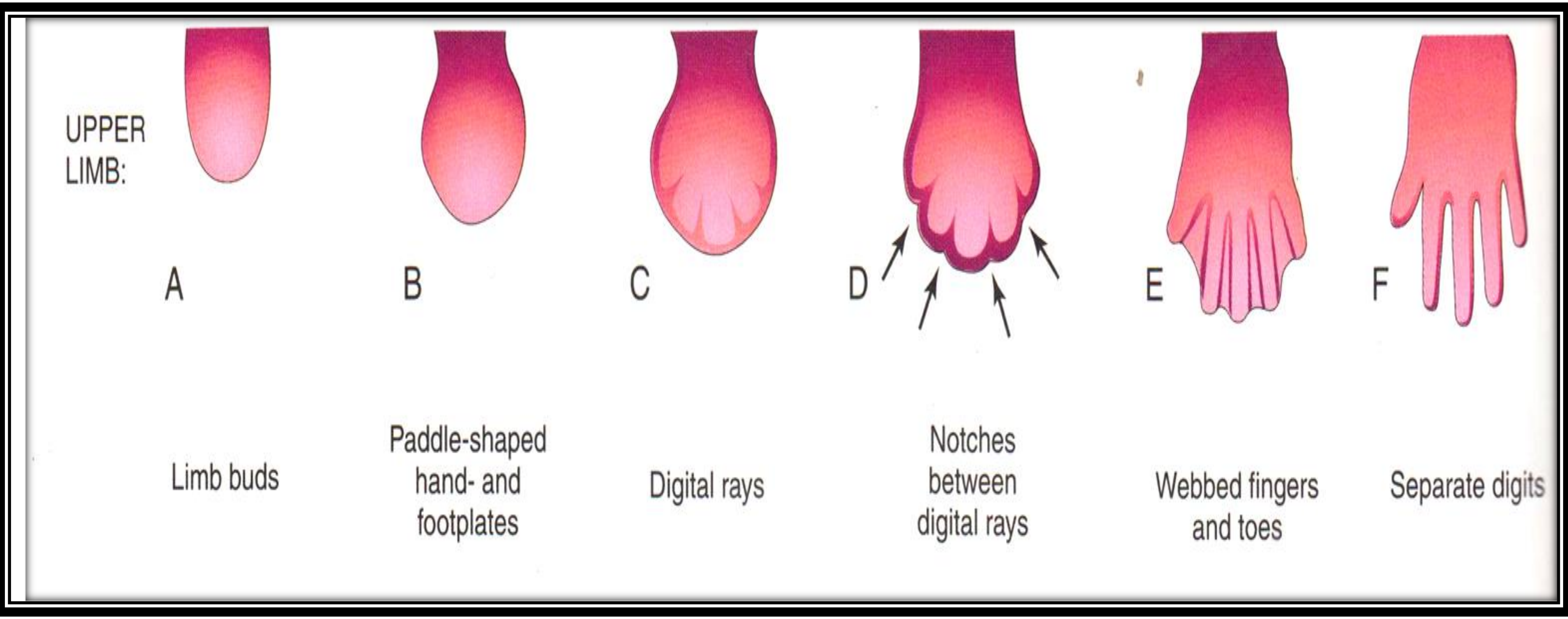
- One of the most important times in Musculoskeletal development



7th week

- Limbs undergo change = elongation
- Notches appear between the digits
- By end of the week, ossification of the bones in the upper limb has begun
  - Clavicle develops first then pectoral girdle and upper limb bones then pelvic girdle and lower limb bones


Flipperlike upper limb bud
Week 5
32 days
Handplate formed
Week 5
35 days
Digital rays appear in handplate
Digital ray
Notch between digital rays, webbed fingers
Week 6
44 days
Upper limbs bend at elbow; fingers are short and slightly webbed
Week 7
48 days
Fingers and toes are distinct and separated
Week 8
56 days


UPPER LIMB:
A
B
C
D
E
F
Limb buds
Paddle-shaped hand- and footplates
Digital rays
Notches between digital rays
Webbed fingers and toes
Separate digits

7th Week

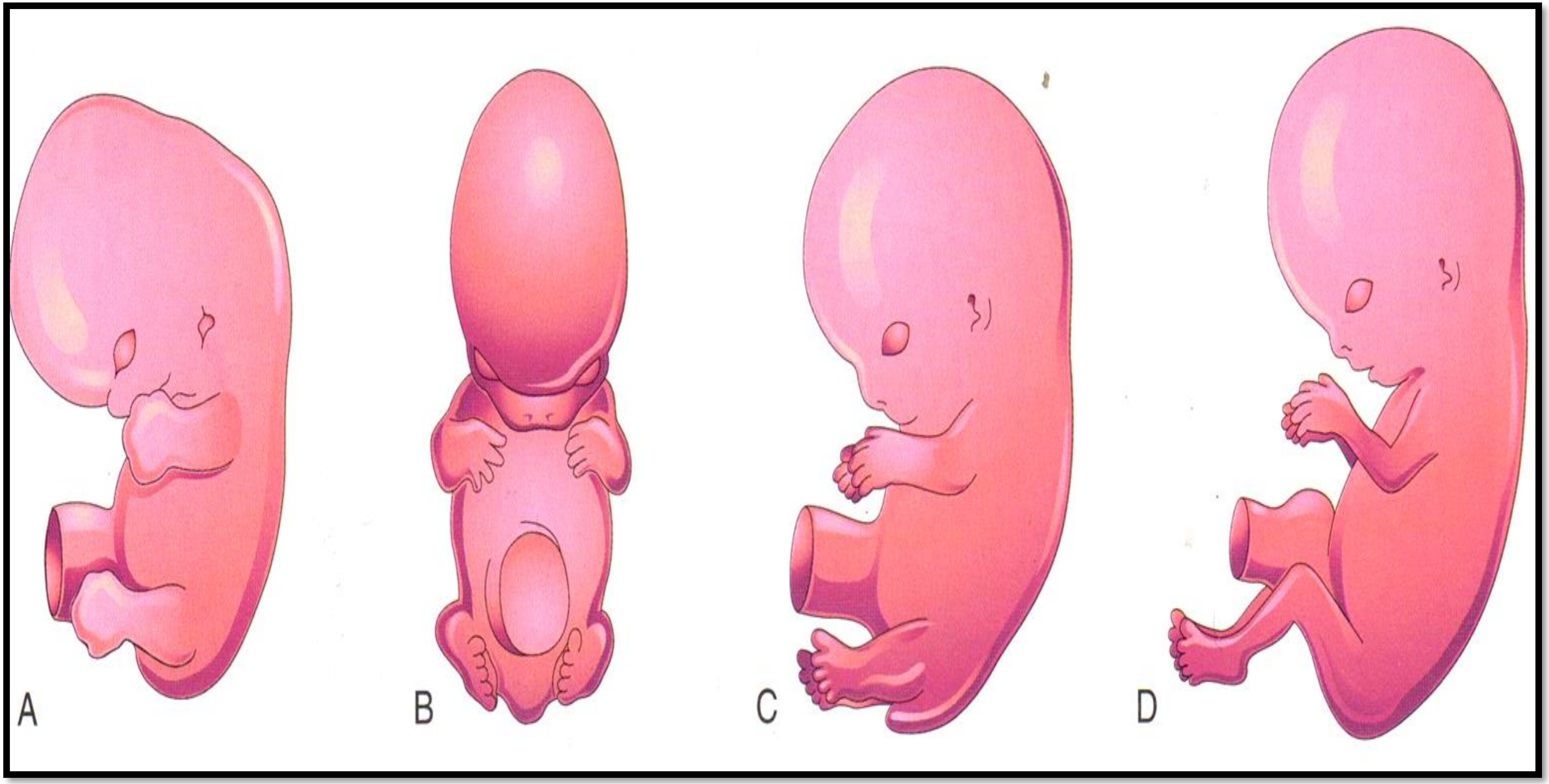
- With elongation of the limb buds, the muscle tissue splits into **flexor** and **extensor** components
- Limbs extend ventrally. Flexor aspect of limbs are ventral, and extensors are dorsal.
  - UL rotate Externally
  - LL rotate Internally

7th Week

- Upper limbs rotate laterally through 90 degrees
  - Elbows face posterior
  - Flexors of elbow are anterior

- Lower limbs rotate medially through almost 90 degrees
  - Knees face anterior
  - Extensors of knee are anterior

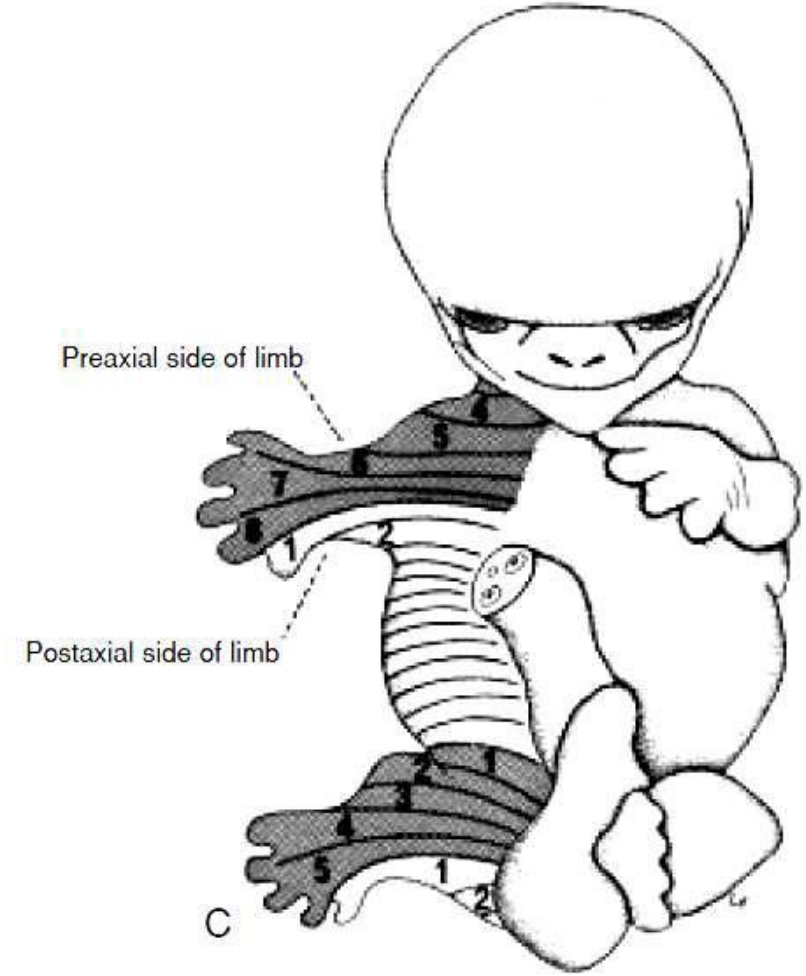
Positional changes of developing limbs



Limb buds

- The upper limb buds lie opposite the lower five cervical and upper two thoracic segments (***Brachial Plexus***)

- The lower limb buds lie opposite the lower four lumbar and upper two sacral segments (***Lumbosacral Plexus***)



8^{th} week

- Digits of the hand are separated but still webbed.
- Notches visible between digital rays of the feet
- All digits have lengthened and are completely separated
- Ossification begins in the femur

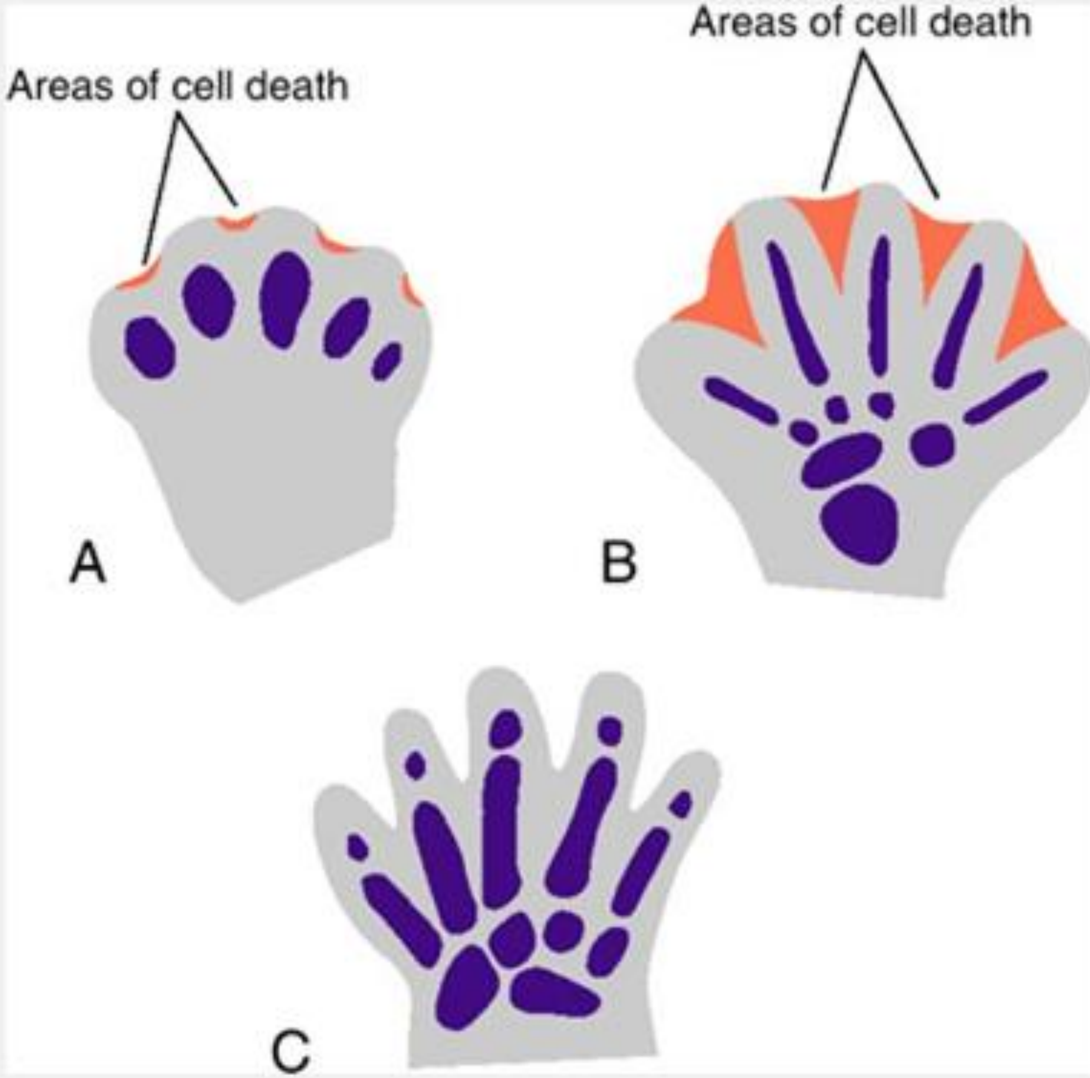
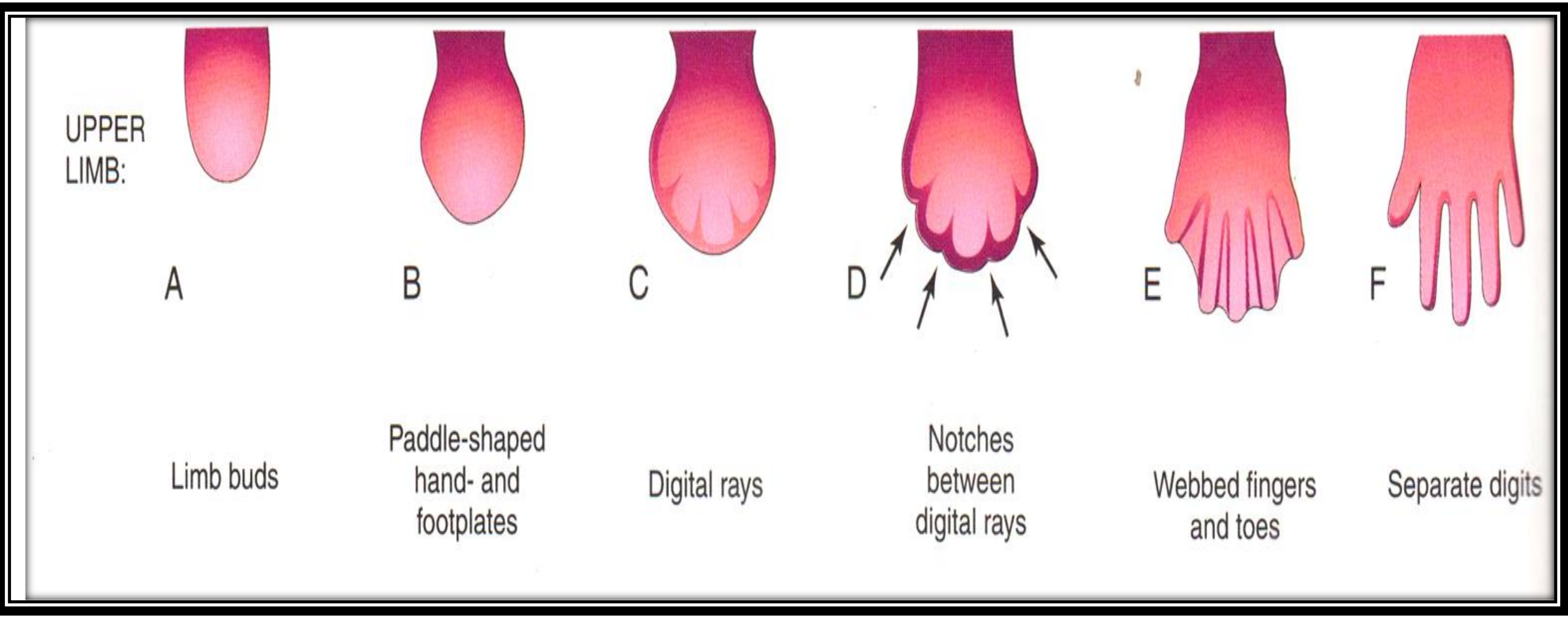


Figure 9.14 Schematic of human hands. **A.** At 48 days. Cell death in the apical ectodermal ridge creates a separate ridge for each digit. **B.** At 51 days. Cell death in the interdigital spaces produces separation of the digits. **C.** At 56 days. Digit separation is complete.


UPPER
LIMB:
A
B
C
D
E
F
Limb buds
Paddle-shaped
hand- and
footplates
Digital rays
Notches
between
digital rays
Webbed fingers
and toes
Separate digits

9-12 weeks

- Head is half the length of the body
- 9th weeks: legs are short, get longer but not to the full extent as at birth, arms are almost their normal length
- Primary ossification centers appear in skeleton by end of 12 weeks

Head Musculature

- All voluntary muscles of the head region are derived from ***mesoderm*** (somites and pharyngeal arches)

- Including muscle of the tongue, eye (except that of the ***iris***, which is derived from optic cup ectoderm), and that associated with the pharyngeal (visceral) arches.

Head Musculature

- ***Tongue Muscles:***

Initially, 4 pairs of occipital somites, ***one disappear***, 3 remaining occipital myotomes migrate forward to form the extrinsic and intrinsic musculature of the tongue except palatoglossus.

Head Musculature

- ***Pharyngeal Arches Muscles:***

- Mesodermal cells located in the pharyngeal arches also differentiate into myoblasts and migrate in various directions but remain innervated by the nerve of the arch of origin

- ***The 1st arch:*** the 4 muscles of mastication (temporalis, masseter, medial & lateral pterygoids) + 4 other muscles (tensor palate, tensor tympani, anterior belly of digastric & mylohyoid). All are supplied by the ***mandibular nerve***.

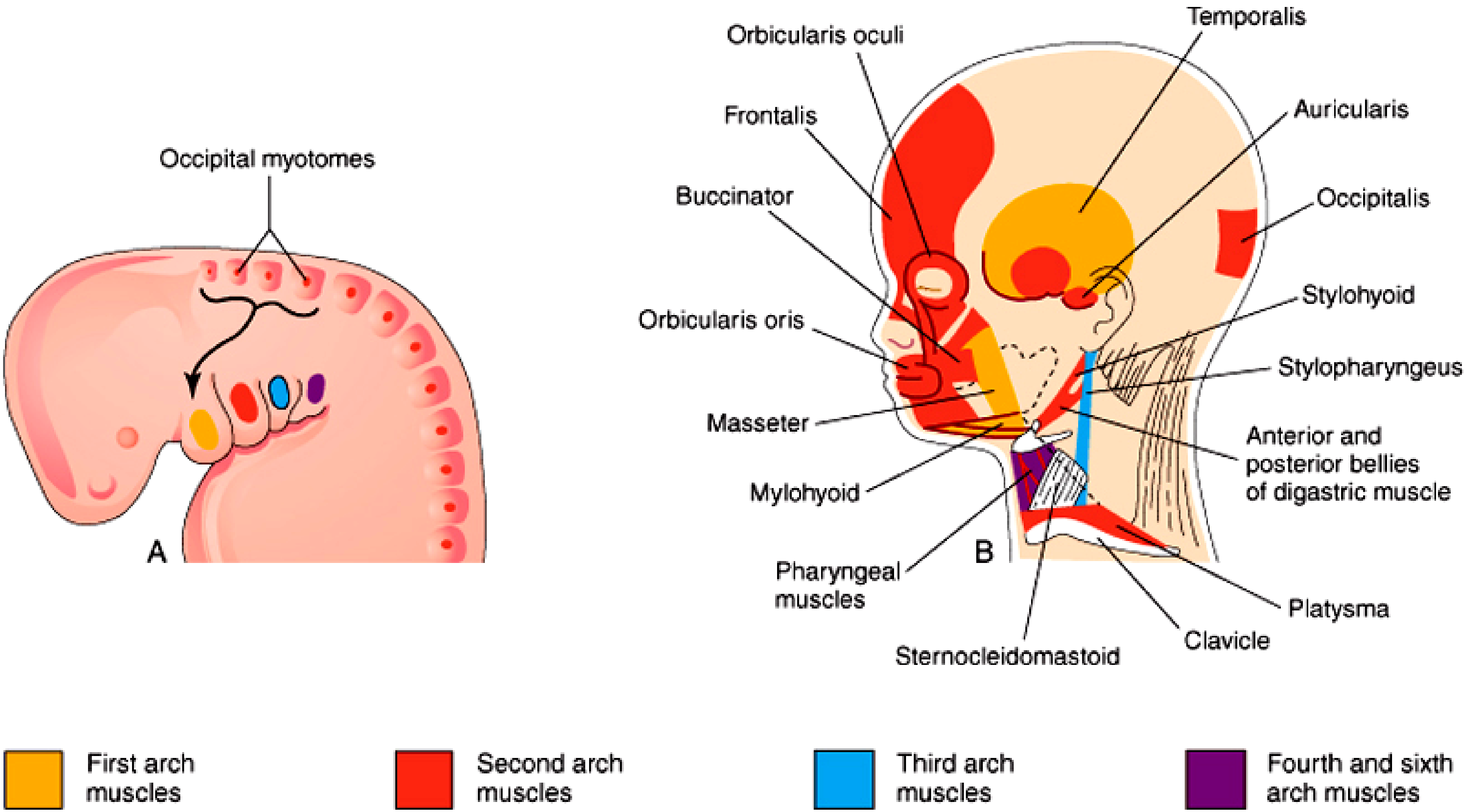
Head Musculature

- ***The 2nd arch:*** muscles of facial expression (muscles of face, scalp & auricle) + 4 other muscles (stapedius, stylohyoid, platysma & posterior belly of digastric). All are supplied by the ***facial nerve***.

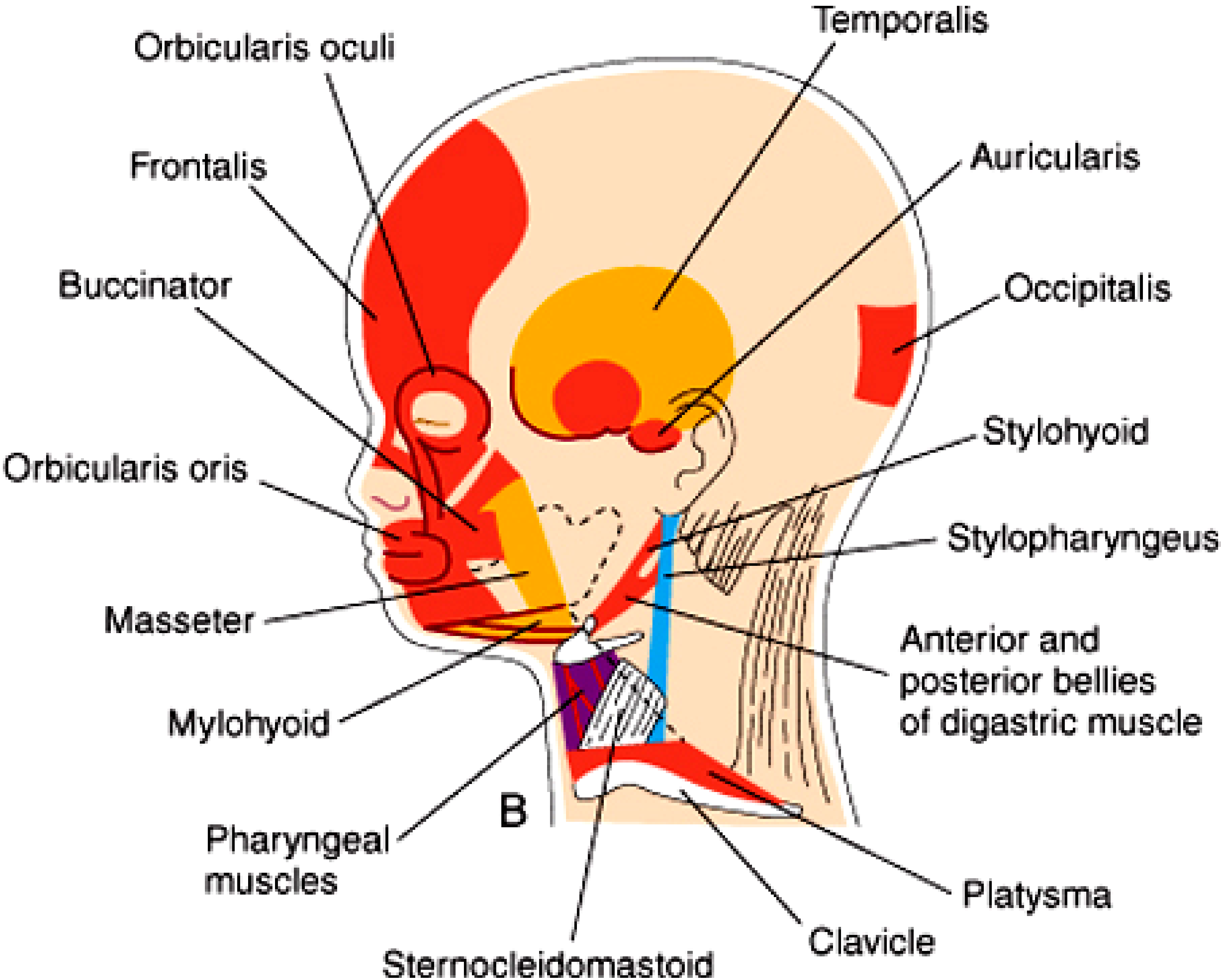
- ***The 3rd arch:*** the stylopharyngeus which is the only muscle supplied by the ***glossopharyngeal nerve.***

- ***The 4th arch:*** the cricothyroid which is supplied by the ***external laryngeal nerve***.

- ***The 6th arch:*** the intrinsic muscles of the larynx (except cricothyroid) supplied by the ***recurrent laryngeal nerve***.



Occipital myotomes
A
Orbicularis oculi
Temporalis
Frontalis
Auricularis
Buccinator
Occipitalis
Stylohyoid
Orbicularis oris
Stylopharyngeus
Masseter
Anterior and
posterior bellies
of digastric muscle
Mylohyoid
B
Pharyngeal
muscles
Platysma
Clavicle
Sternocleidomastoid
First arch
muscles
Second arch
muscles
Third arch
muscles
Fourth and sixth
arch muscles



Orbicularis oculi
Temporalis
Frontalis
Auricularis
Buccinator
Occipitalis
Stylohyoid
Orbicularis oris
Stylopharyngeus
Masseter
Anterior and
posterior bellies
of digastric muscle
Mylohyoid
B
Pharyngeal
muscles
Platysma
Clavicle
Sternocleidomastoid

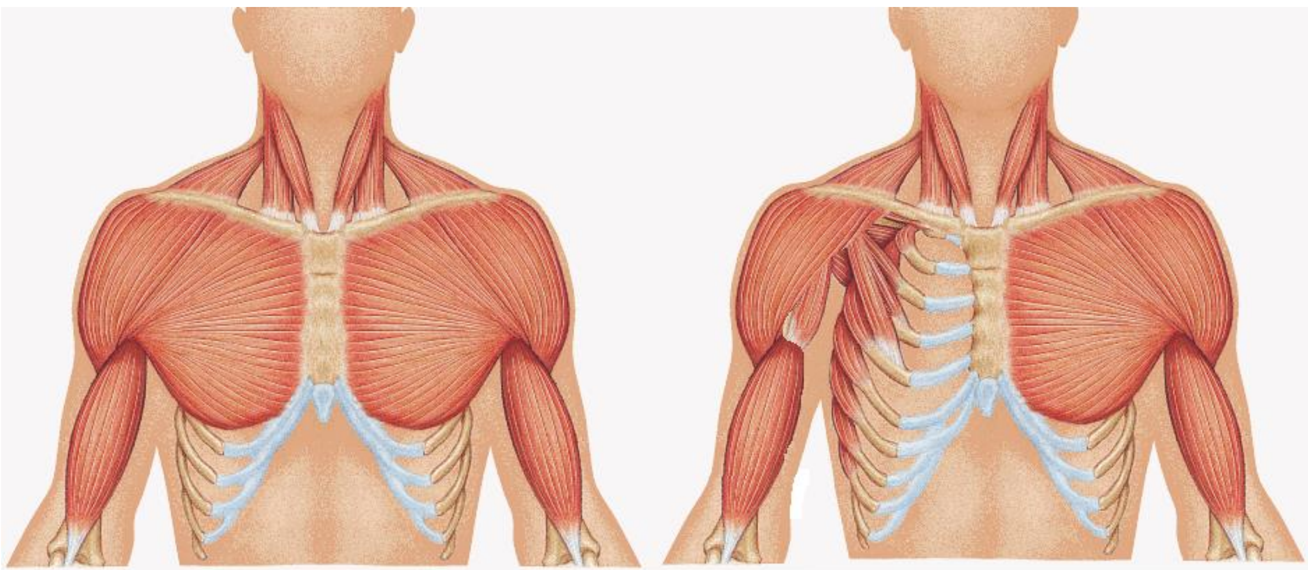
Limb Anomalies

Anomalies

- ***Muscle Abnormalities***

- Partial or complete absence of one or more muscles e.g., the pectoralis major, palmaris longus, serratus anterior and quadratus femoris.

Poland Anomaly



Typical symmetry seen in pectoralis major muscles

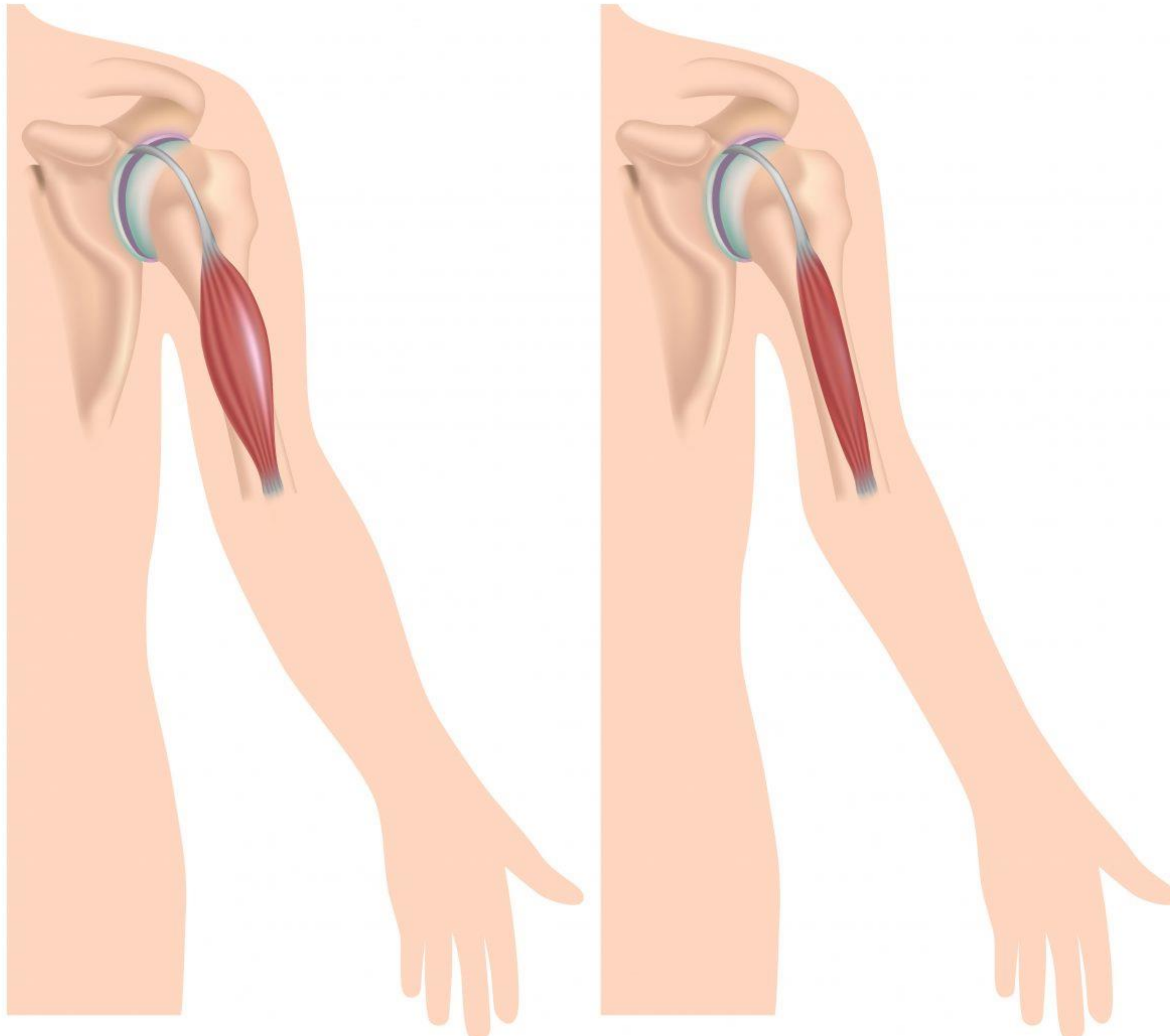
Asymmetry seen due to absent pectoral muscle

Figure-1: Underdeveloped of right pectoralis major muscle.

Duchenne Muscular Dystrophy

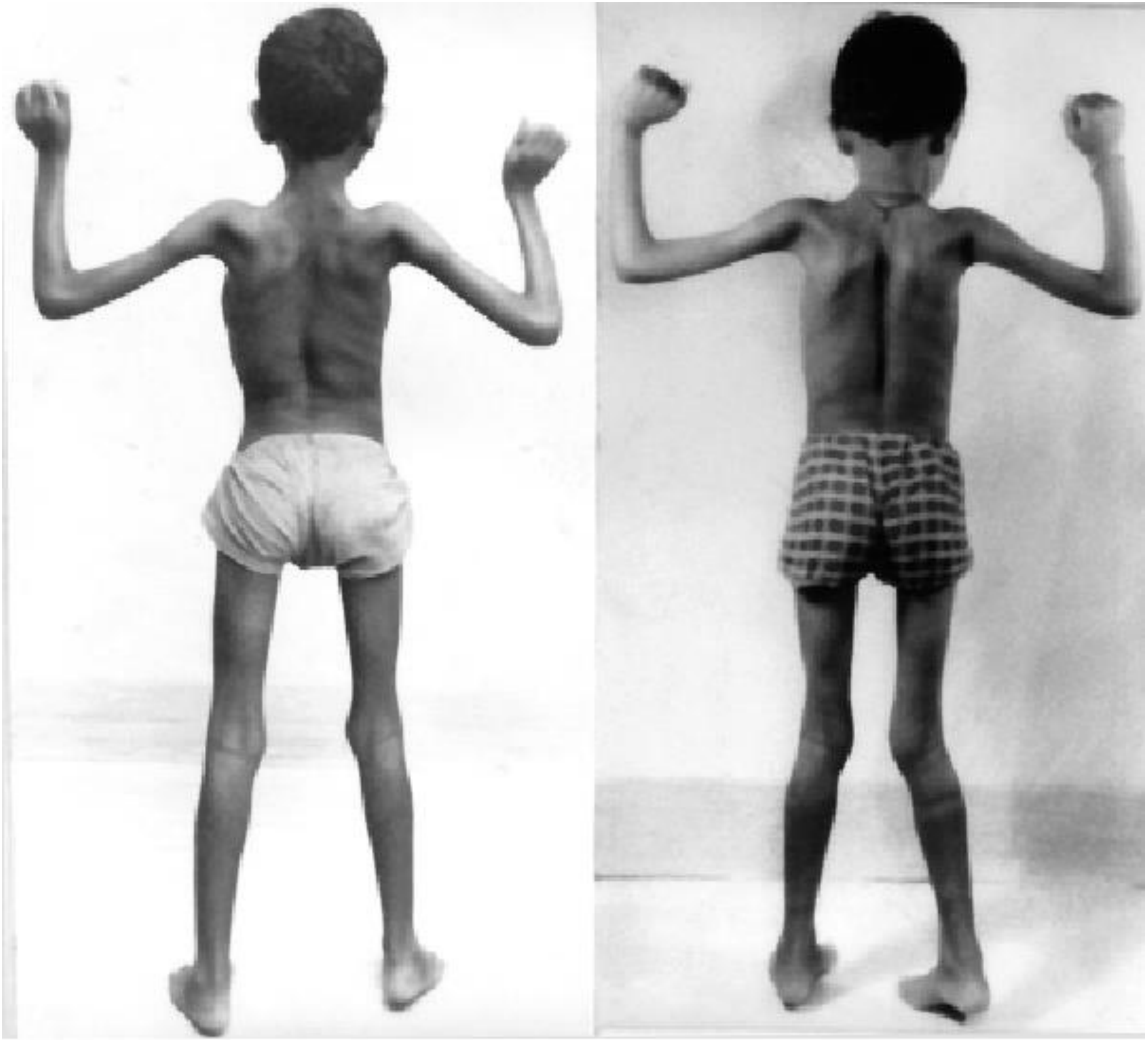
- The most common occurring in Boys (*X-linked recessive gene*). This cause of the disease was discovered in 1988 as a mutation in dystrophin, a protein that lies under the muscle fiber membrane and maintains the cell's integrity.

- This is a progressive disease usually detected between 3-5 years old. Patients die by puberty



Normal biceps

Muscular dystrophy



Complete absence of one or more limbs.

Amelia

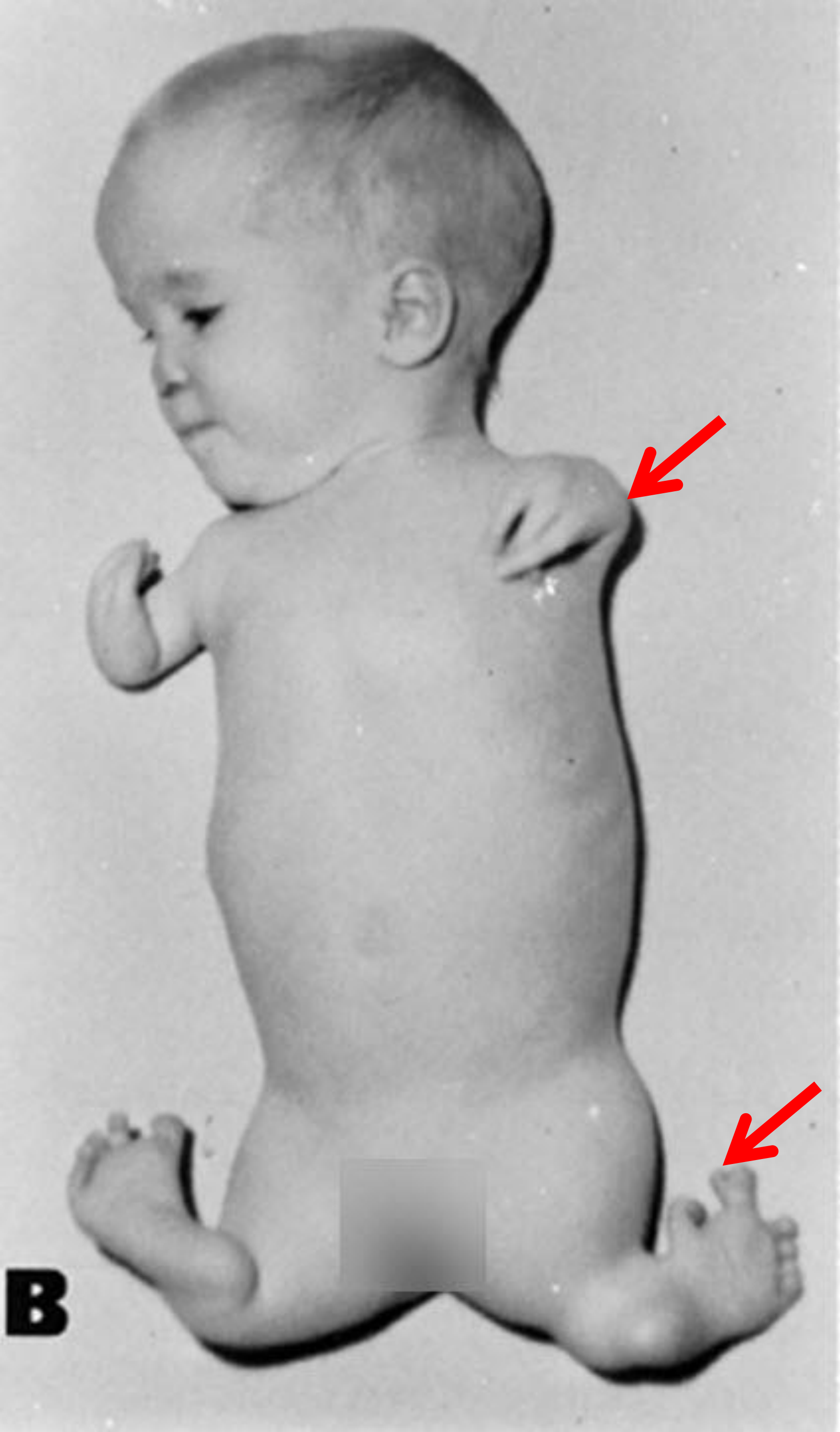
Thalidomide

- The thalidomide disaster is one of the darkest episodes in pharmaceutical research history. The drug was marketed as a mild sleeping pill safe even for pregnant women.

- However, it caused thousands of babies worldwide to be born with malformed limbs.

The limb is represented only by the hand or foot

Meromelia



Syndactyly

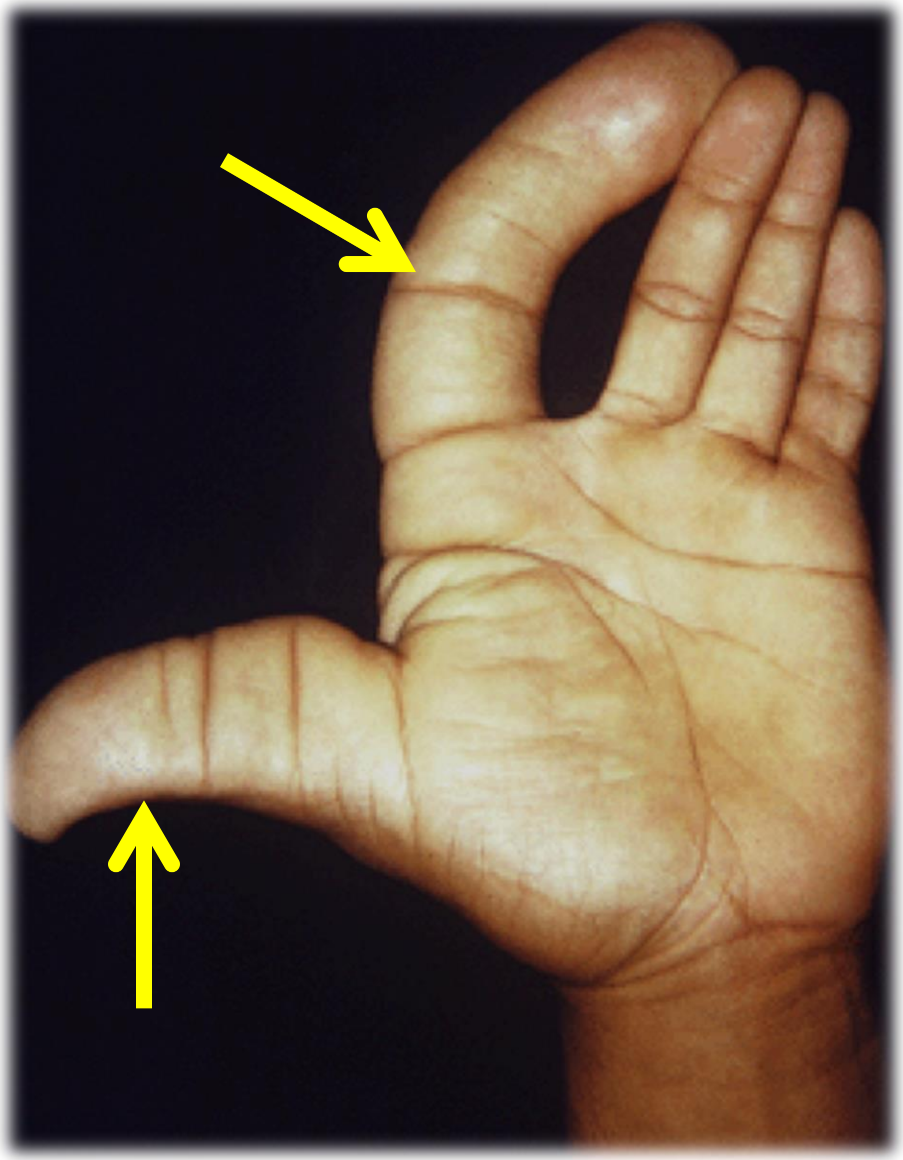
Fusion of one or more digits.

Polydactyly

Bradydactyly

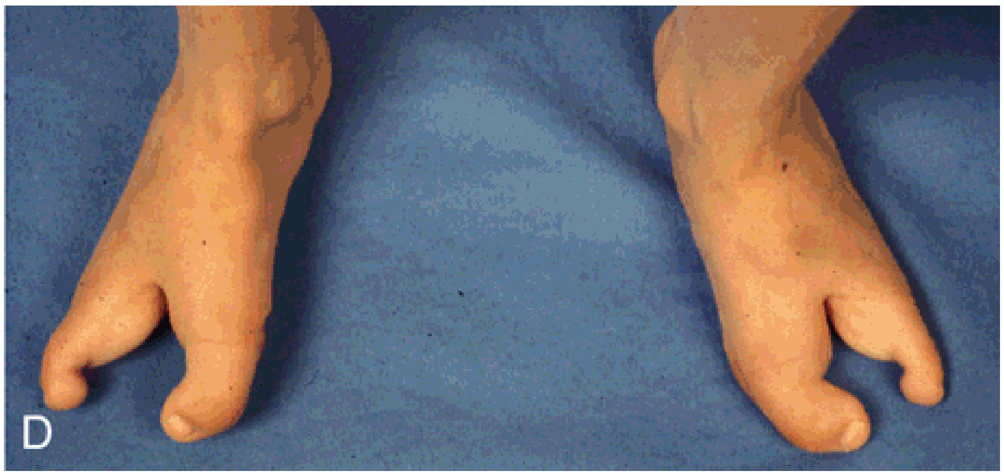
Short Digits

Macrodactyly



Lobster claw

(Cleft hand or foot)



One or more middle digit(s) is absent, the hand or foot is divided into 2 parts.

In each part, the digits are fused.

Club foot

Triphalangeal Thumb

- For further inquiries ***PLZ*** feel free to contact at any time through email

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Thank You