Embryology II

Kamila Procházková

science of prenatal development of organism

- embryonic period – first 8 weeks of development
  - according to some authors can be divided into preembryonic period (first 2 weeks) and organogenesis (3rd – 8th weeks)
- fetal period – from 9th week to delivery
  - perinatal period is possible to detach (up to the 4th postnatal week)

Human pregnancy

40 gestational weeks (gestation) counted from the first day of the last menstrual period preceeding fertilization

38 weeks (anatomical age) counted since fertilization

Leden

T	P	Ú	S	Č	P	S	N
1	1	2	3	4	5	6	7
2	8	9	10	11	12	13	14
3	15	16	17	18	19	20	21
4	22	23	24	25	26	27	28
5	29	30	31				

Únor

T	P	Ú	S	Č	P	S	N
5				1	2	3	4
6	5	6	7	8	9	10	11
7	12	13	14	15	16	17	18
8	19	20	21	22	23	24	25
9	26	27	28				

Březen

T	P	Ú	S	Č	P	S	N
9				1	2	3	4
10	5	6	7	8	9	10	11
11	12	13	14	15	16	17	18
12	17	20	21	22	23	24	25
13	26	27	28	29	30	31	

Duben

T	P	Ú	S	Č	P	S	N
13							1
14	2	3	4	5	6	7	8
15	9	10	11	12	13	14	15
16	16	17	18	19	20	21	22
17	23	24	25	26	27	28	29
18	30						

Květen

T	P	Ú	S	Č	P	S	N
18			2	3	4	5	6
19	7	8	9	10	11	12	13
20	14	15	16	17	18	19	20
21	21	22	23	24	25	26	27
22	28	29	30	31			

Červen

T	P	Ú	S	Č	P	S	N
22					1	2	3
23	4	5	6	7	8	9	10
24	11	12	13	14	15	16	17
25	18	19	20	21	22	23	24
26	25	26	27	28	29	30	

Červenec

T	P	Ú	S	Č	P	S	N
26							1
27	2	3	4	5	6	7	8
28	9	10	11	12	13	14	15
29	16	17	18	19	20	21	22
30	23	24	25	26	27	28	29
31	30	31					

Srpen

T	P	Ú	S	Č	P	S	N
31			1	2	3	4	5
32	6	7	8	9	10	11	12
33	13	14	15	16	17	18	19
34	20	21	22	23	24	25	26
35	27	28	29	30	31		

Září

T	P	Ú	S	Č	P	S	N
35						1	2
36	3	4	5	6	7	8	9
37	10	11	12	13	14	15	16
38	17	18	19	20	21	22	23
39	24	25	26	27	28	29	30

Říjen

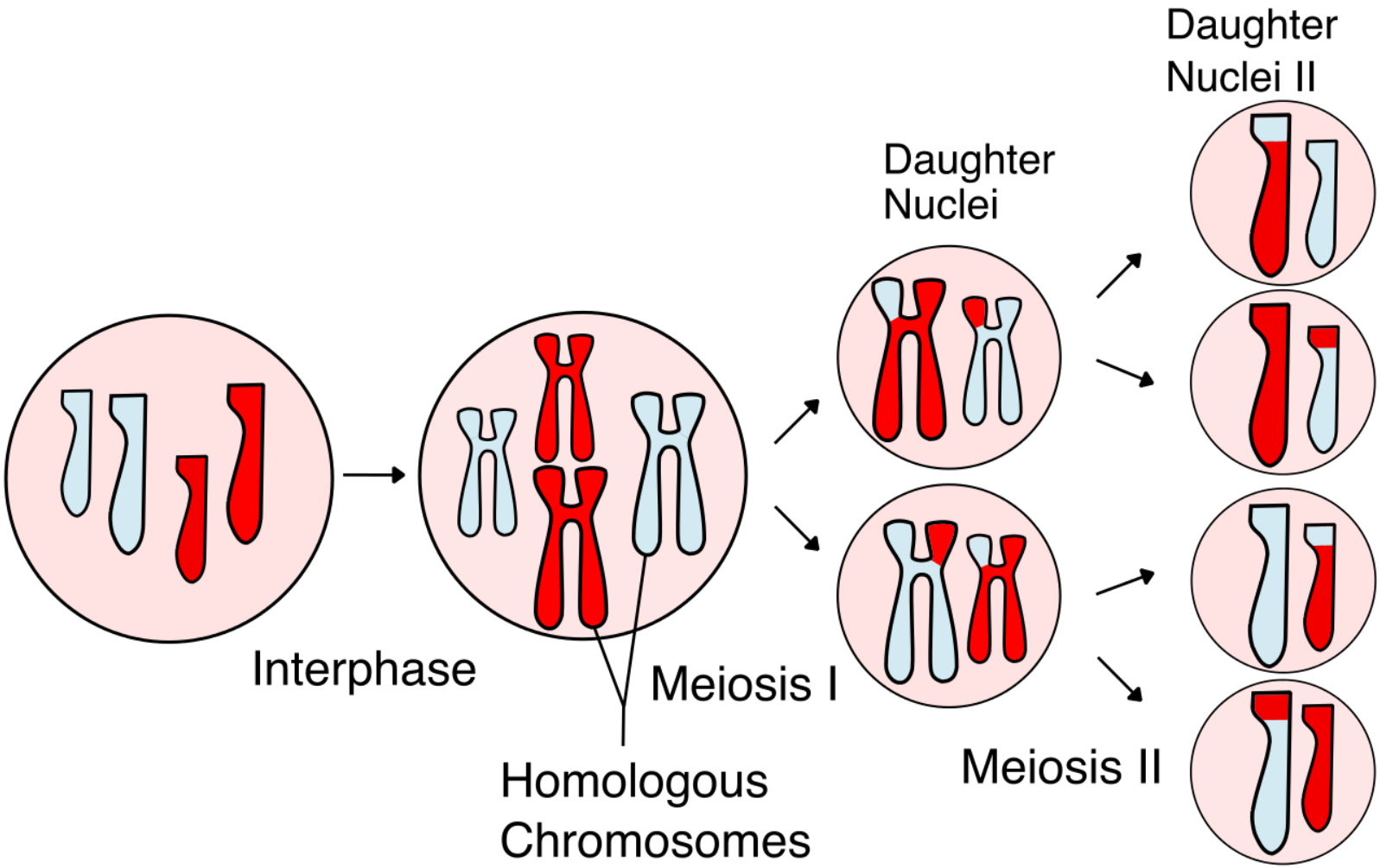
T	P	Ú	S	Č	P	S	N
40	1	2	3	4	5	6	7
41	8	9	10	11	12	13	14
42	15	16	17	18	19	20	21
43	22	23	24	25	26	27	28
44	29	30	31				

Listopad

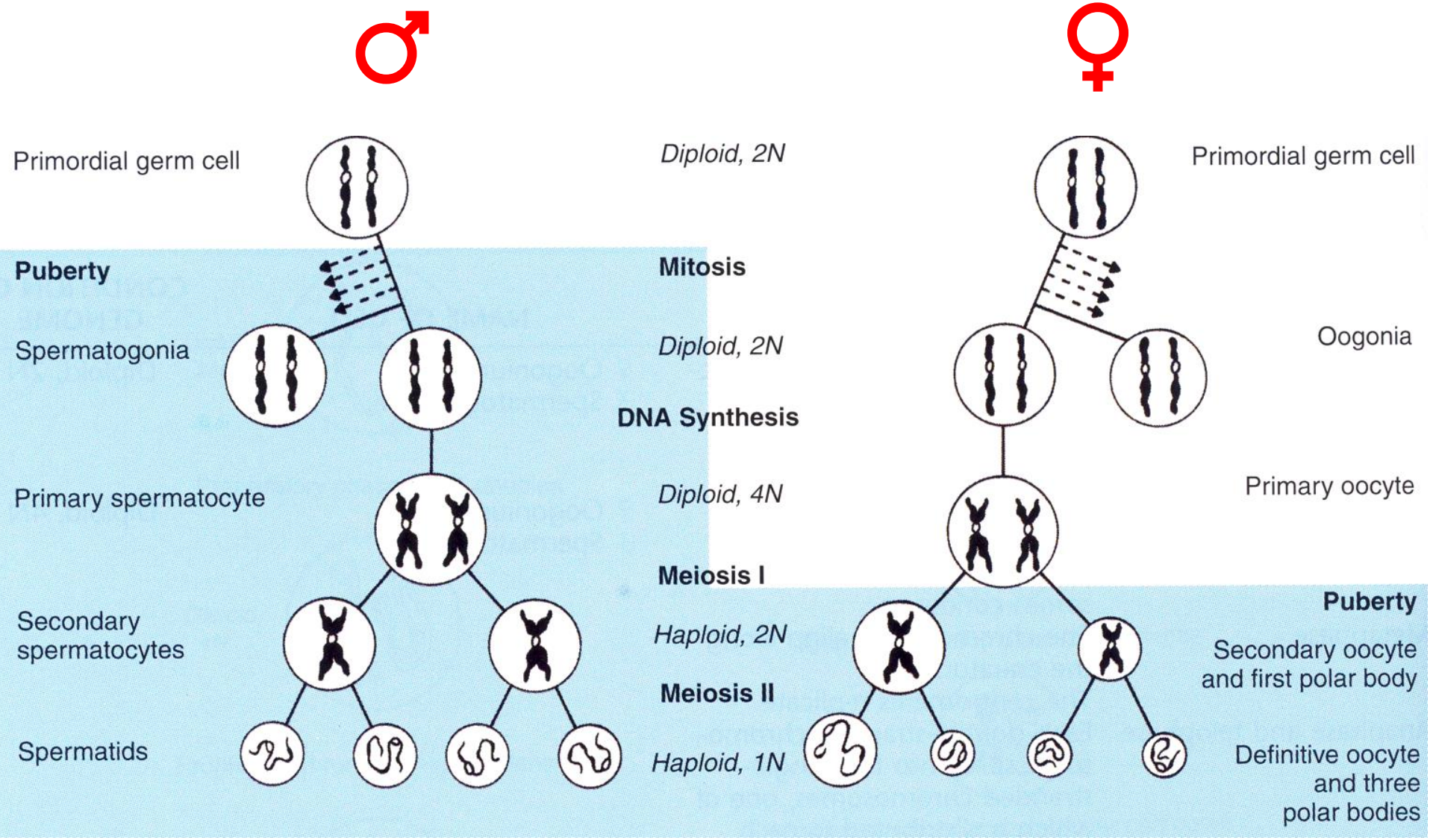
T	P	Ú	S	Č	P	S	N
44				1	2	3	4
45	5	6	7	8	9	10	11
46	12	13	14	15	16	17	18
47	19	20	21	22	23	24	25
48	26	27	28	29	30		

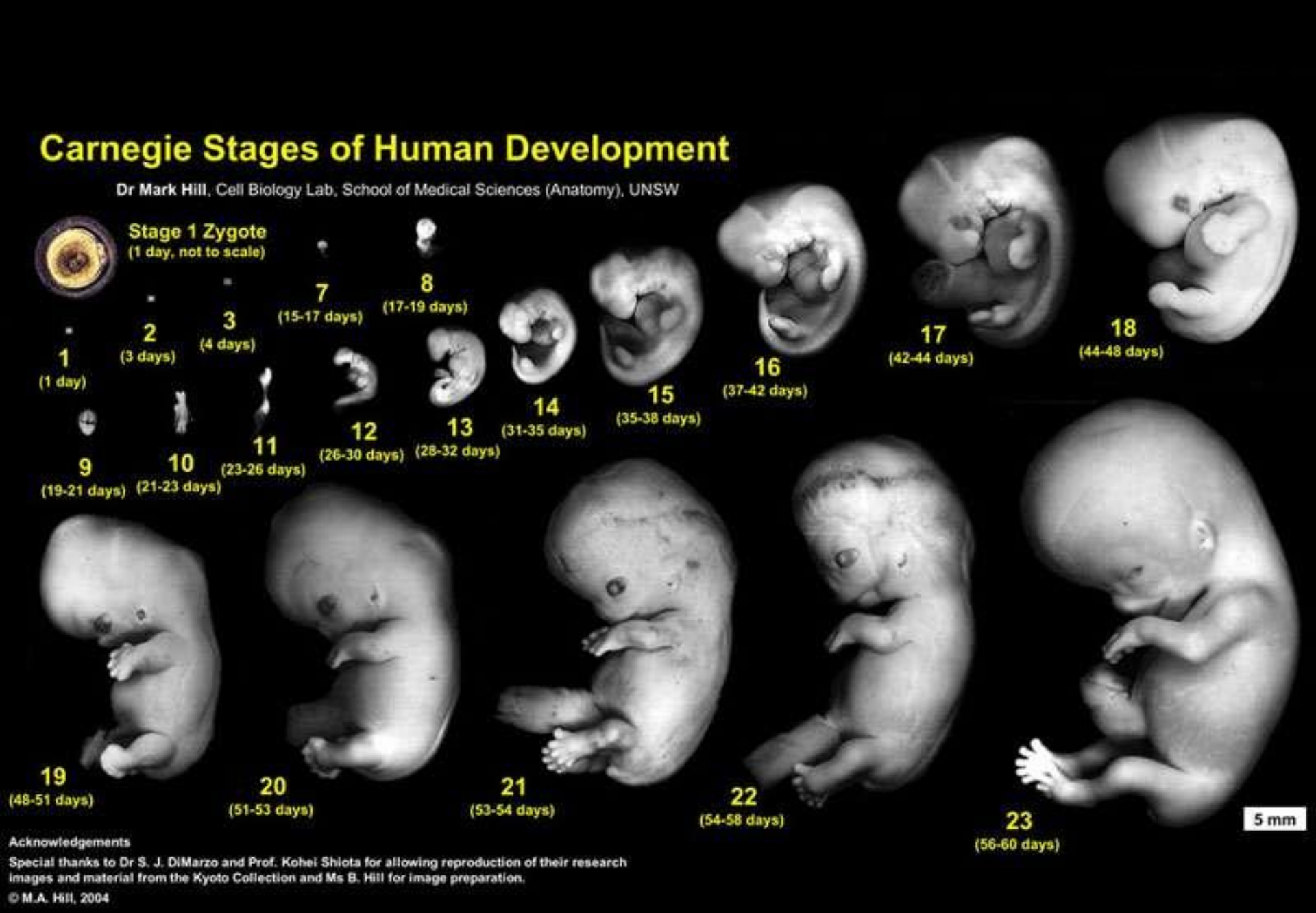
Prosinec

T	P	Ú	S	Č	P	S	N
48						1	2
49	3	4	5	6	7	8	9
50	10	11	12	13	14	15	16
51	17	18	19	20	21	22	23
52	24	25	26	27	28	29	30
1	31						



2n → (4x) 1n


♂
♀
Primordial germ cell
Diploid, 2N
Primordial germ cell
Puberty
Mitosis
Spermatogonia
Diploid, 2N
Oogonia
DNA Synthesis
Primary spermatocyte
Diploid, 4N
Primary oocyte
Meiosis I
Puberty
Secondary spermatocytes
Haploid, 2N
Secondary oocyte and first polar body
Meiosis II
Spermatids
Haploid, 1N
Definitive oocyte and three polar bodies



https://emb.carnegiescience.edu/

Jirásek's (J) stages of human prenatal development

based completely on external characteristics

A – embryonic stages (1-8)

1 – unicellular (fertilization)

2 – blastomeric (morula, cleavage of oocyte)

3 – blastodermic (blastocyst)

4 – bilaminar germ disc (epiblast, hypoblast)

5 – trilaminar germ disc with axial structures

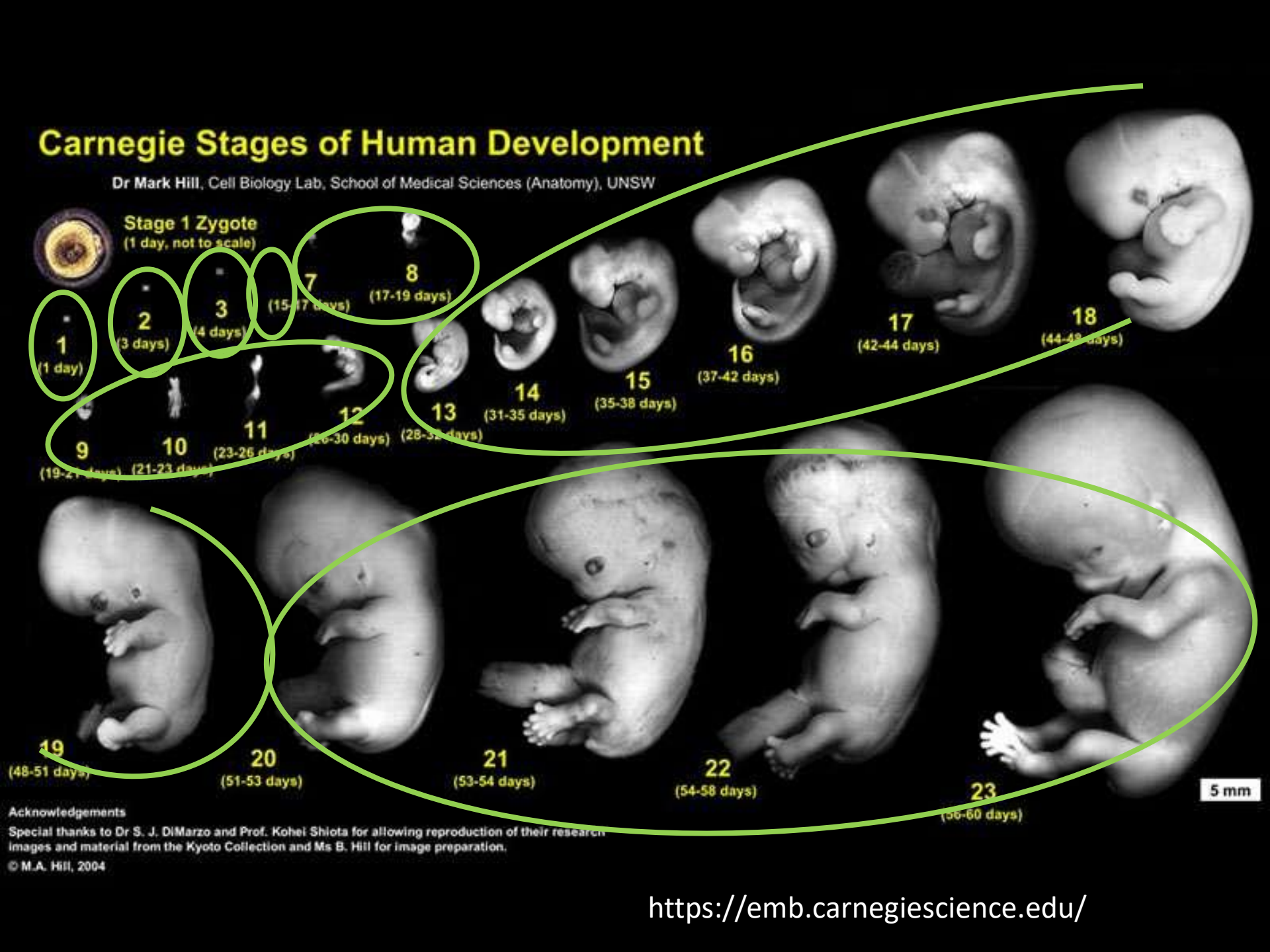
6 – cylindrical embryo (formation of somites, closing of neural tube)

7 – C shaped embryo (formation of limbs)

8 – late embryonic stage (limbs fully differentiated including fingers and toes, closing eye fissures)

B – fetal stages (9)

C – perinatal stages (10)



https://emb.carnegiescience.edu/

Embryonic stages
J 1 to J 8

1 – unicellular (fertilization) C1

2 – blastomeric (morula, cleavage of oocyte) C2

3 – blastodermic (blastocyst) C3/4

4 – bilaminar embryo (epiblast, hypoblast) C5/6

5 – trilaminar embryo with axial structures C7/9

6 – cylindrical embryo (formation of somites, closing of neural tube) C9/12

7 – C shaped embryo (formation of limbs) C13/19

8 – late embryonal stage (limbs fully differentiated including fingers and toes, closing eye fissures) C20/23

Embryonic stages
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Stage J 5 (C7-9)

Trilaminar embryo (germ disc) with axial structures

days 15 – 20, MLL 0.5 – 1.5 mm

axial structures: primitive streak, primitive node, oropharyngeal membrane, cloacal membrane, prenotochordal plate, notochordal process and plate, notochord, allantois

Substages

J 5–1	notochordal node and notochordal tubule (prenotochord)	C7
J 5–2	notochordal plate, primitive streak, intraembryonic mesoderm	C8
J 5–3	notochord, neural folds	C9

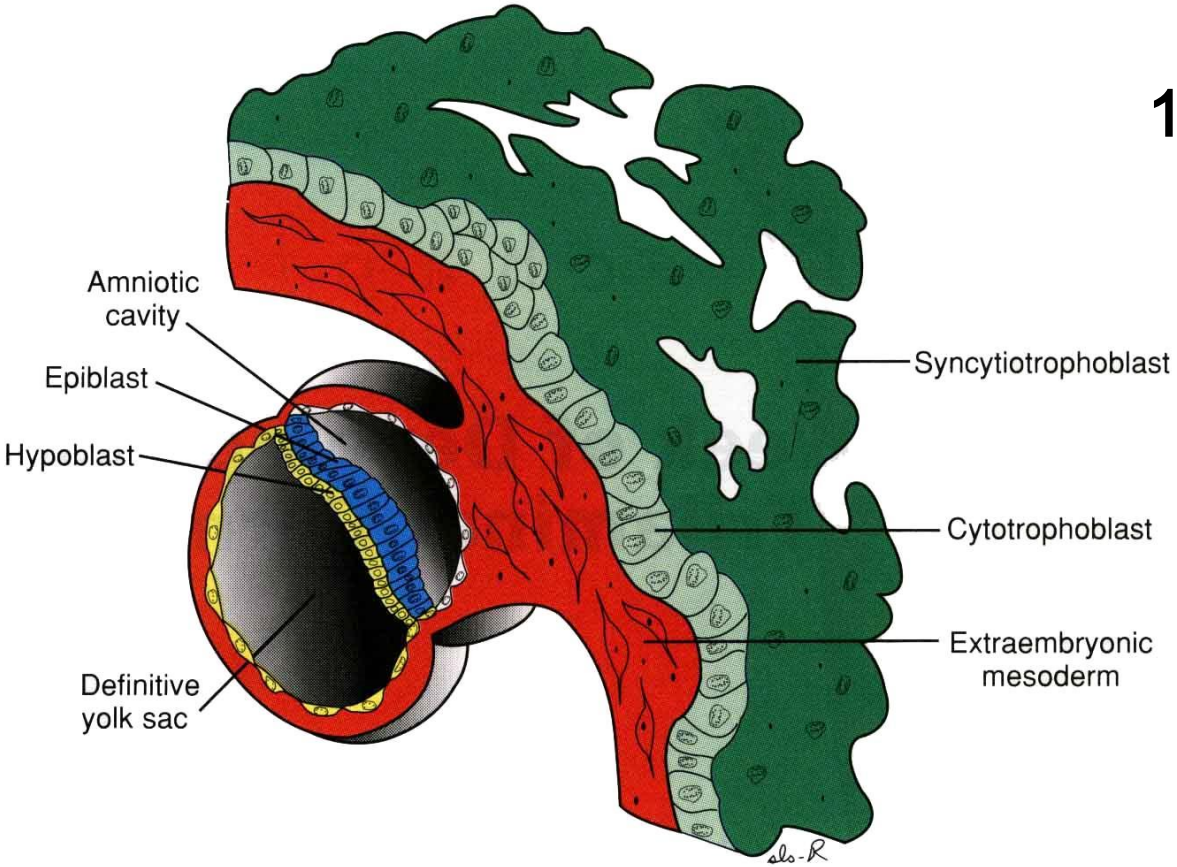
Third week

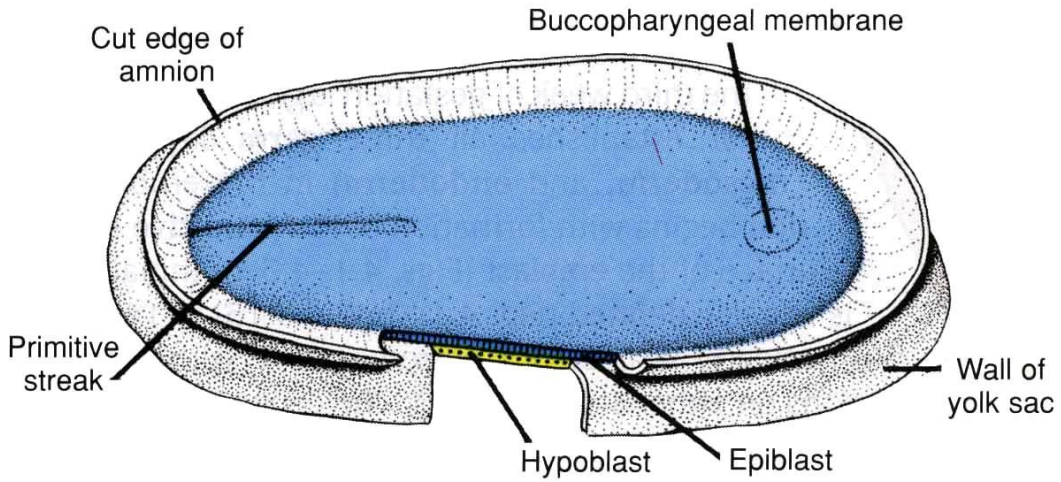
Trilaminar germ disc

days 15 – 20, MLL 0.5 – 1.5 mm

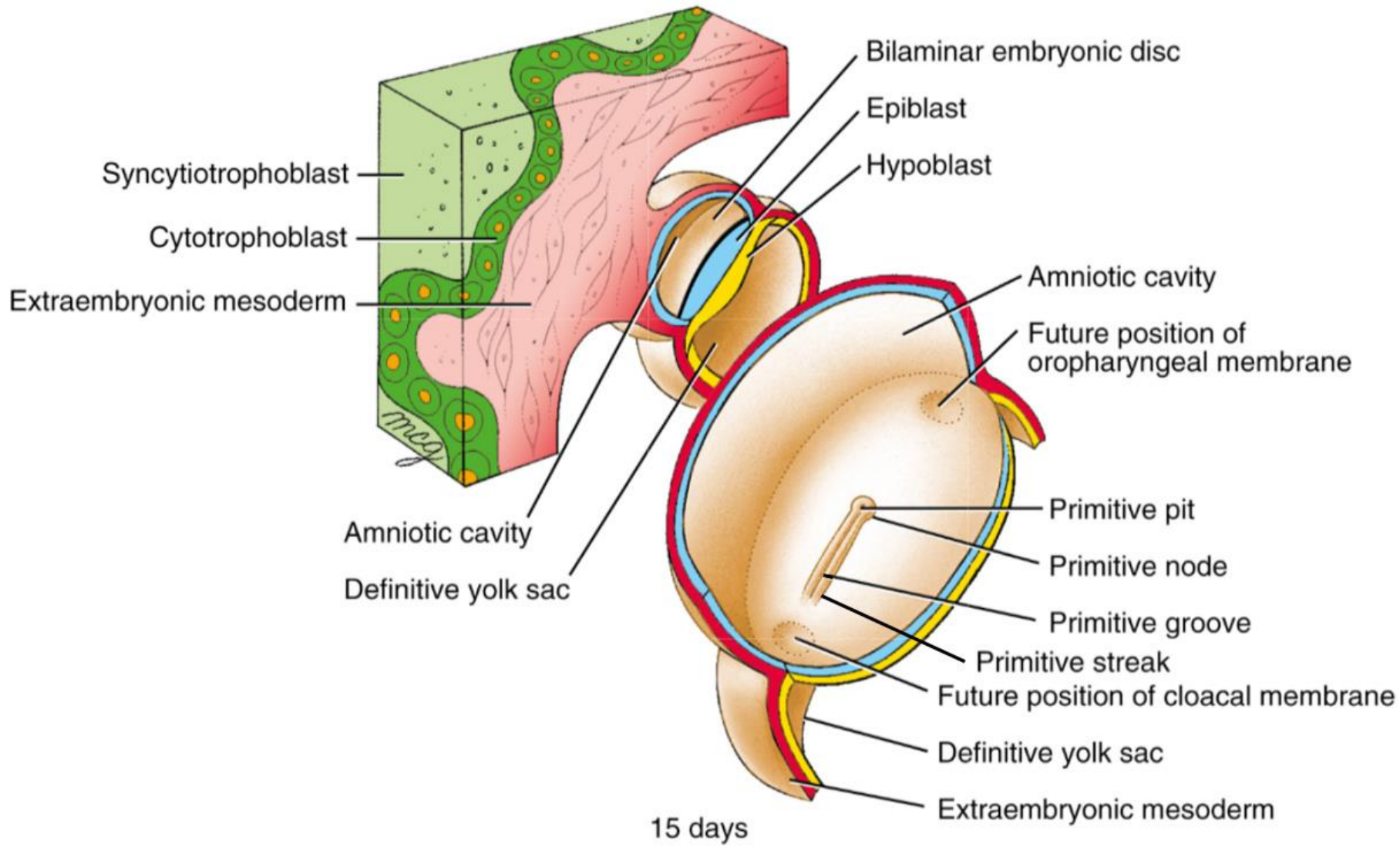
GASTRULATION
NOTOGENESIS
NEURULATION

14 - 15 d



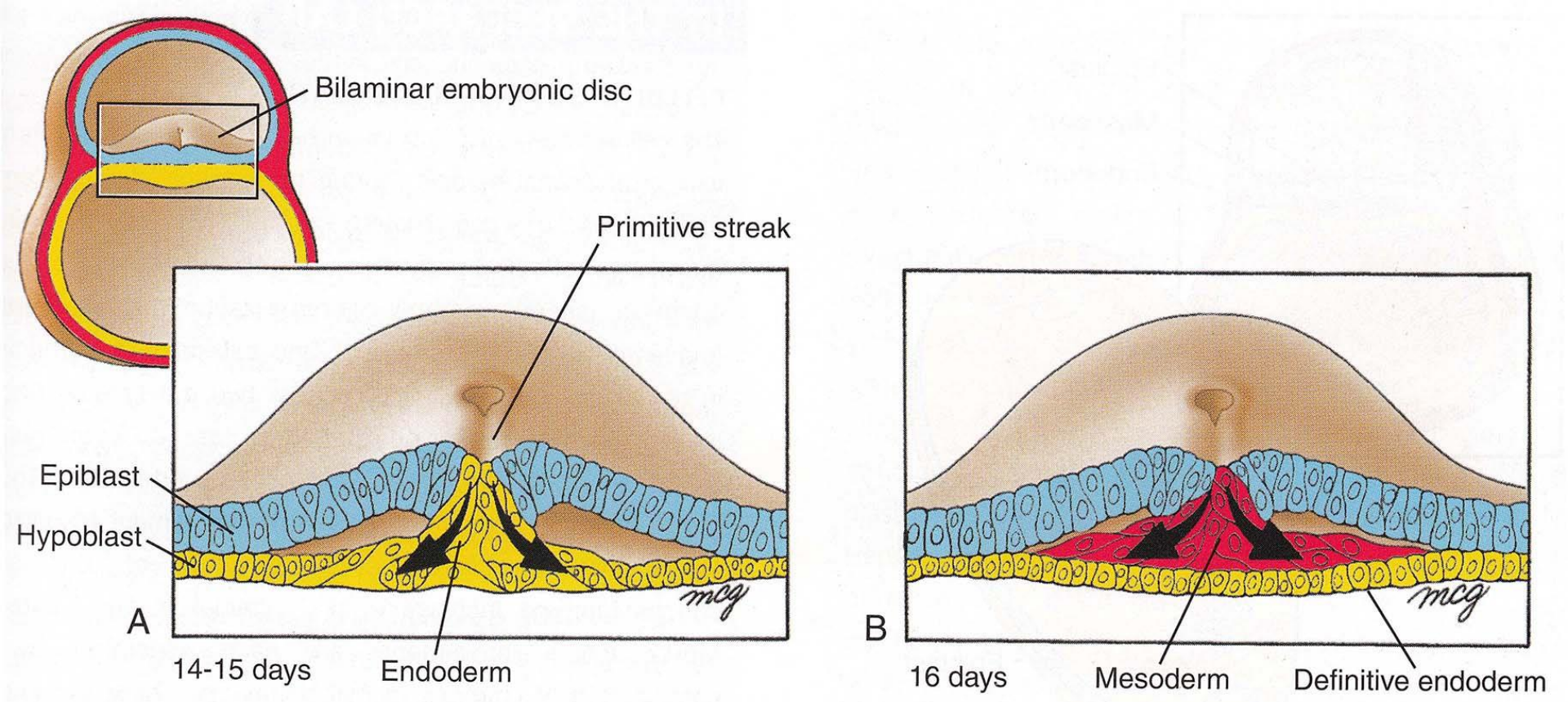


J 5–1/2, C7/8


Syncytiotrophoblast
Cytotrophoblast
Extraembryonic mesoderm
Amniotic cavity
Definitive yolk sac
Bilaminar embryonic disc
Epiblast
Hypoblast
Amniotic cavity
Future position of oropharyngeal membrane
Primitive pit
Primitive node
Primitive groove
Primitive streak
Future position of cloacal membrane
Definitive yolk sac
Extraembryonic mesoderm
15 days

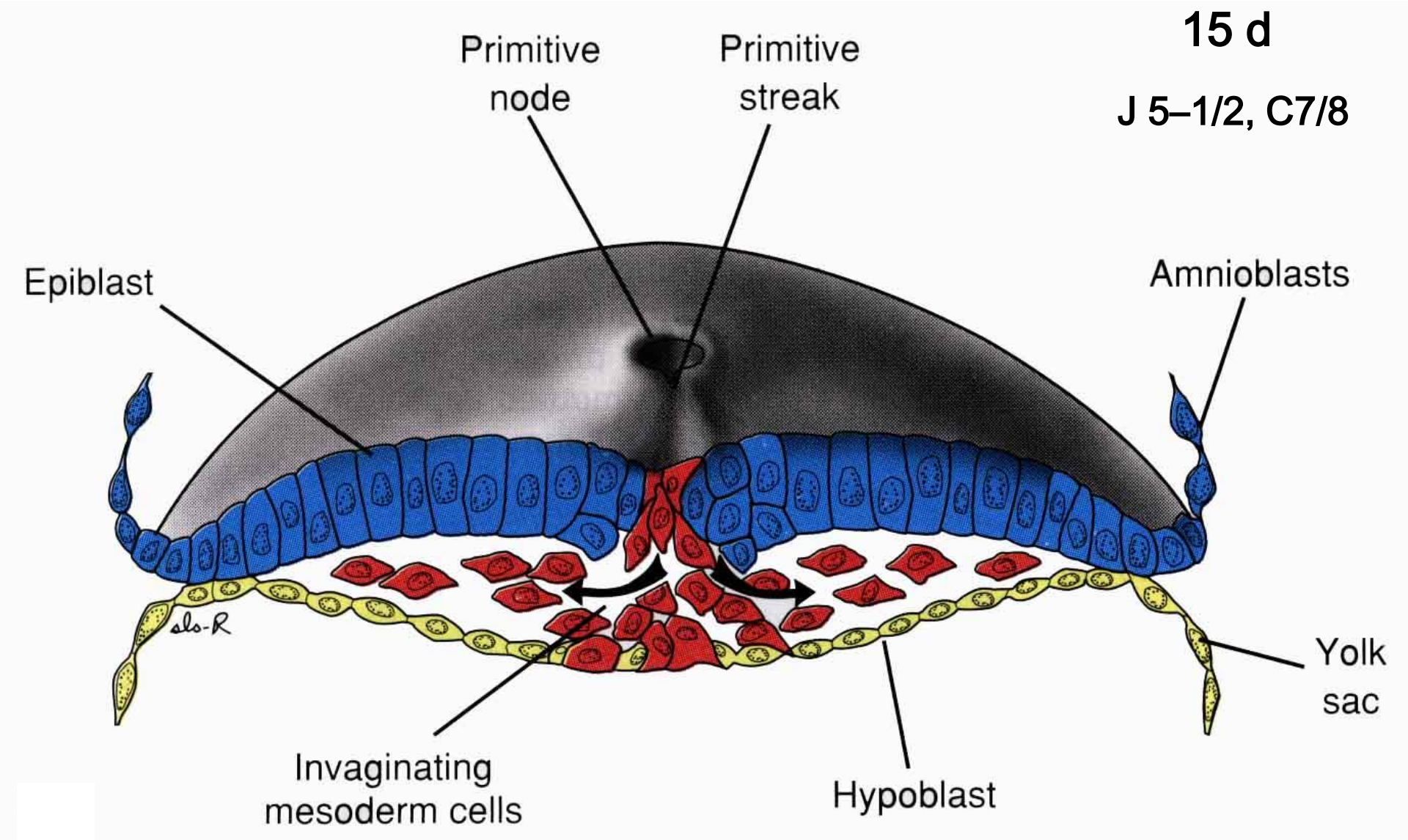
Gastrulation

J5–1/2, C7/8



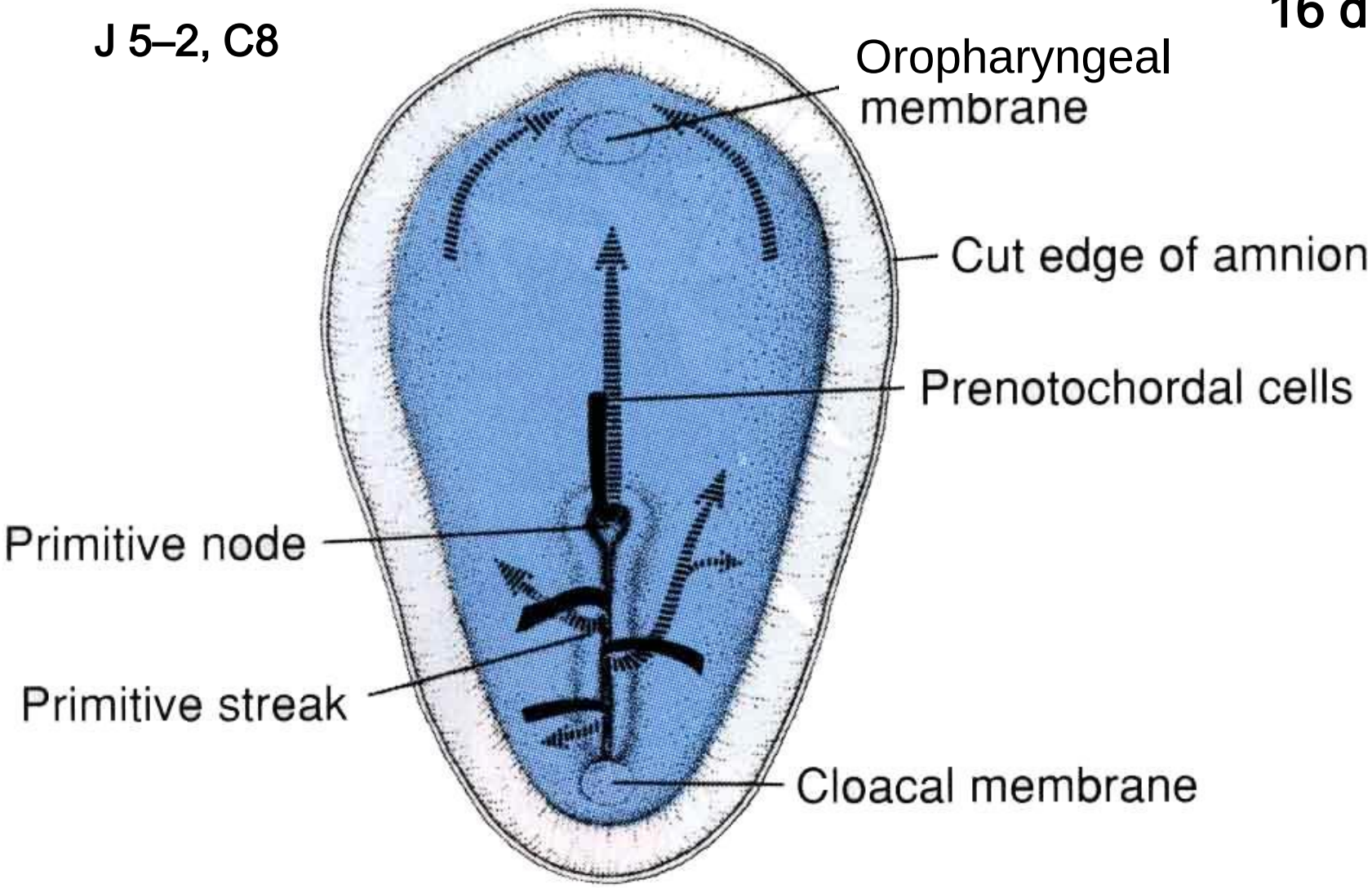
Schoenwolf, G.C. et al: Larsen's Human Embryology, Elsevier 2009

Gastrulation



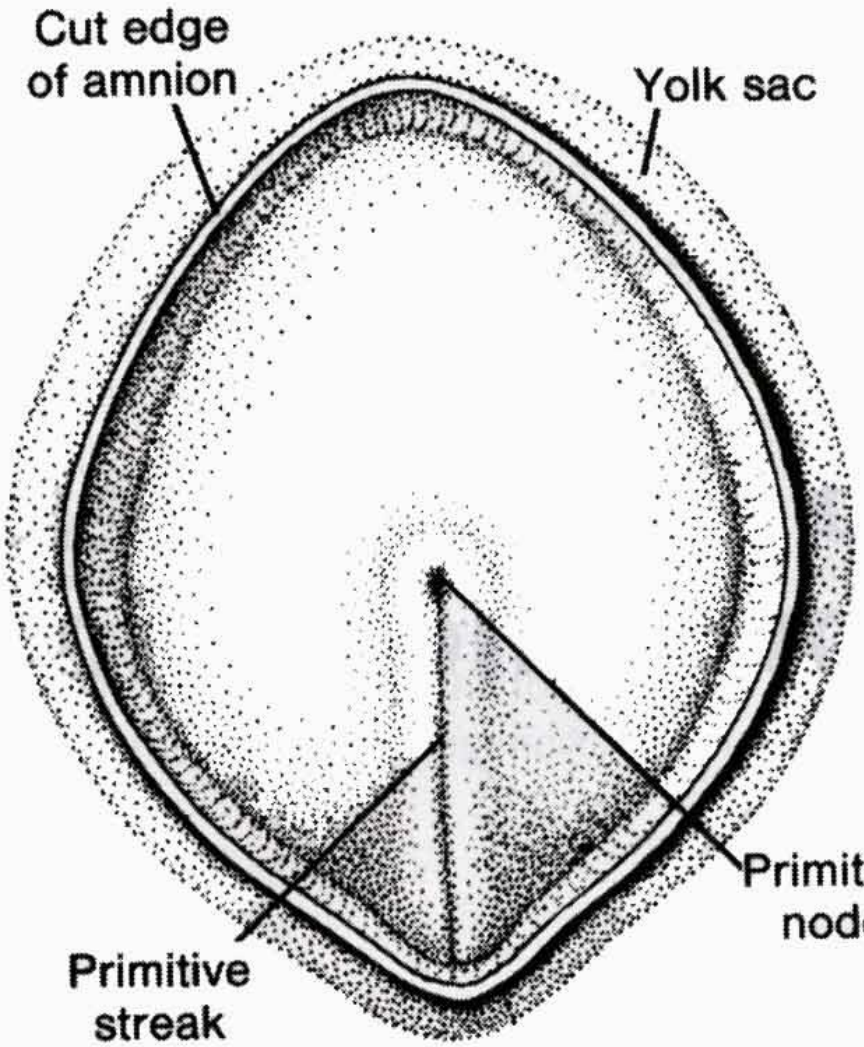
J 5–2, C8

16 d

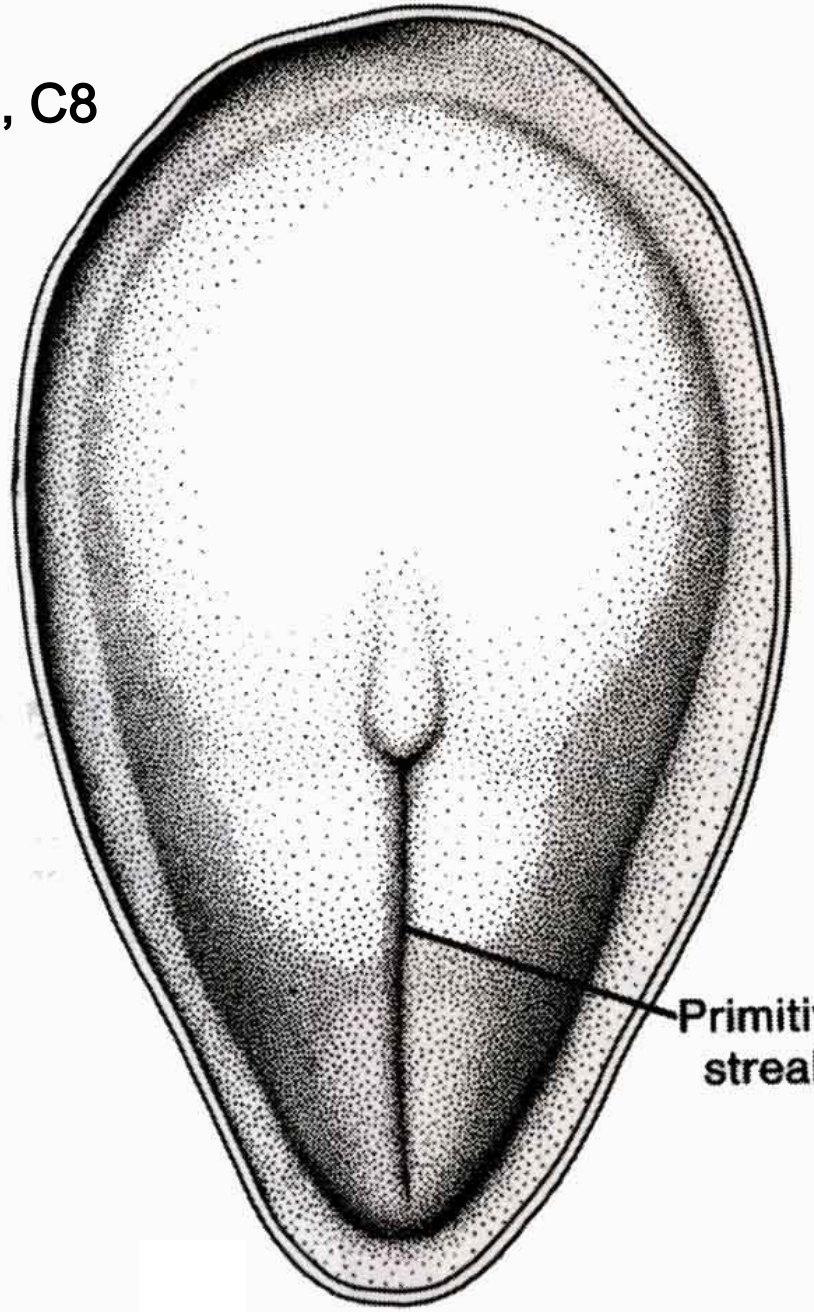

Oropharyngeal membrane
Cut edge of amnion
Prenotochordal cells
Primitive node
Primitive streak
Cloacal membrane

J5–1, C7

J 5–2, C8

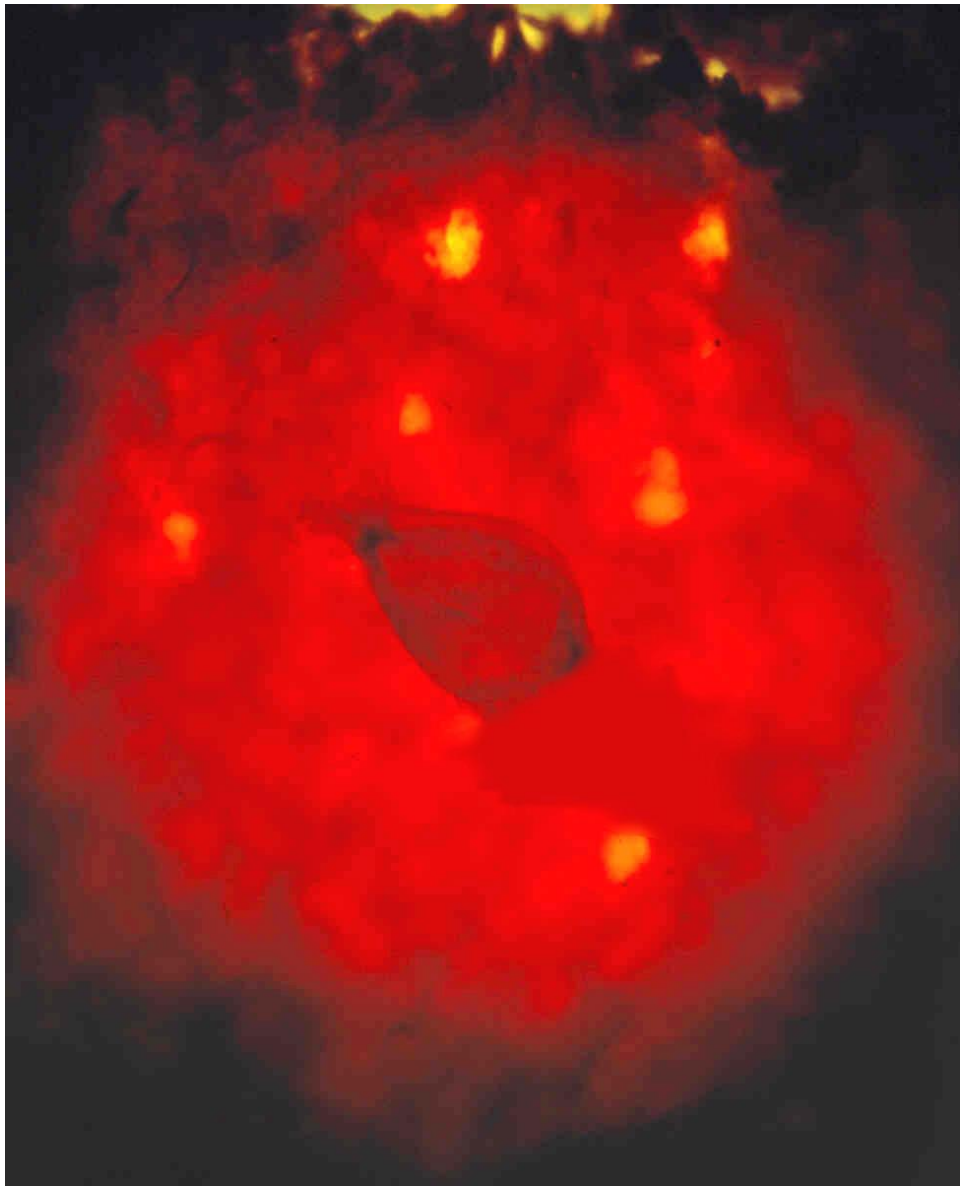


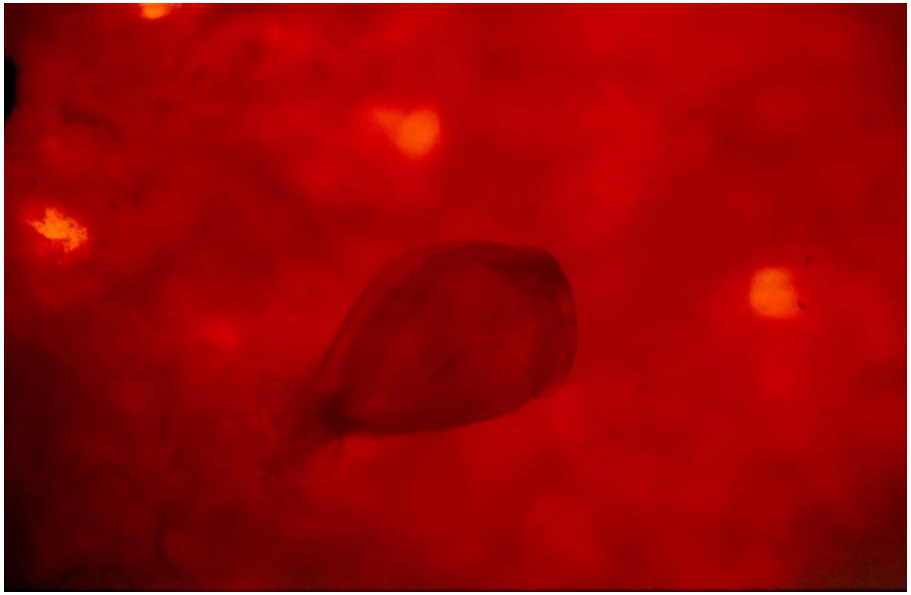
16 days

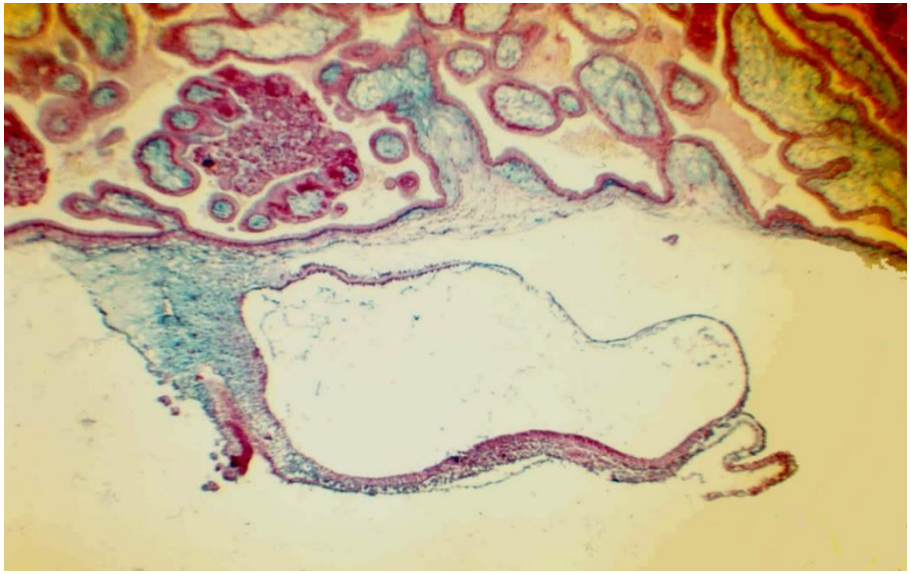


18 days

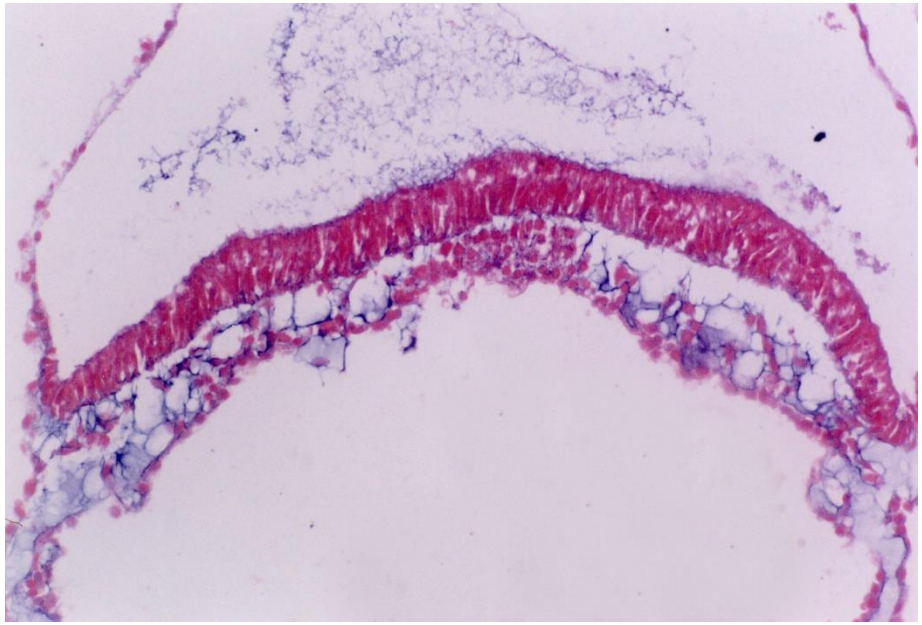
J 5 – 2, C8

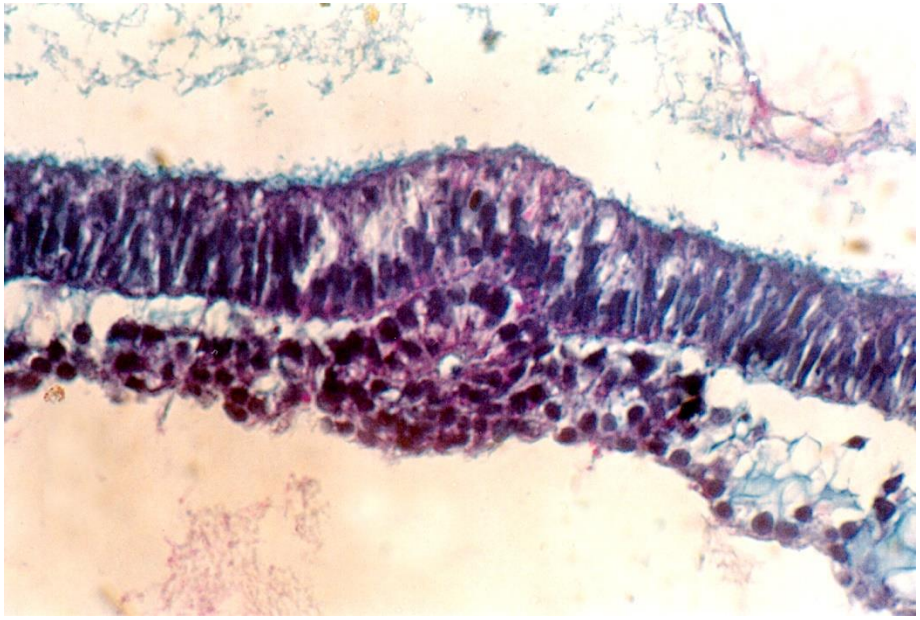


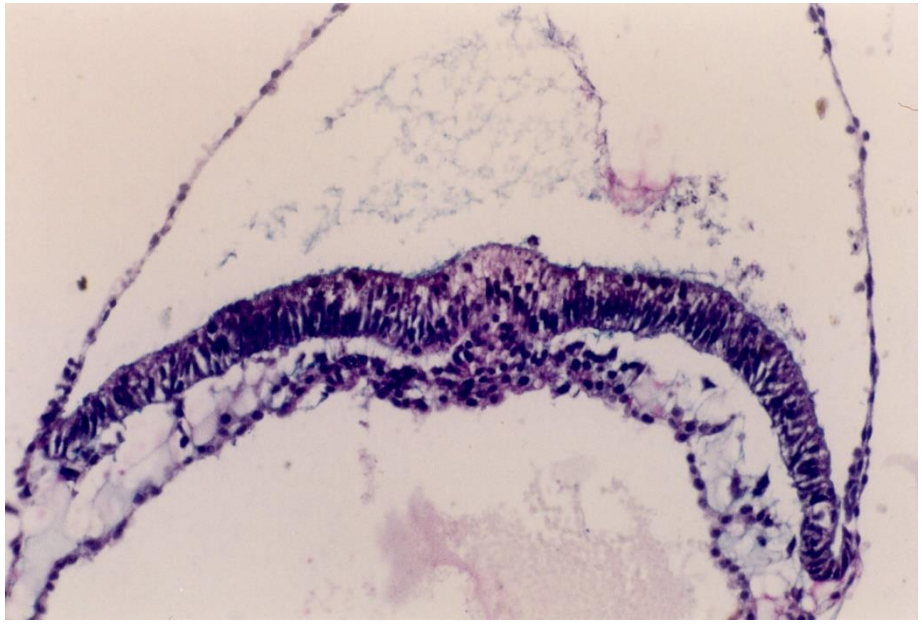


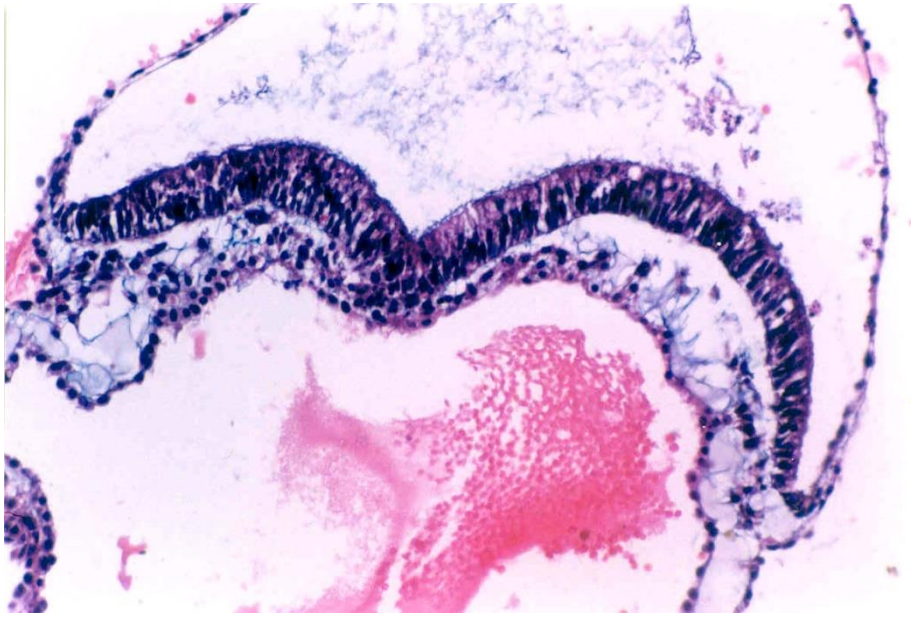


J 5 – 2, C8



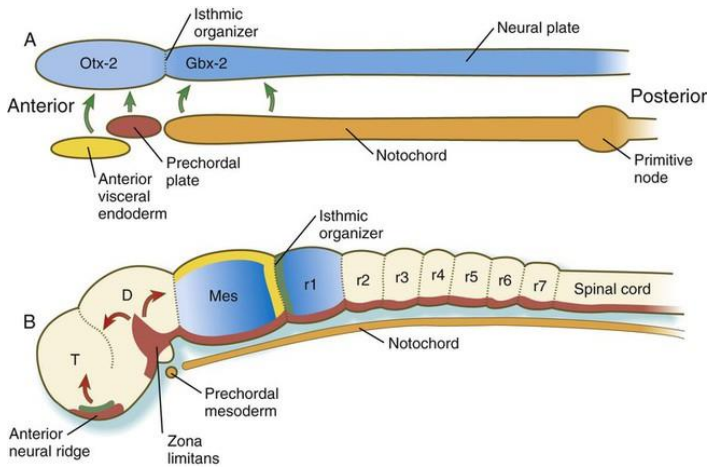






General strategy of pattern formation

1. Formation of the basic body plan (establishment of the body axes)
2. Gradual formation of details by means of intercellular inductive interactions. Cells diversify and their arrangement depends on:
    a) position signaling between the cells
    b) cell programme that modifies the response of cell to these signals in dependence on time



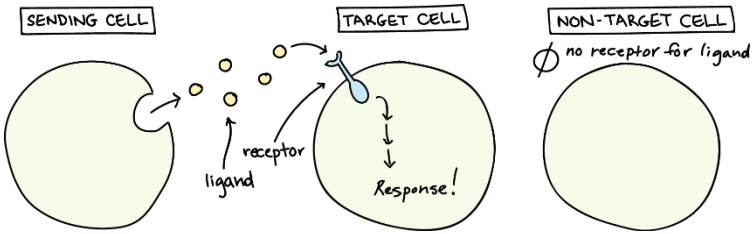
https://clinicalgate.com/establishment-of-the-basic-embryonic-body-plan/

Competence

cell ability to respond to an inducing signal

Requires a presence of:

a) receptors
b) transport mechanisms
c) transkription factors



https://www.khanacademy.org/science/biology/cell-signaling/mechanisms-of-cell-signaling/a/introduction-to-cell-signaling

Position information

Determines a cell identity

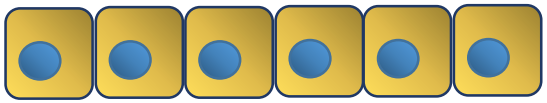
depends upon the genetic constitution and developmental history of the cell and provides the basis for pattern formation

Morphogene

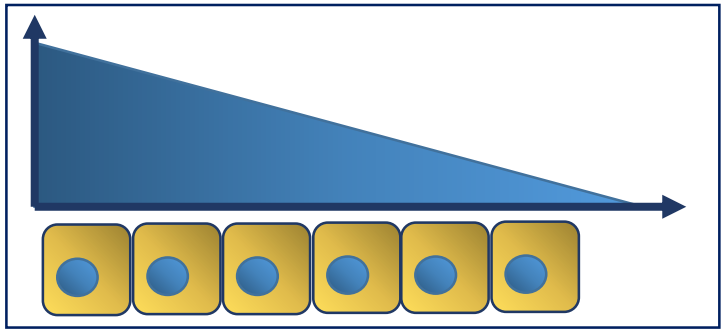
any substance active in pattern formation on the basis of its gradient that provides positional value to the cells

French flag model - model of pattern formation

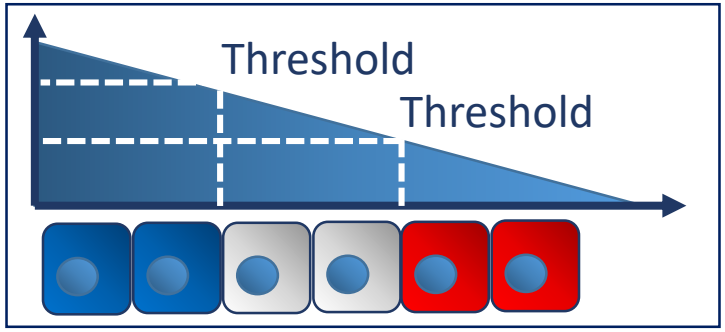
Each cell has the potential to develop as blue, white, or red.



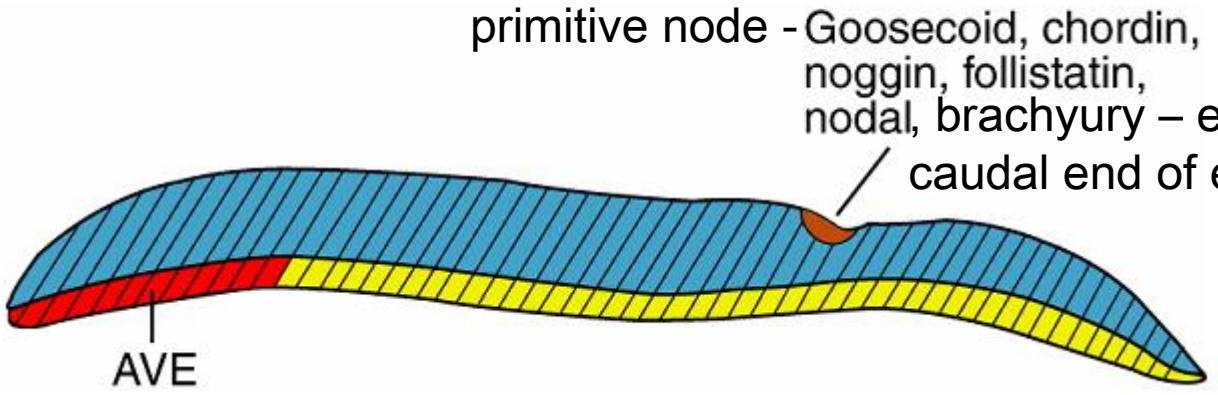
Position of each cell is defined by the concentration of morphogene.



Positional value is interpreted by the cells which differentiate to form a pattern.



Establishment of the body axes

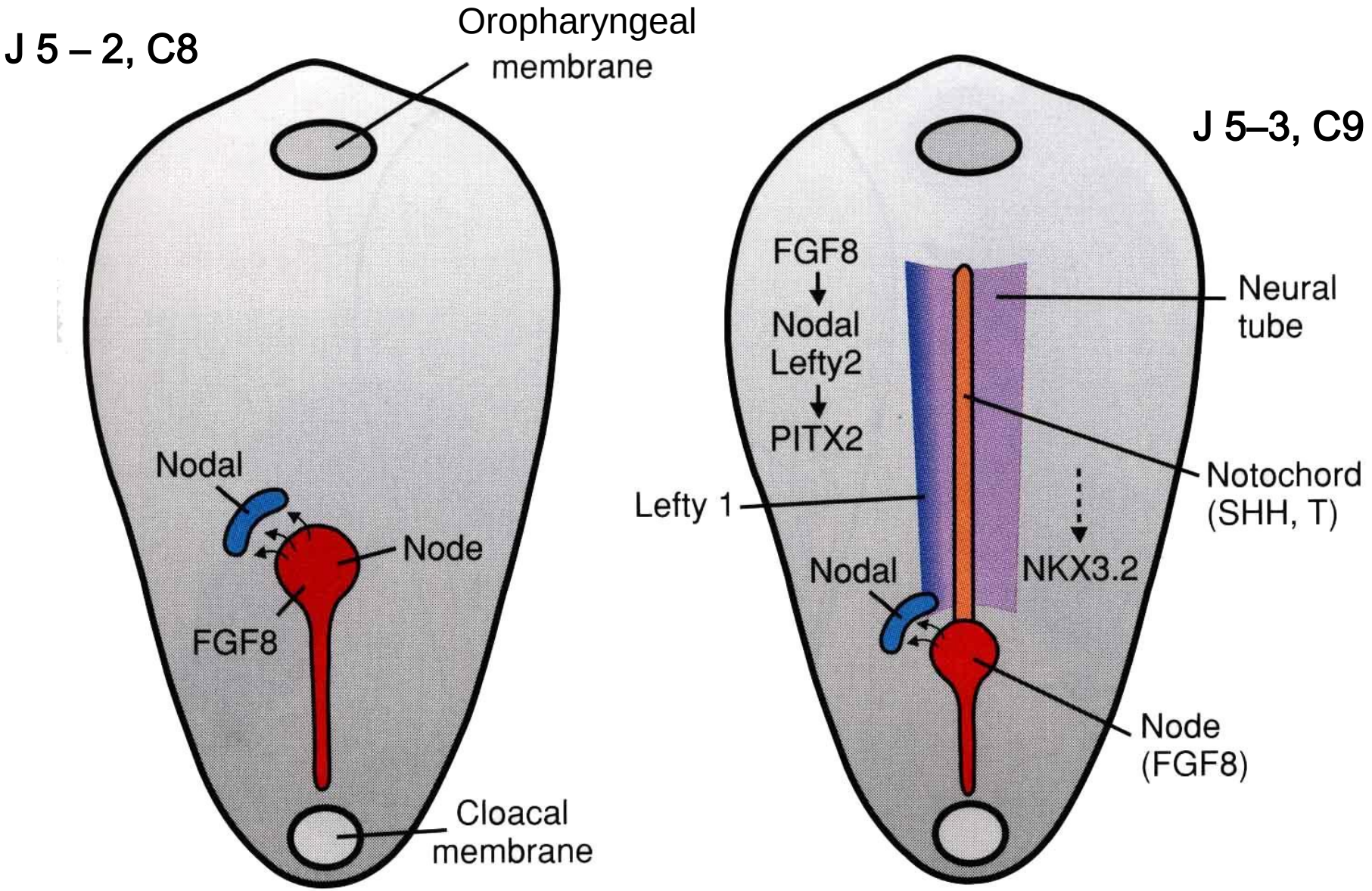


↑ BMP4 (hatched area) = ventralization or mesoderm (formation of intermediate and lateral mesoderm)

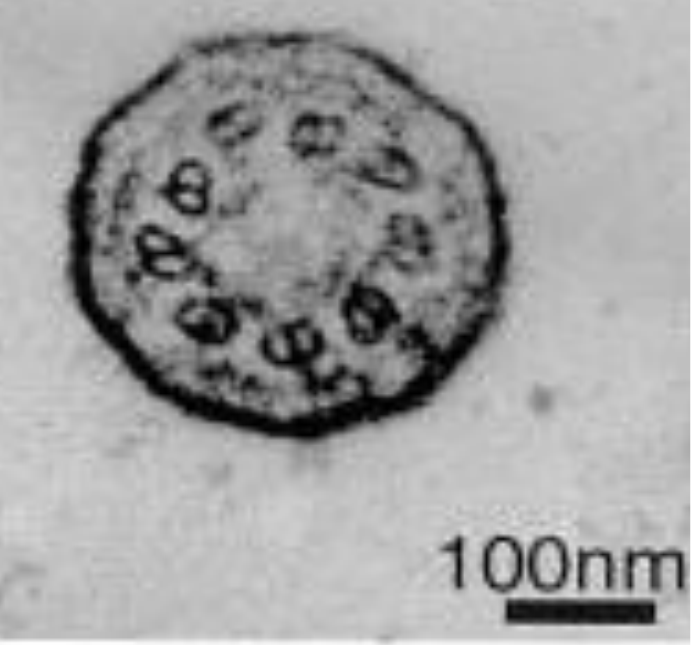
↓ BMP4 in the primitive node (goosecoid, brachyury) = dorsalization of mesoderm (formation of paraxial mesoderm and notochord)

Other mechanisms of position information

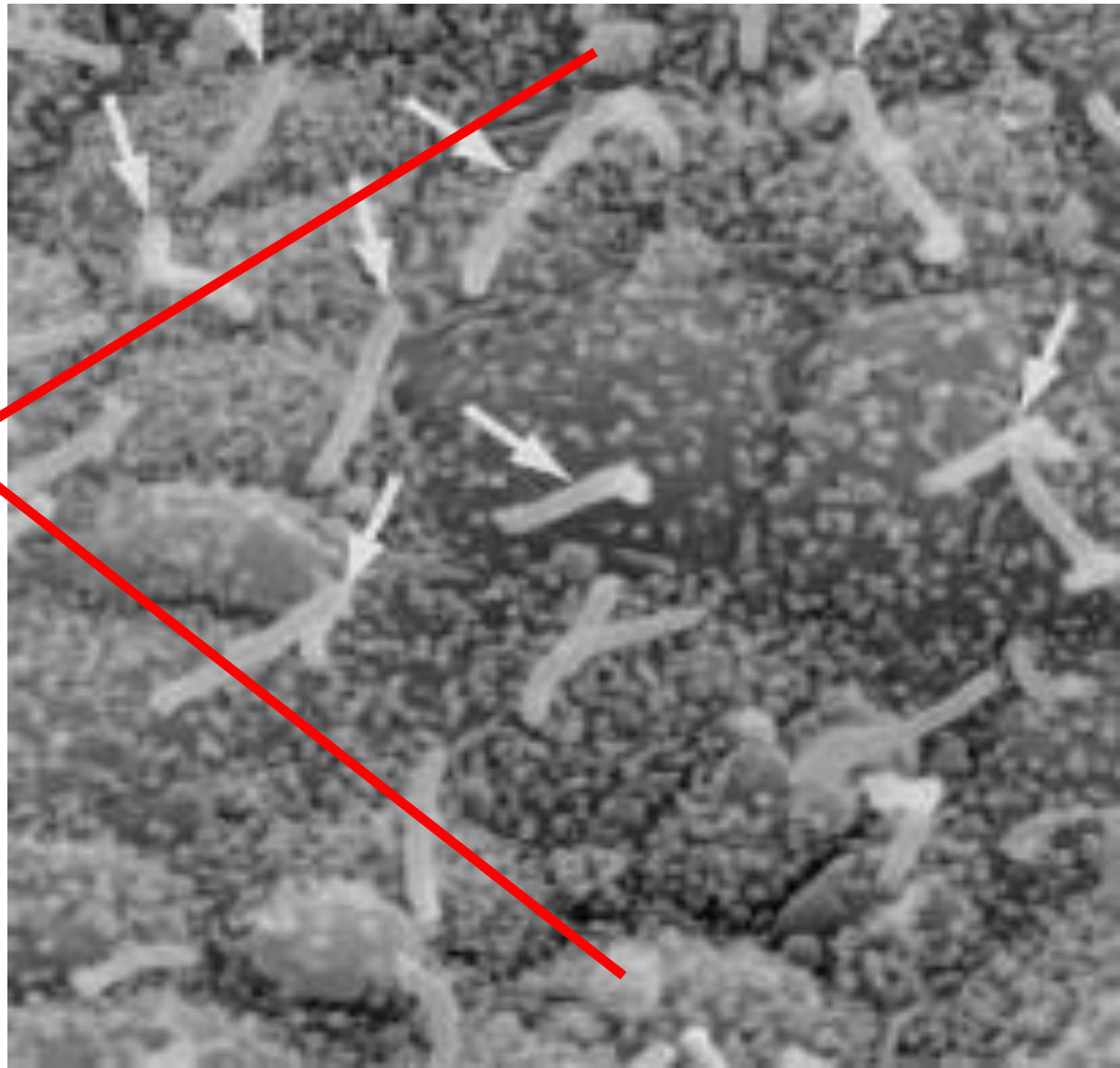
in seminar



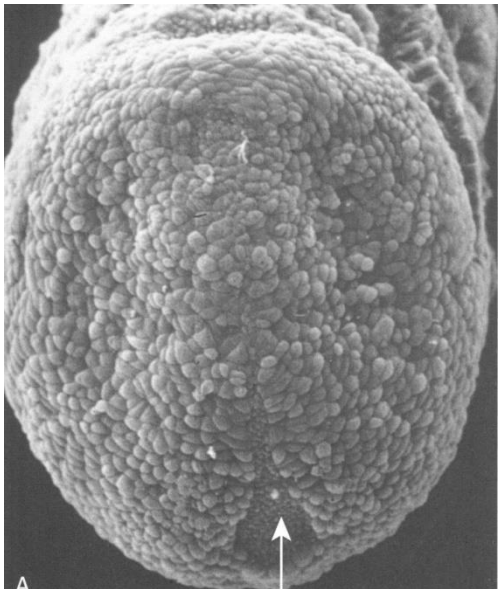
Establishment of right-left asymmetry



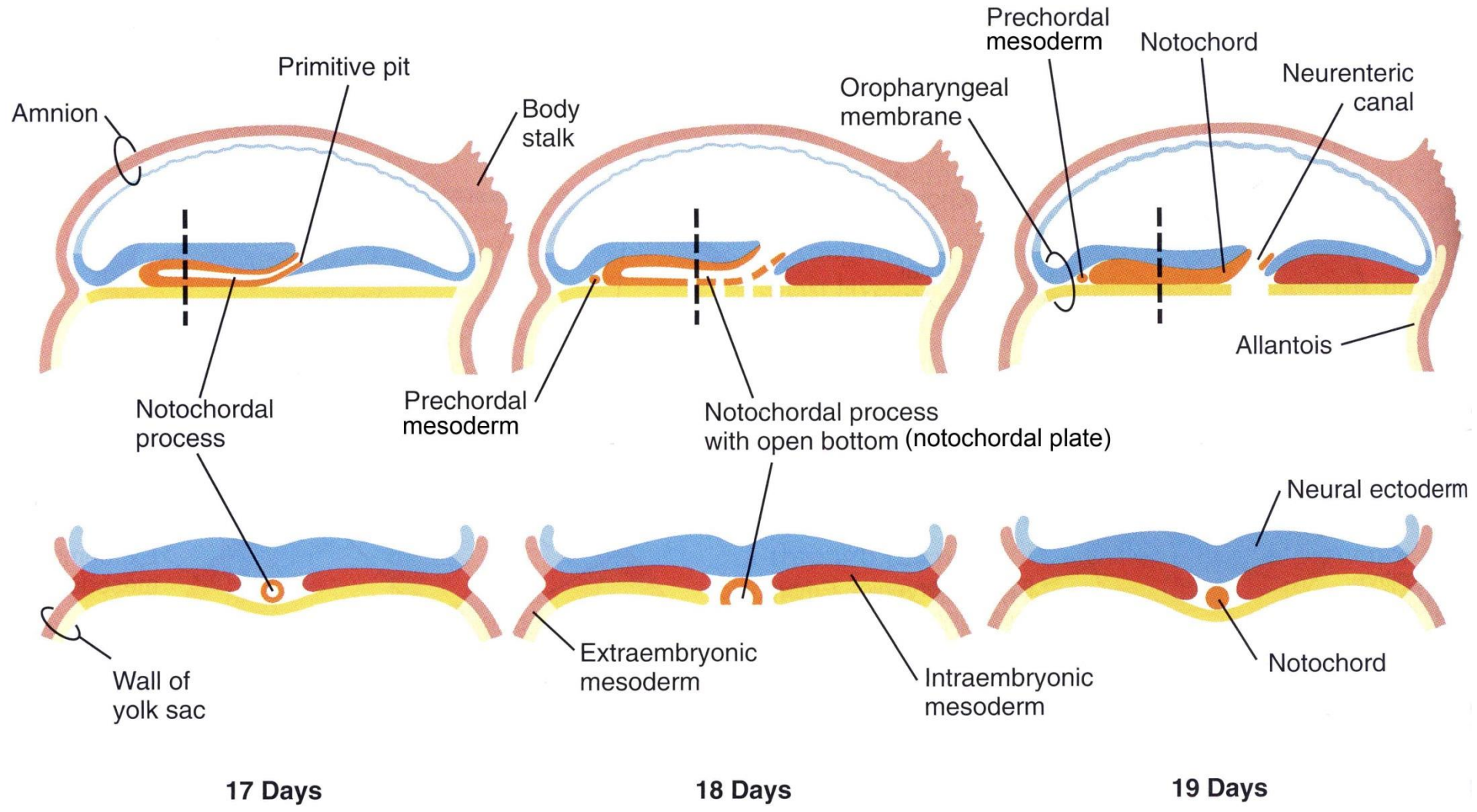
node monocilia (white arrows)



nodal vesicular parcels

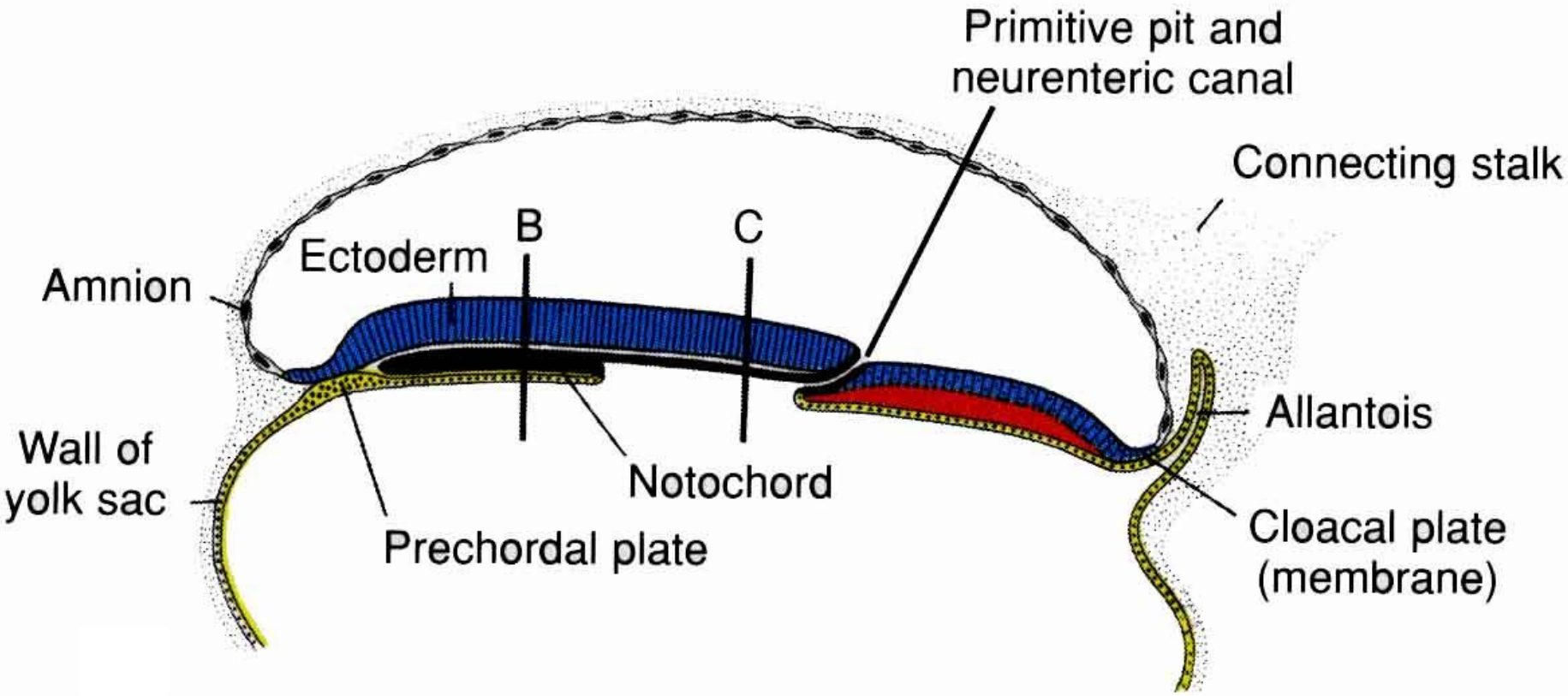


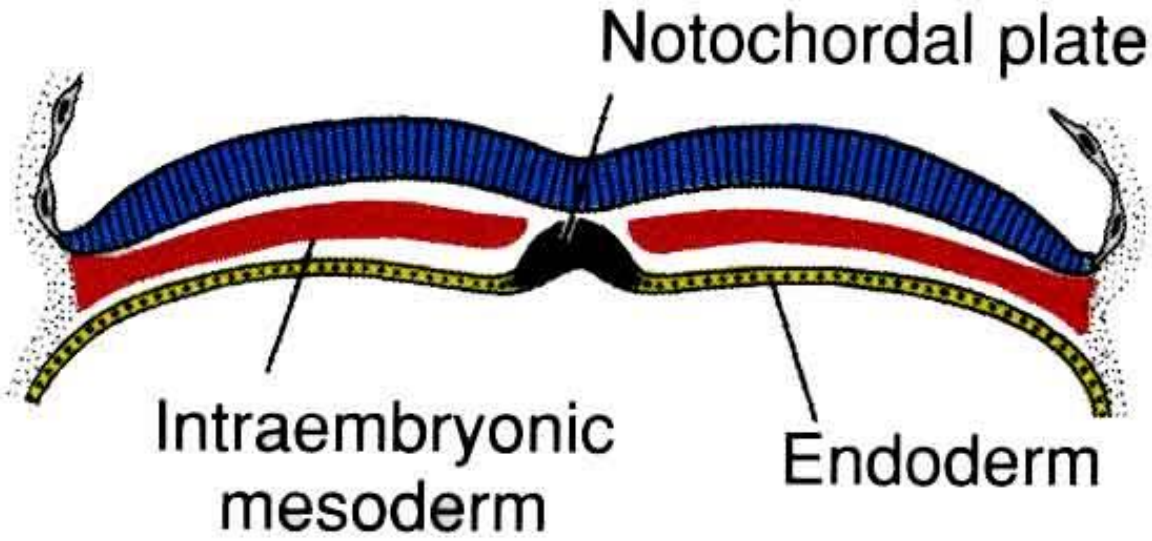
Development of the notochord - notogenesis



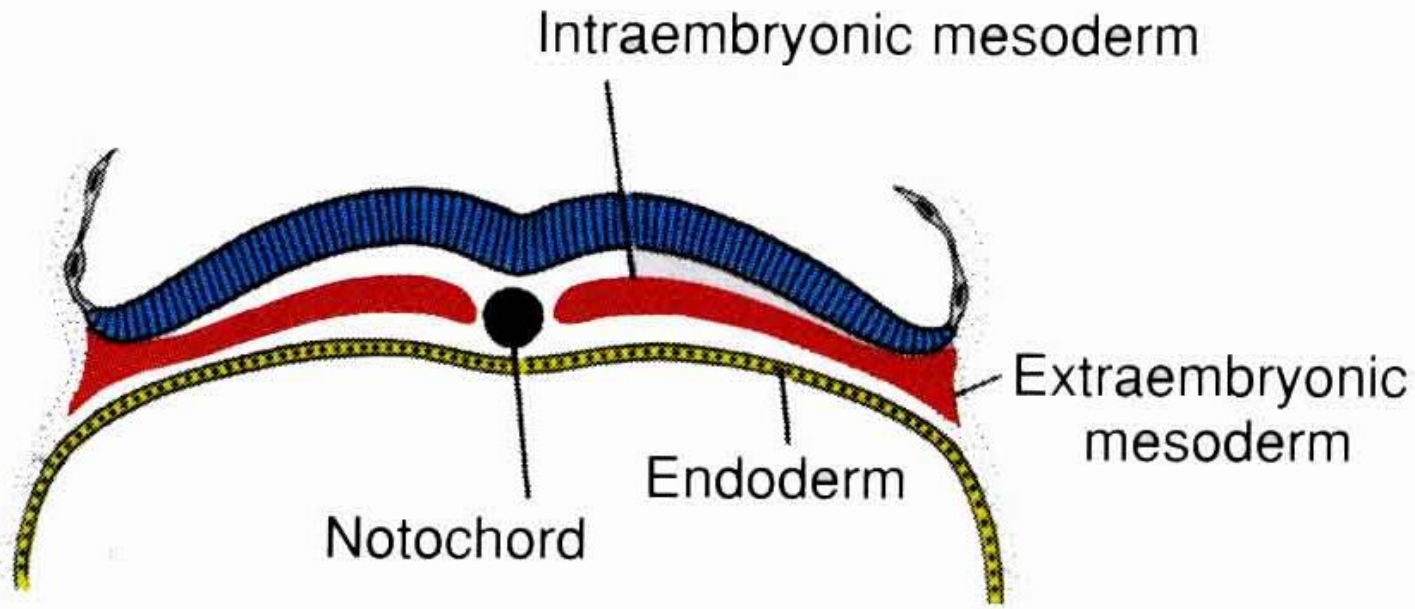
J 5–2, C8

17 d


Primitive pit and
neurenteric canal
Connecting stalk
B
C
Ectoderm
Amnion
Allantois
Wall of
yolk sac
Notochord
Prechordal plate
Cloacal plate
(membrane)

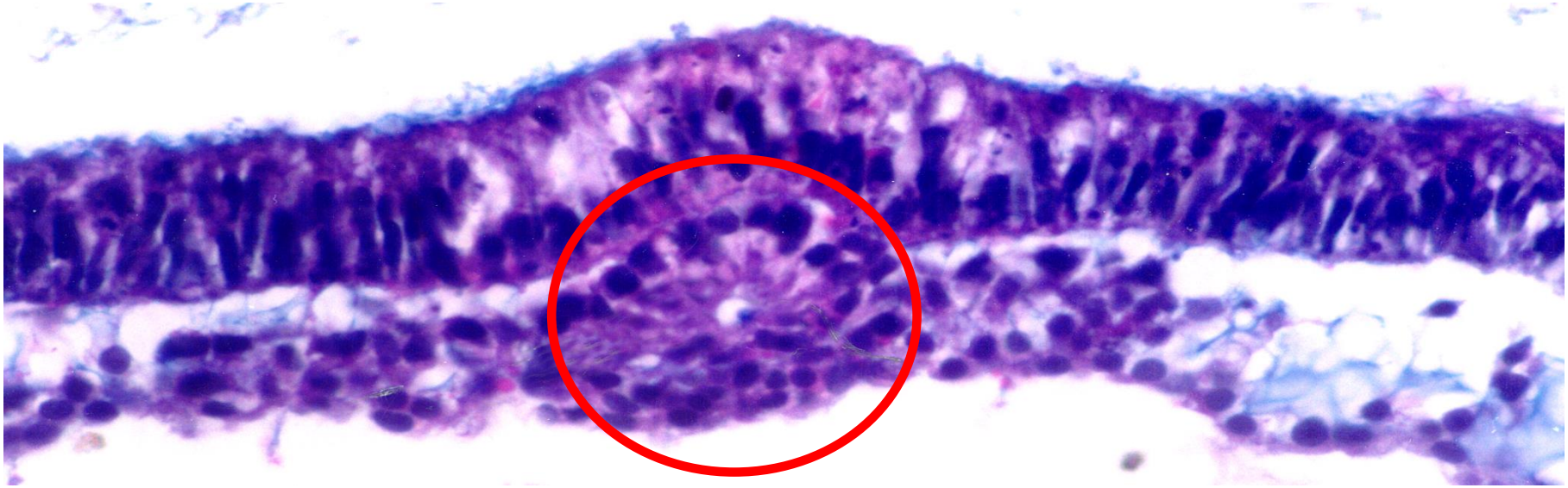


J 5–2, C8

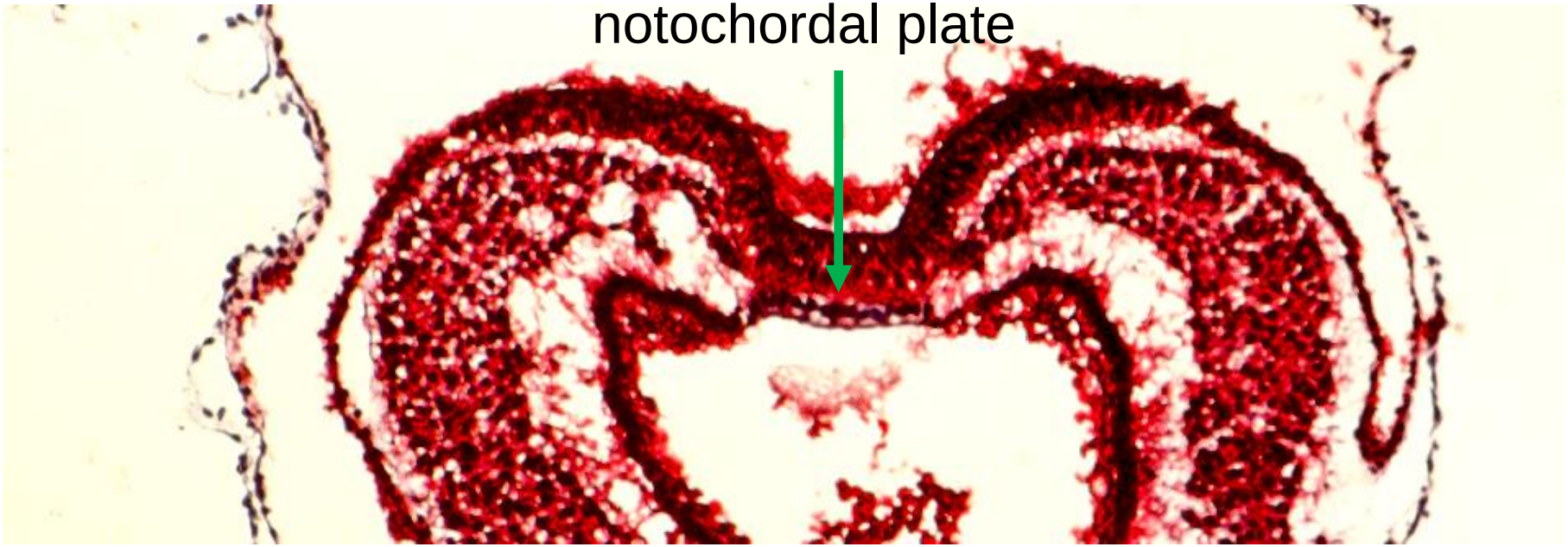

Intraembryonic mesoderm
Extraembryonic mesoderm
Endoderm
Notochord

J 5–2/3, C8/9

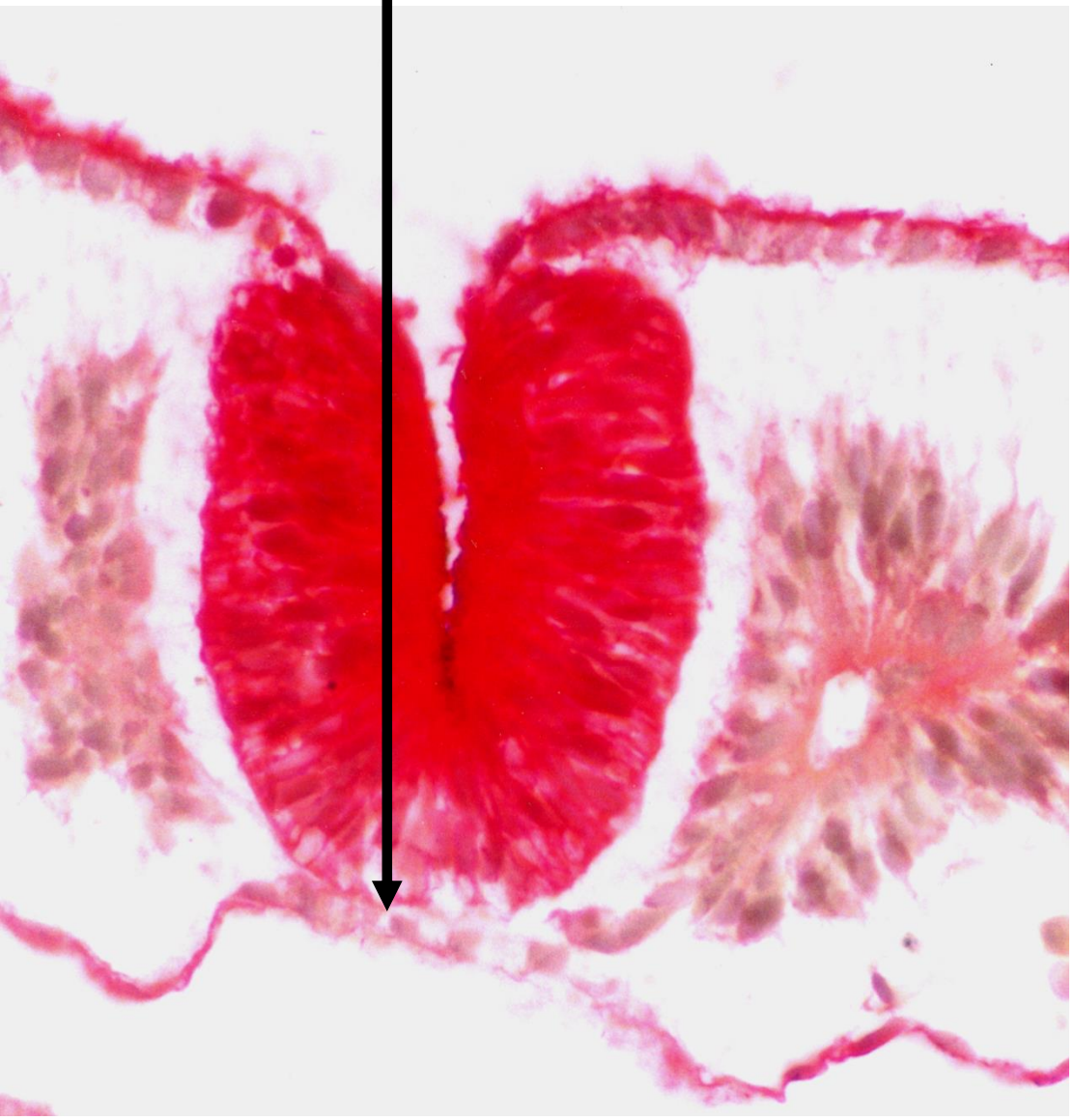
luminized prenotochord



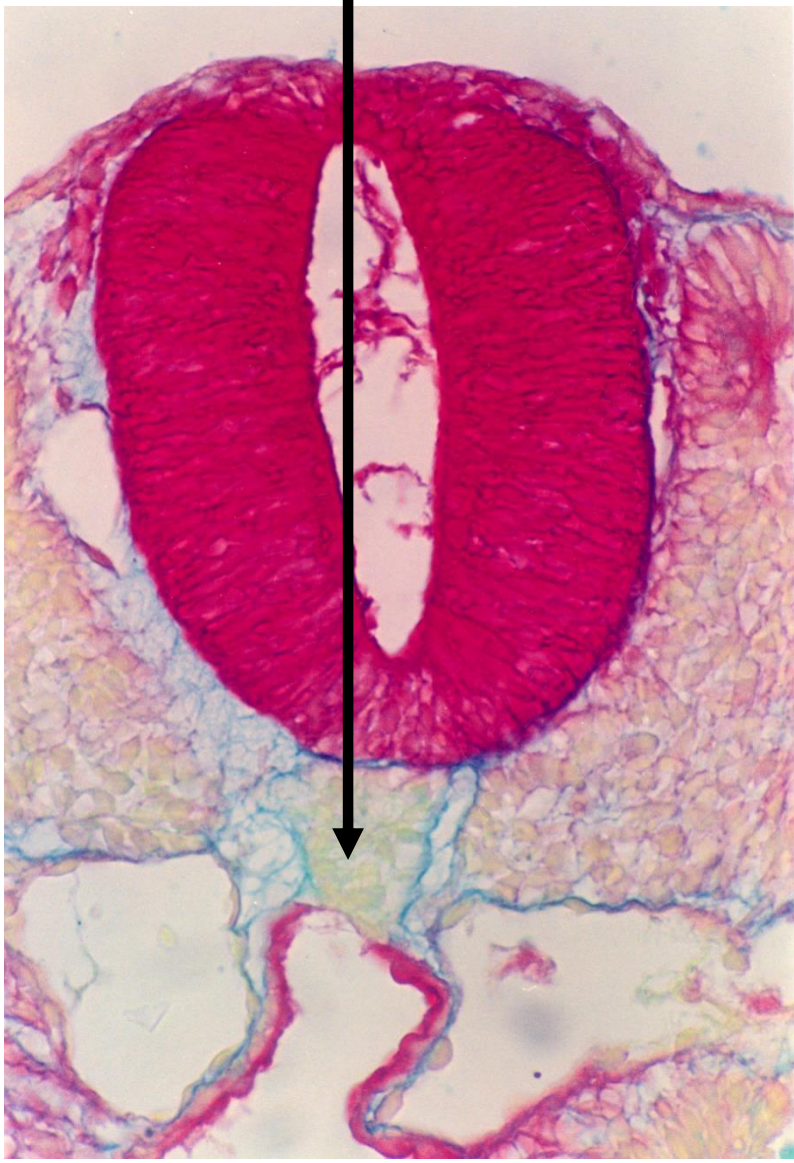
notochordal plate



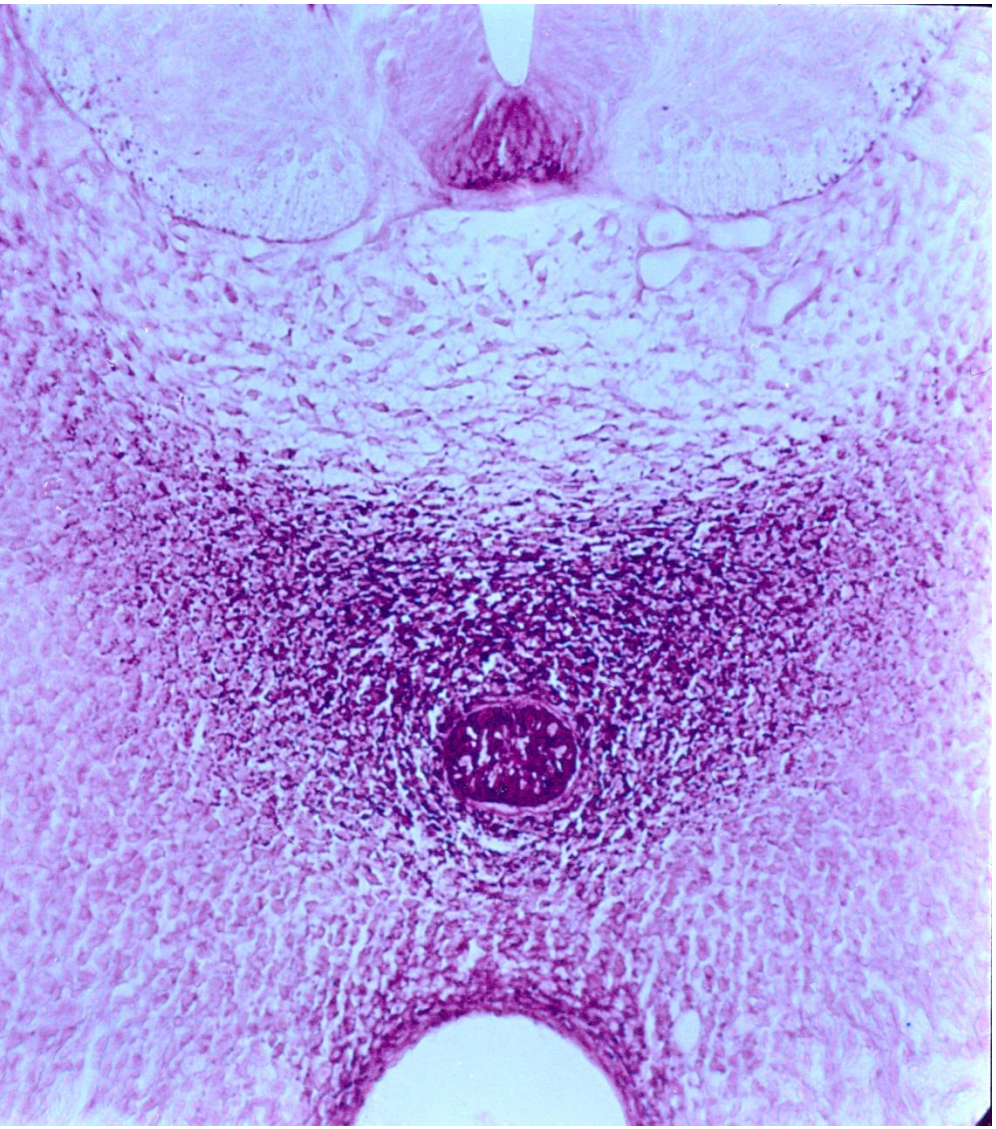
late notochordal plate

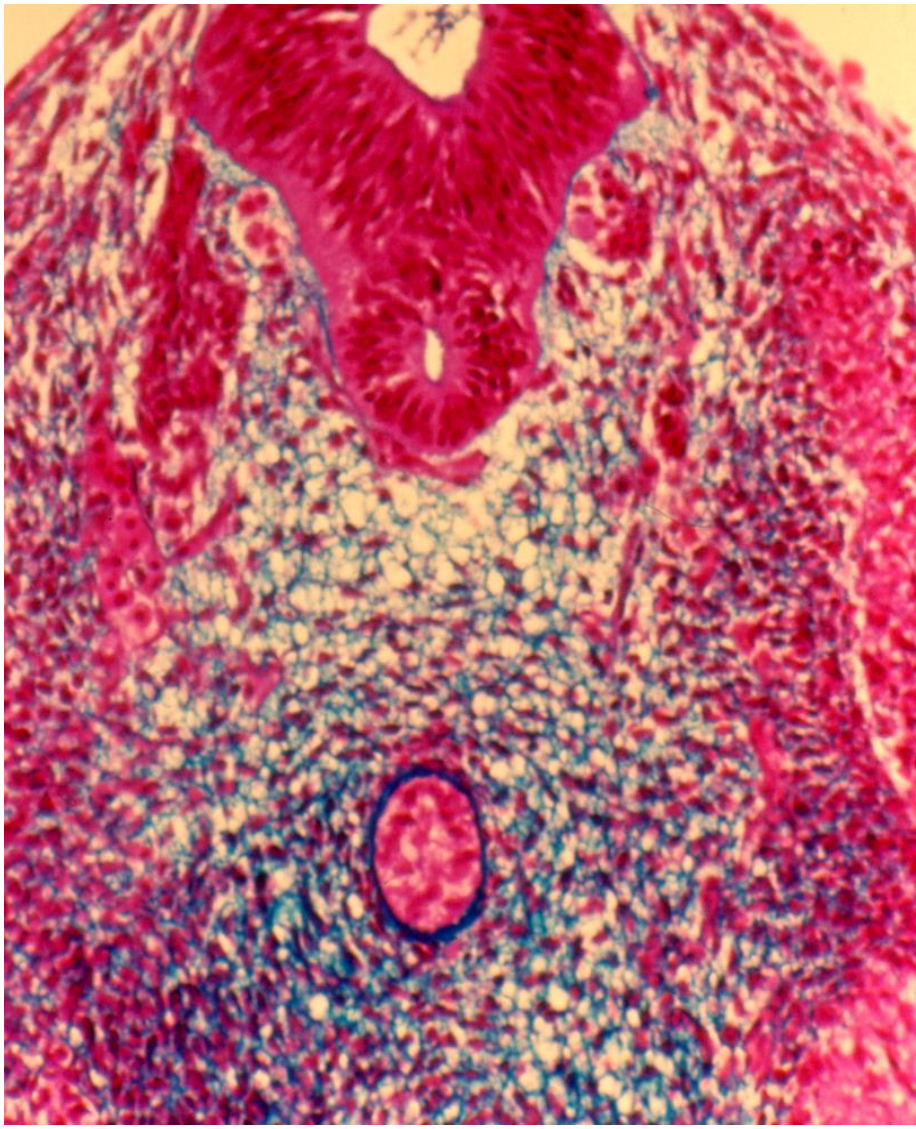


interposed notochord



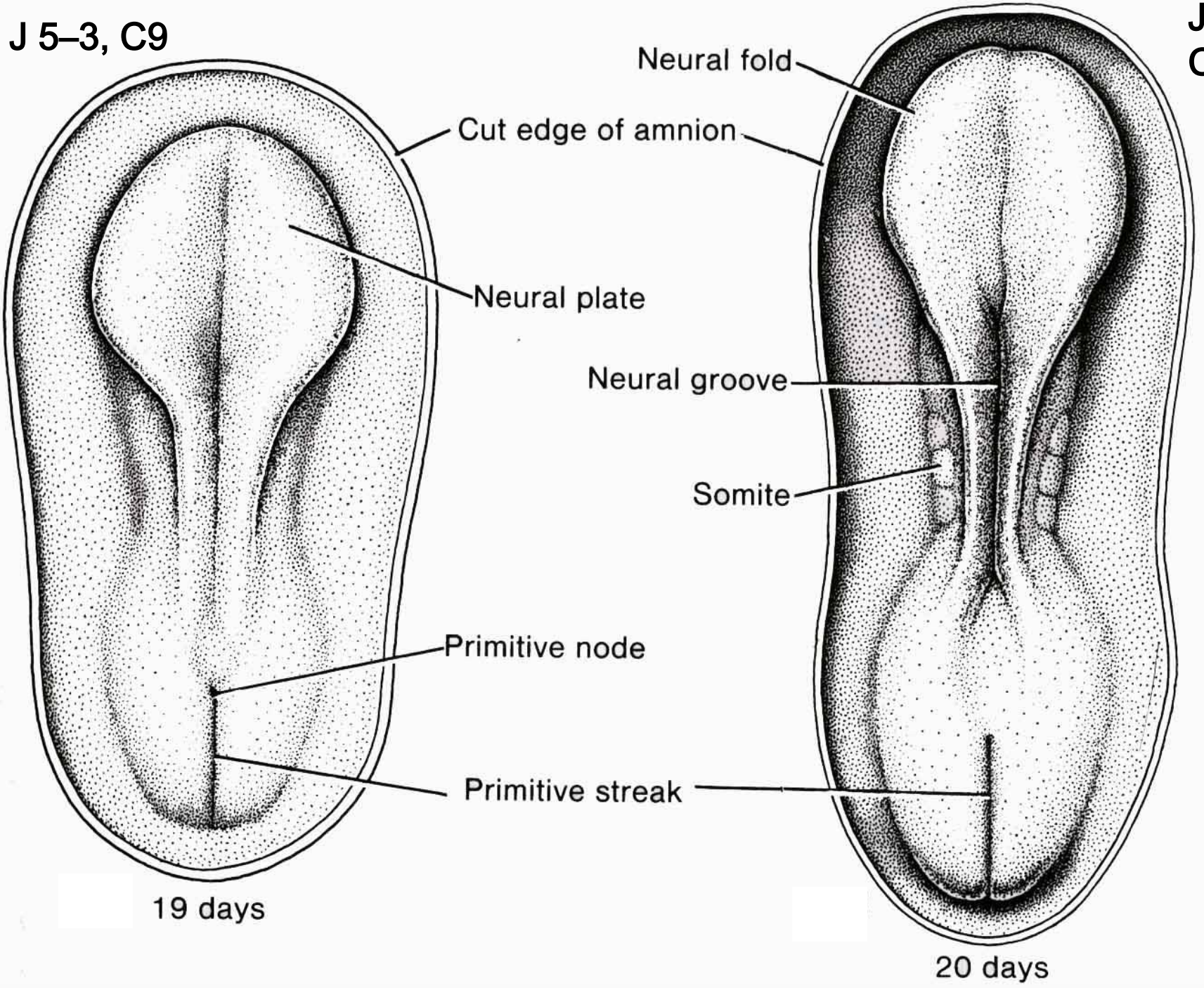
Notochord (Chorda dorsalis)





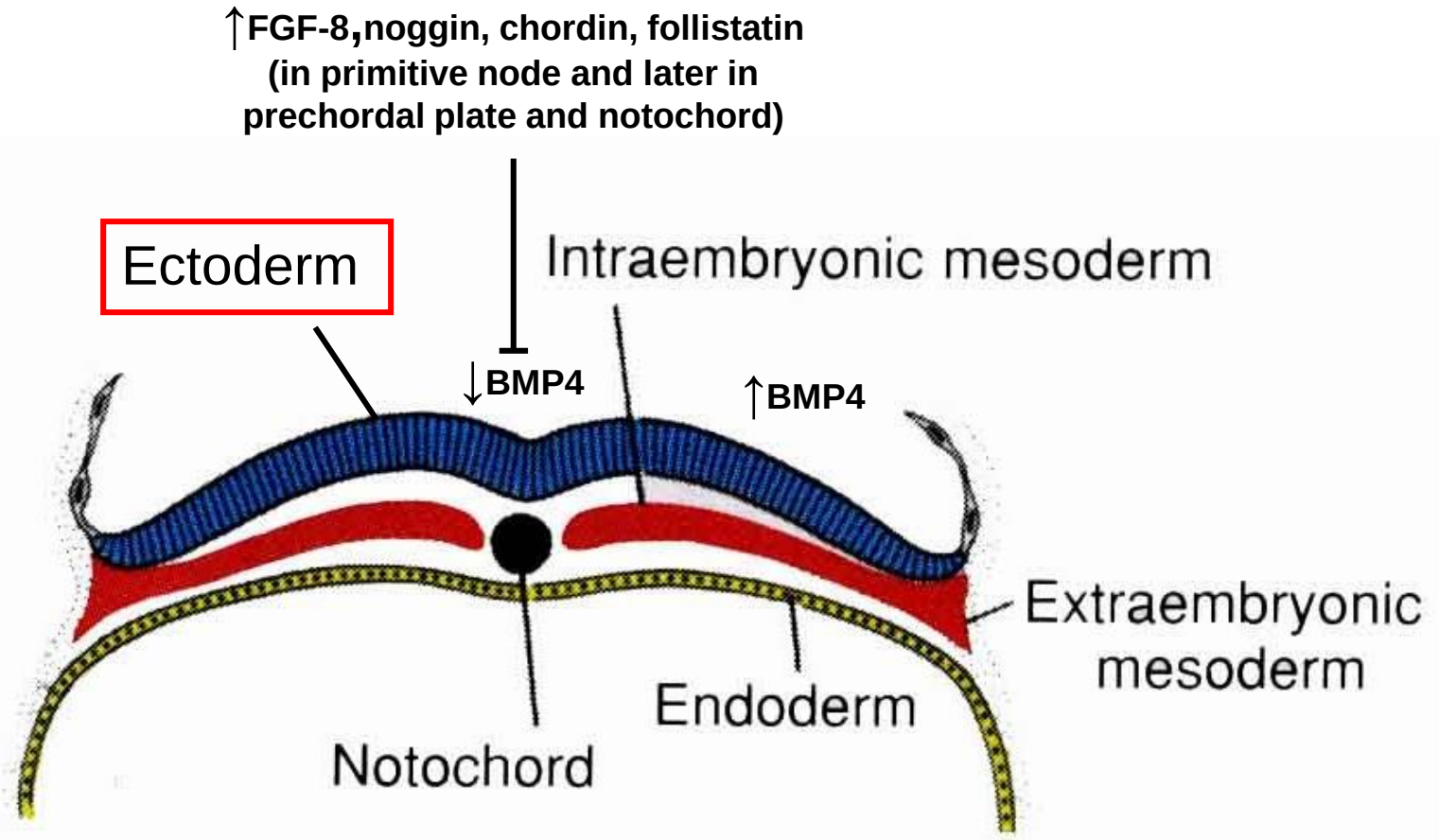
J 5–3, C9

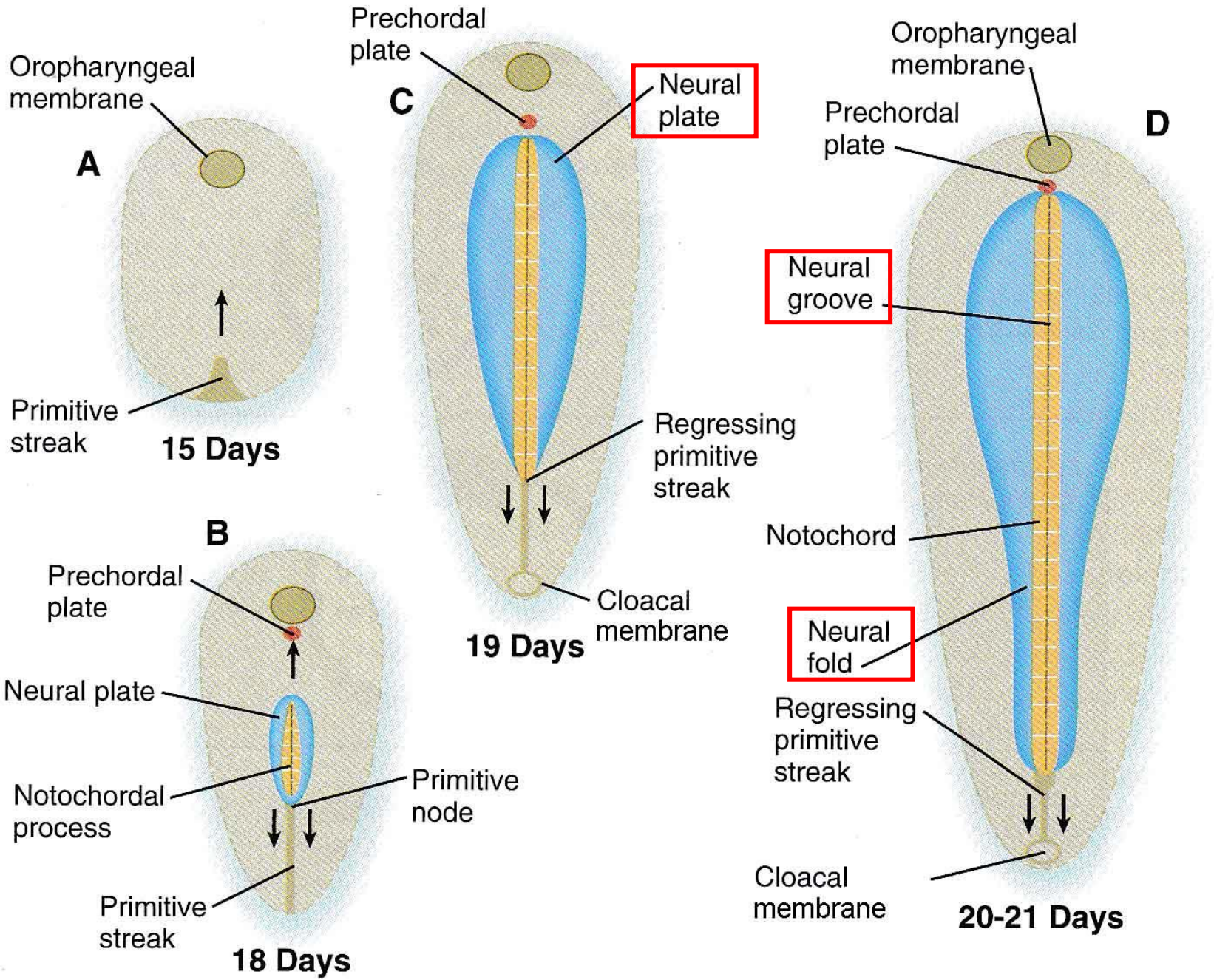
J 6–1, C9/10



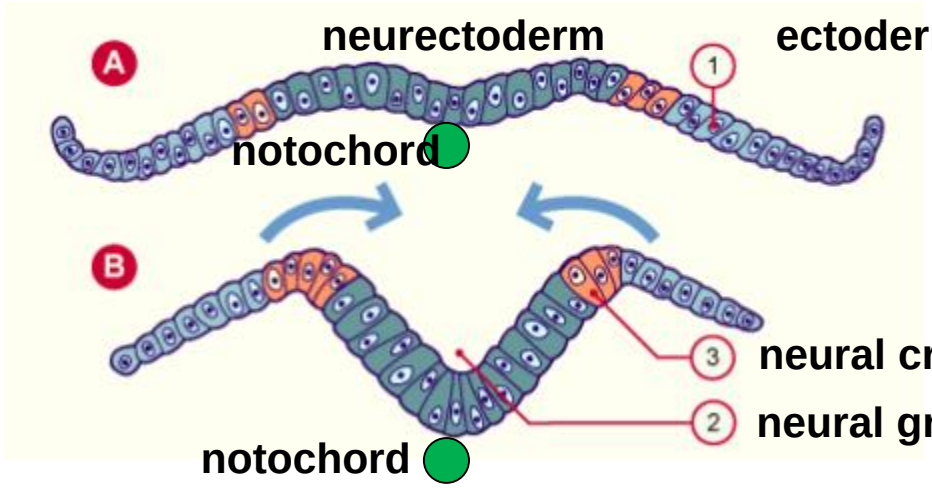

J 5–3, C9

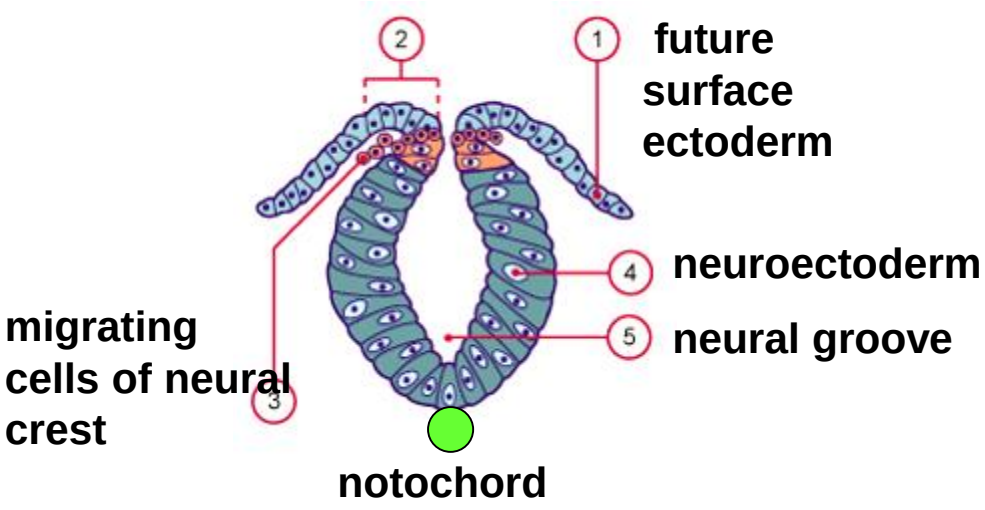
Neurulation

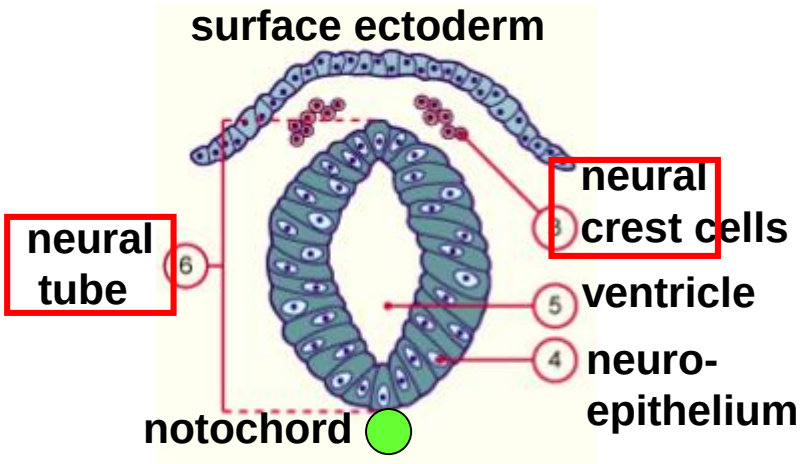


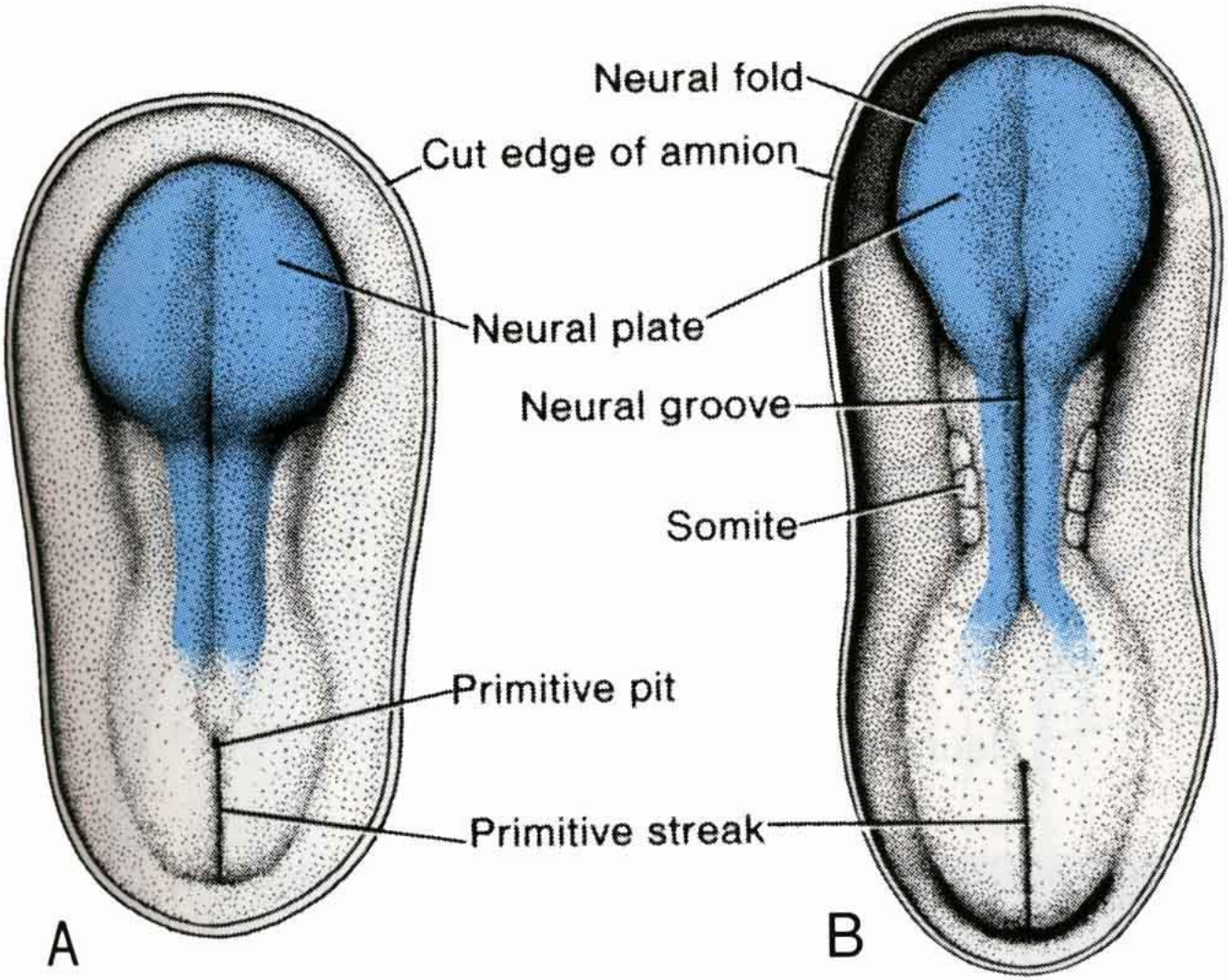


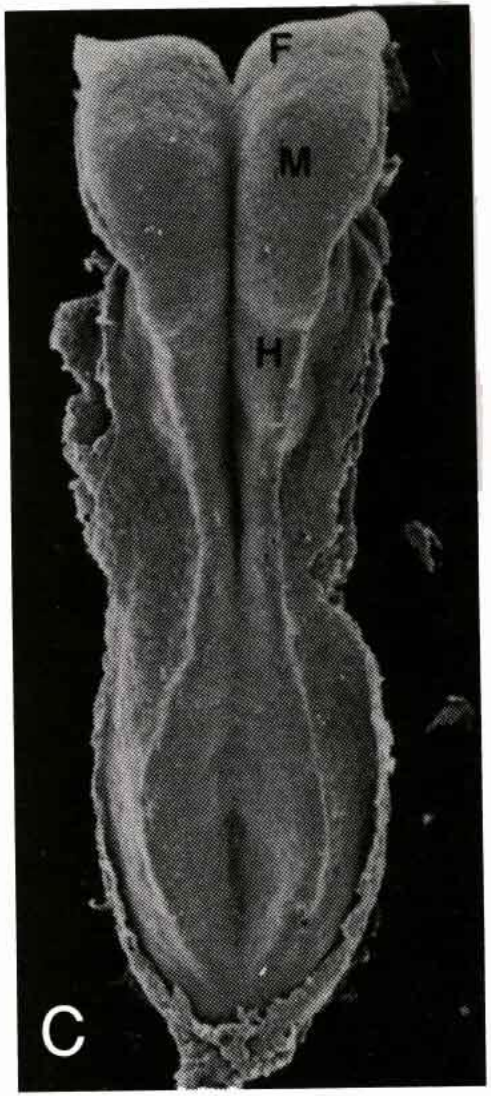
Carlson B.: Human Embryology and Developmental Biology, Elsevier 2014


A
neurectoderm
ectoderm
1
notochord
B
3
neural crest cells
2
neural groove
notochord


2
1
future surface ectoderm
4
neuroectoderm
5
neural groove
migrating cells of neural crest
3
notochord

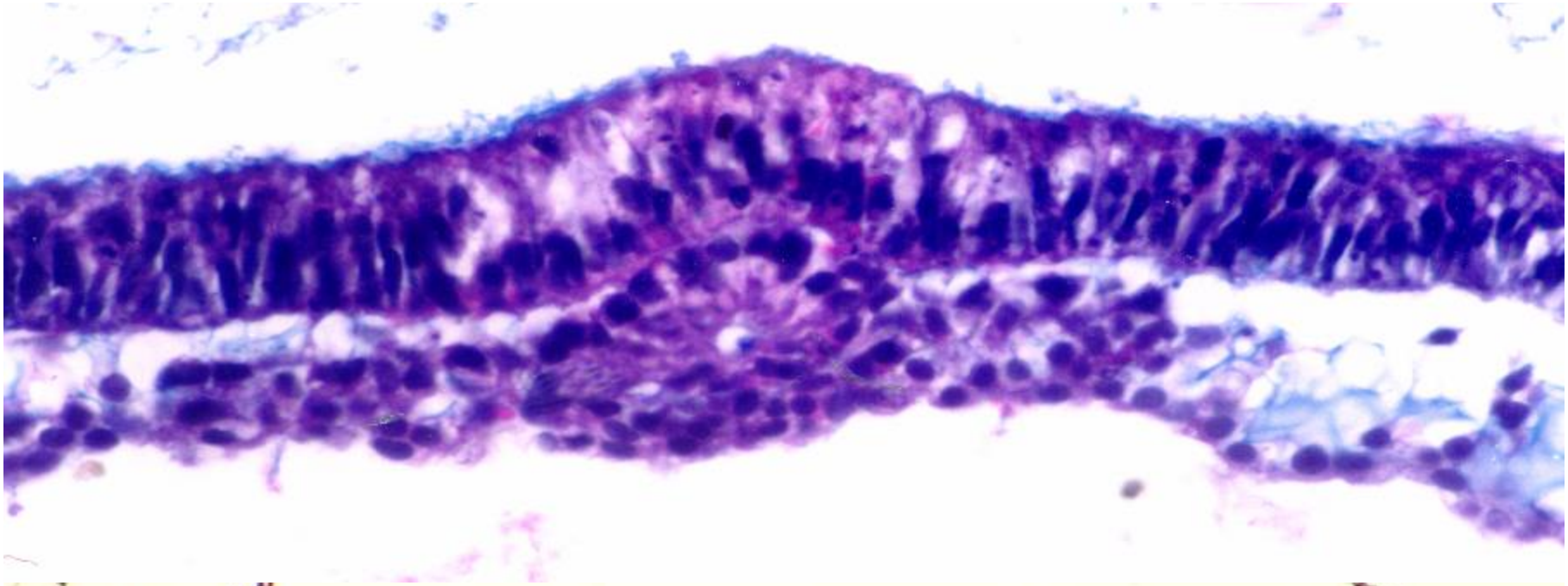

surface ectoderm
neural crest cells
neural tube
6
5
ventricle
4
neuro-epithelium
notochord

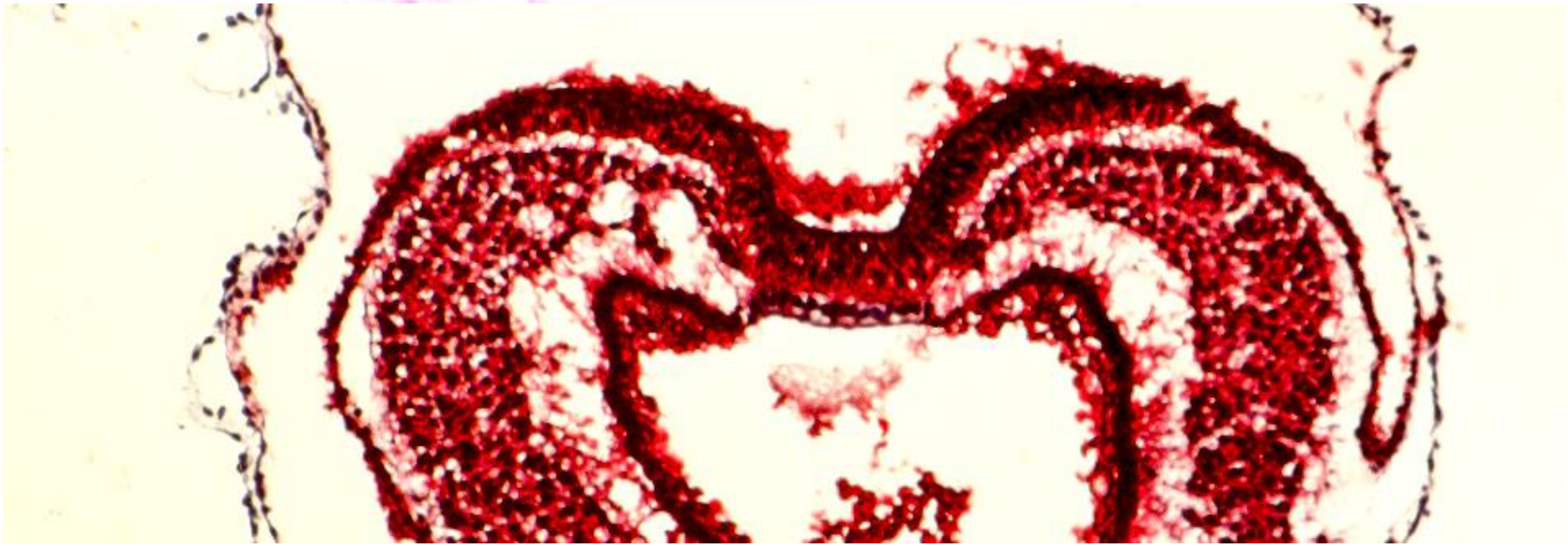




19th day

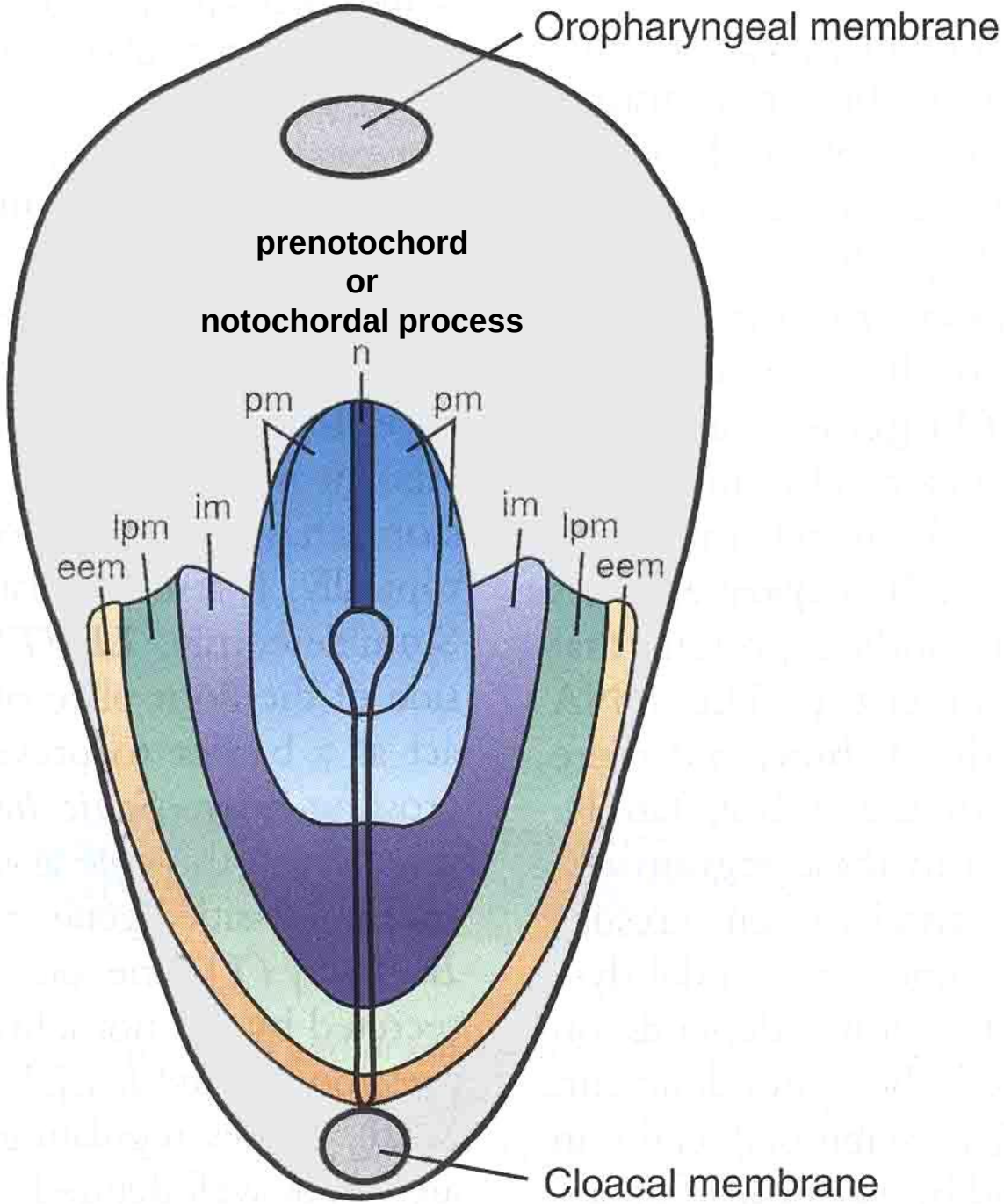
20th day

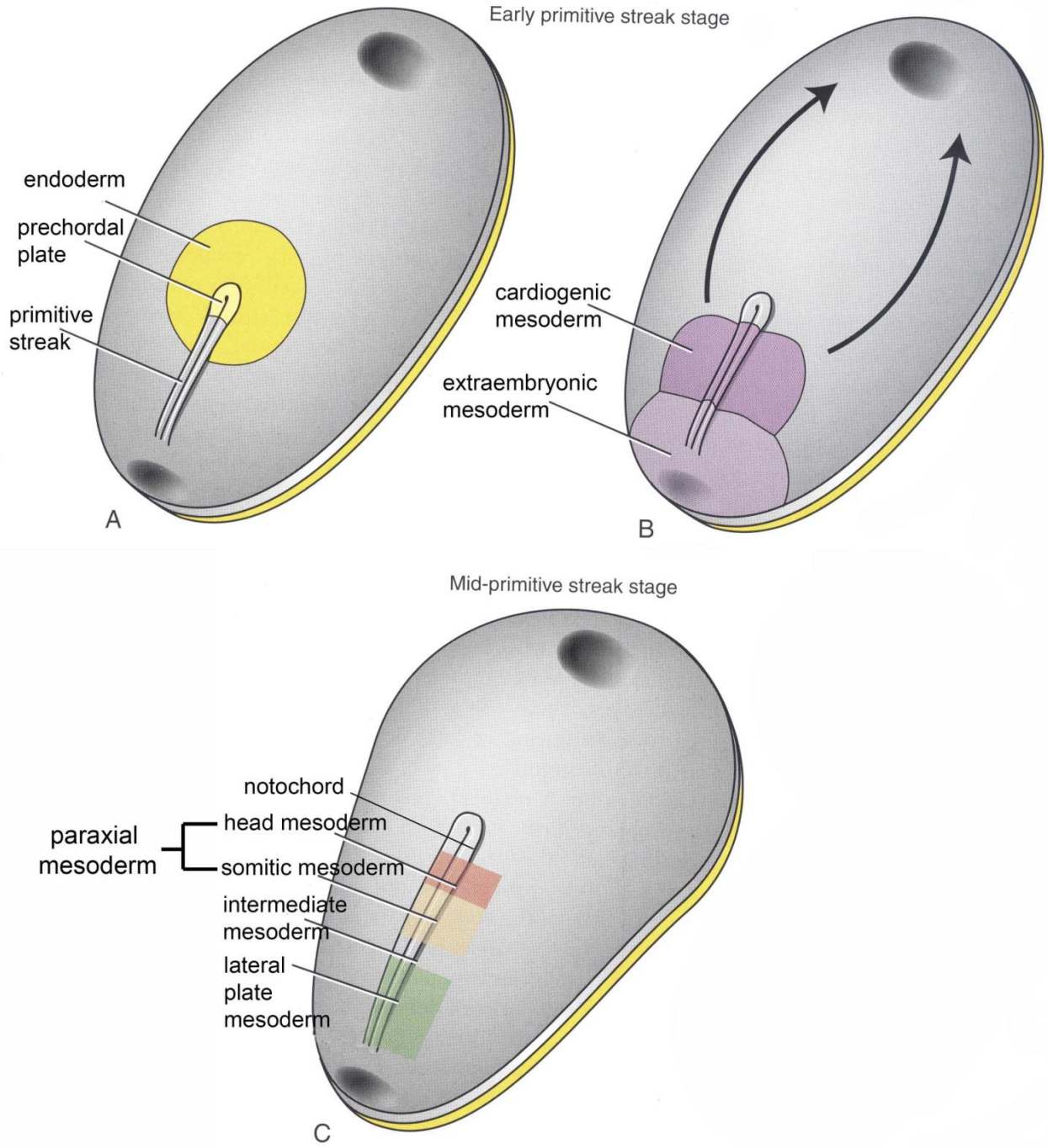


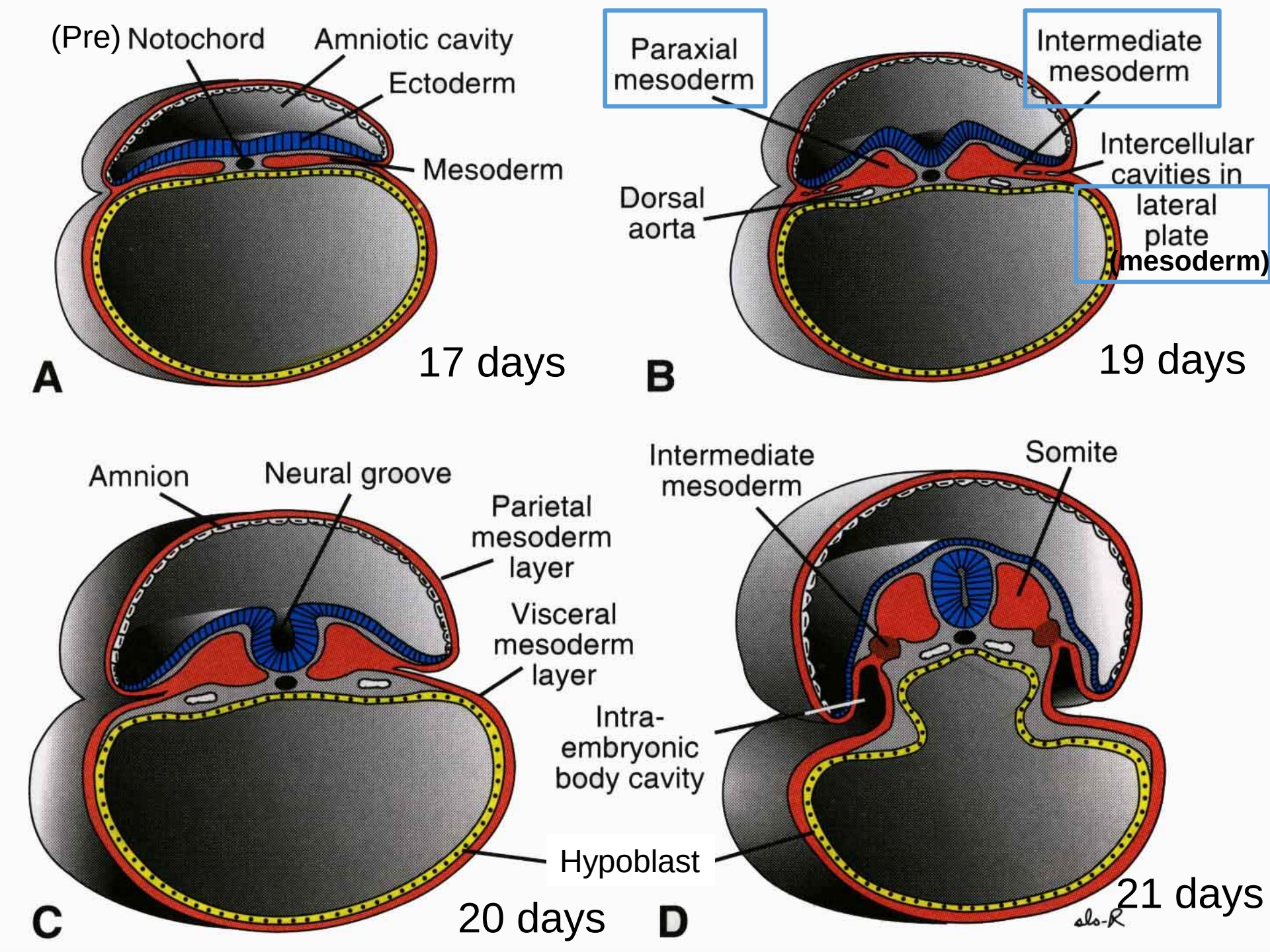


gastrulation

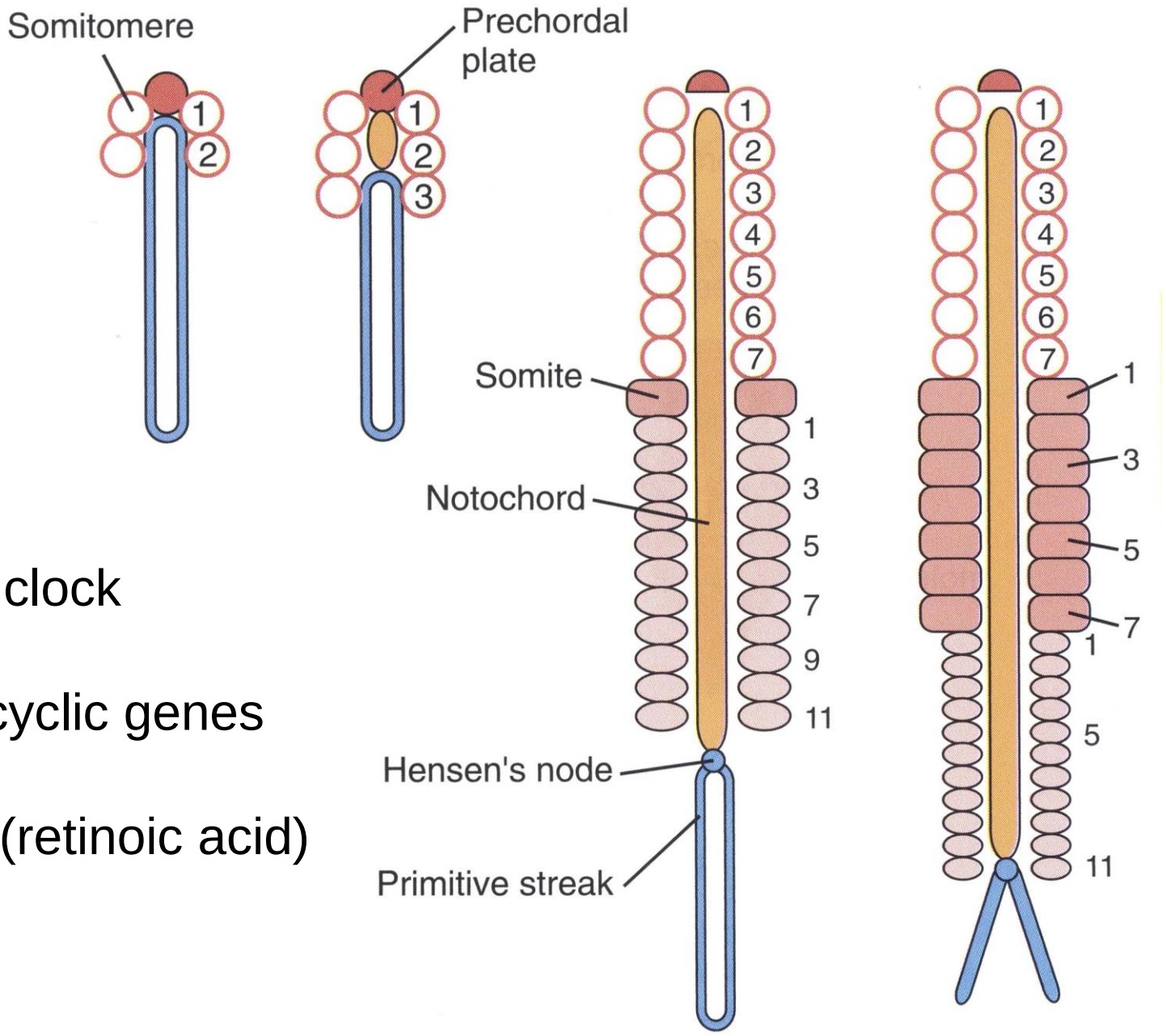
DIFFERENTIATION
OF THE INTRAEMBRYONIC MESODERM


Oropharyngeal membrane
prenotochord
or
notochordal process
n
pm
pm
im
im
lpm
lpm
eem
eem
Cloacal membrane


Early primitive streak stage
endoderm
prechordal plate
primitive streak
A
cardiogenic mesoderm
extraembryonic mesoderm
B
Mid-primitive streak stage
notochord
paraxial mesoderm
head mesoderm
somitic mesoderm
intermediate mesoderm
lateral plate mesoderm
C


(Pre) Notochord
Amniotic cavity
Ectoderm
Mesoderm
A
17 days
Paraxial mesoderm
Intermediate mesoderm
Intercellular cavities in lateral plate (mesoderm)
Dorsal aorta
B
19 days
Amnion
Neural groove
Parietal mesoderm layer
Visceral mesoderm layer
Intra-embryonic body cavity
Hypoblast
C
20 days
Intermediate mesoderm
Somite
D
21 days

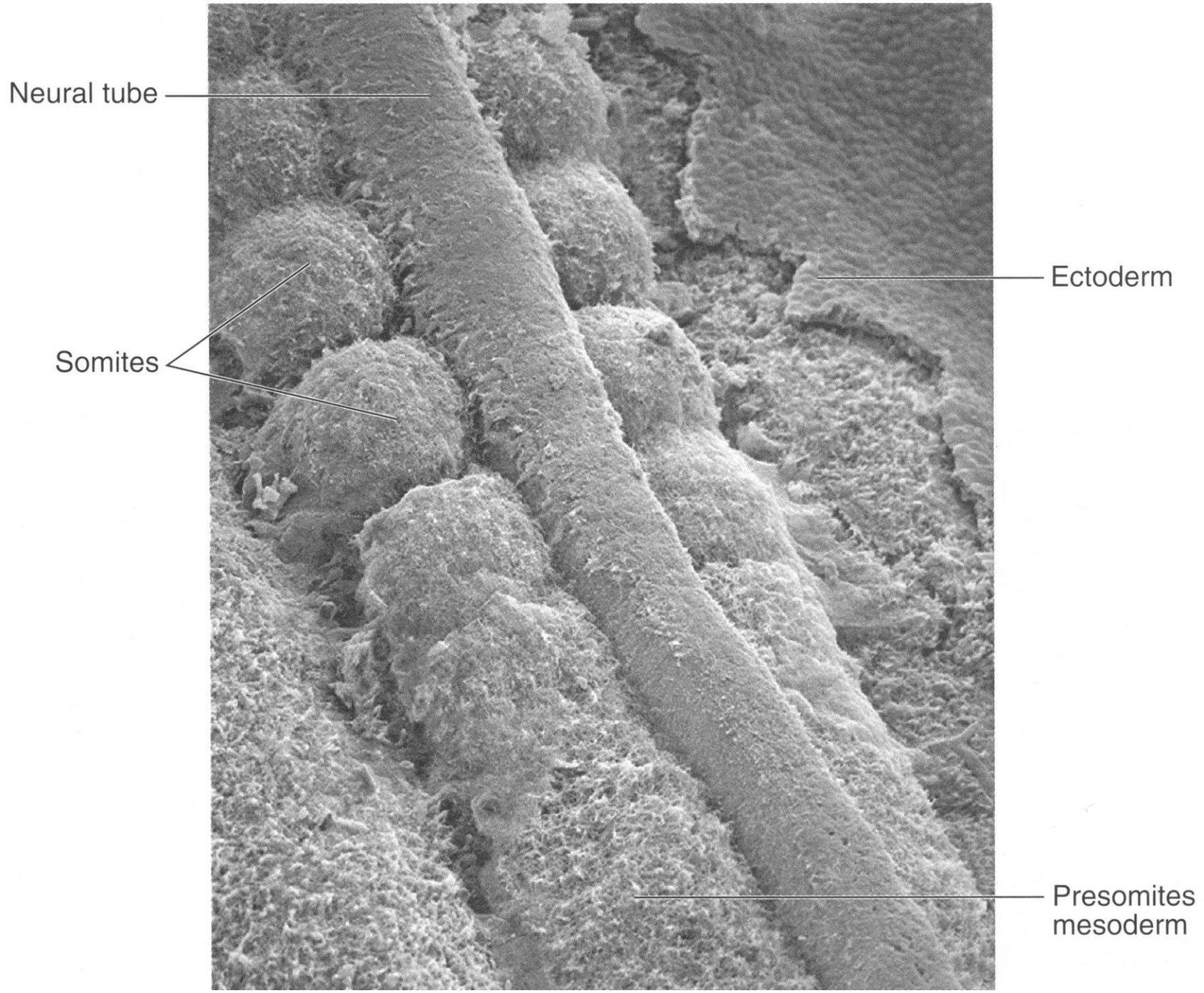
Paraxial mesoderm



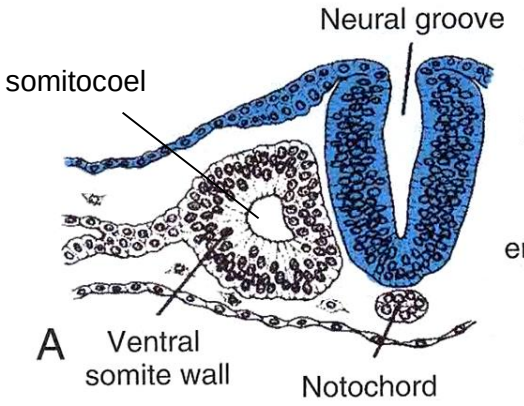
Segmentation clock

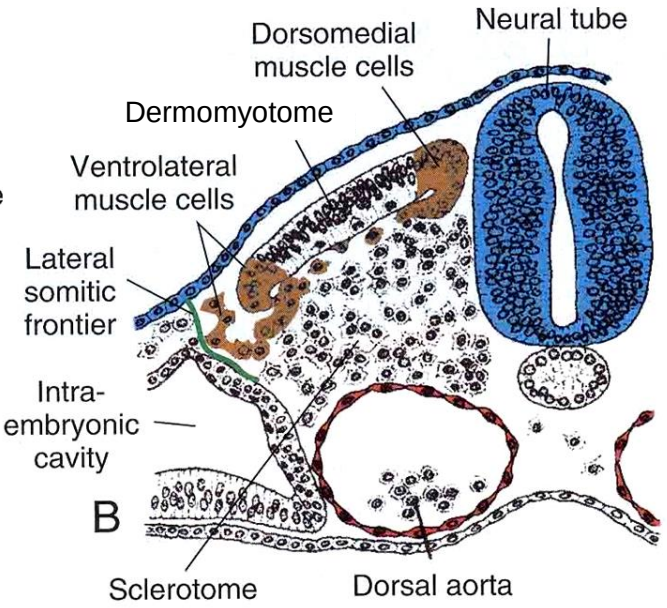
Wnt, Notch – cyclic genes

↓FGF8 ↑RA (retinoic acid)

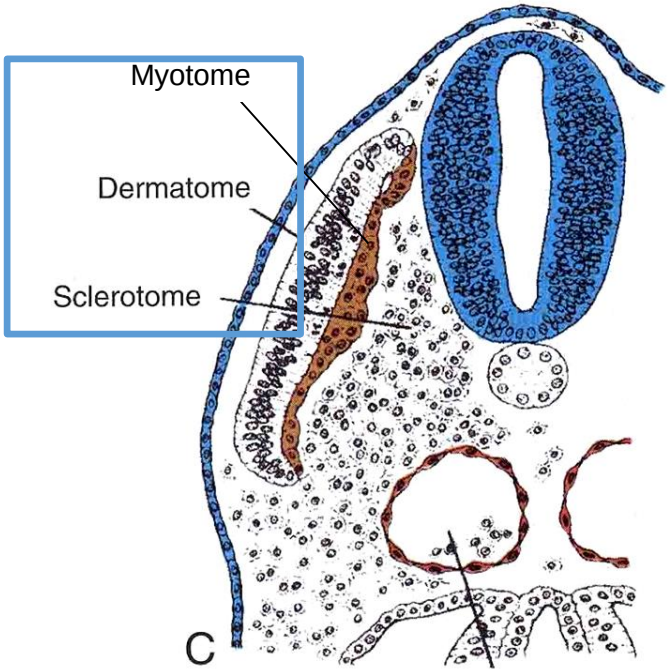

Neural tube
Somites
Ectoderm
Presomites
mesoderm

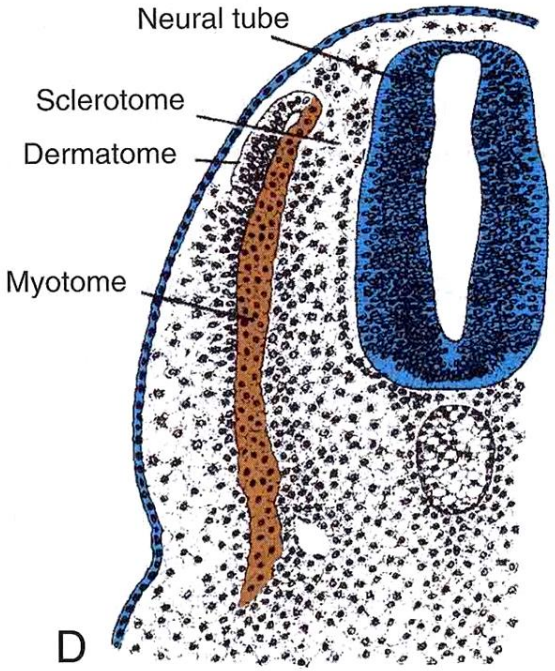
Somites



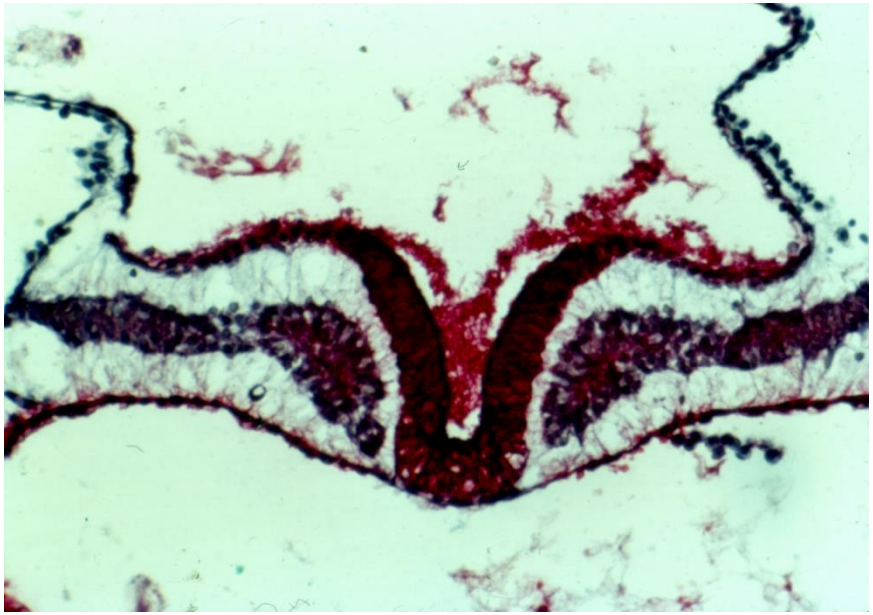


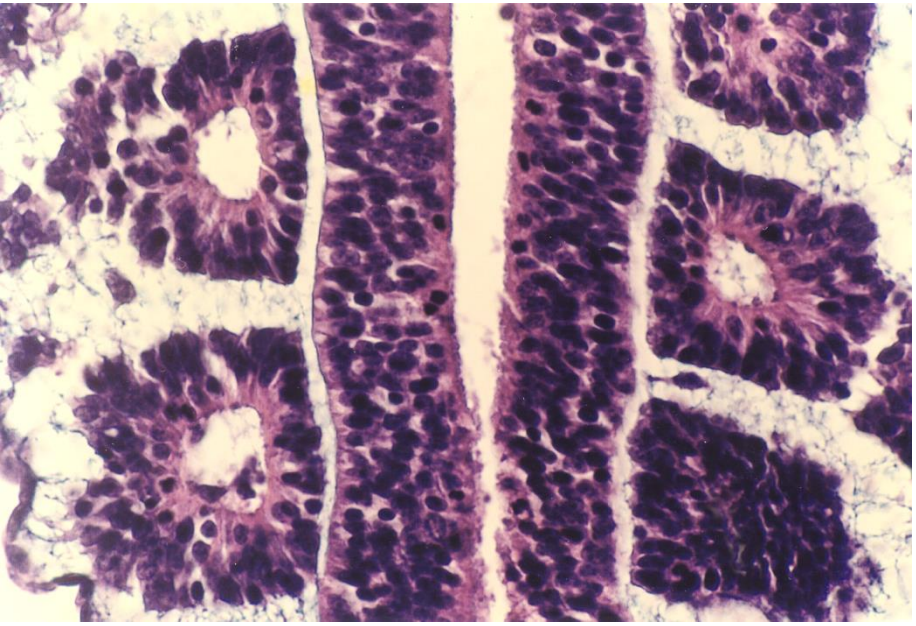
1st pair of somites on the day 20
till the end of the 5th week 42-44 somite pairs

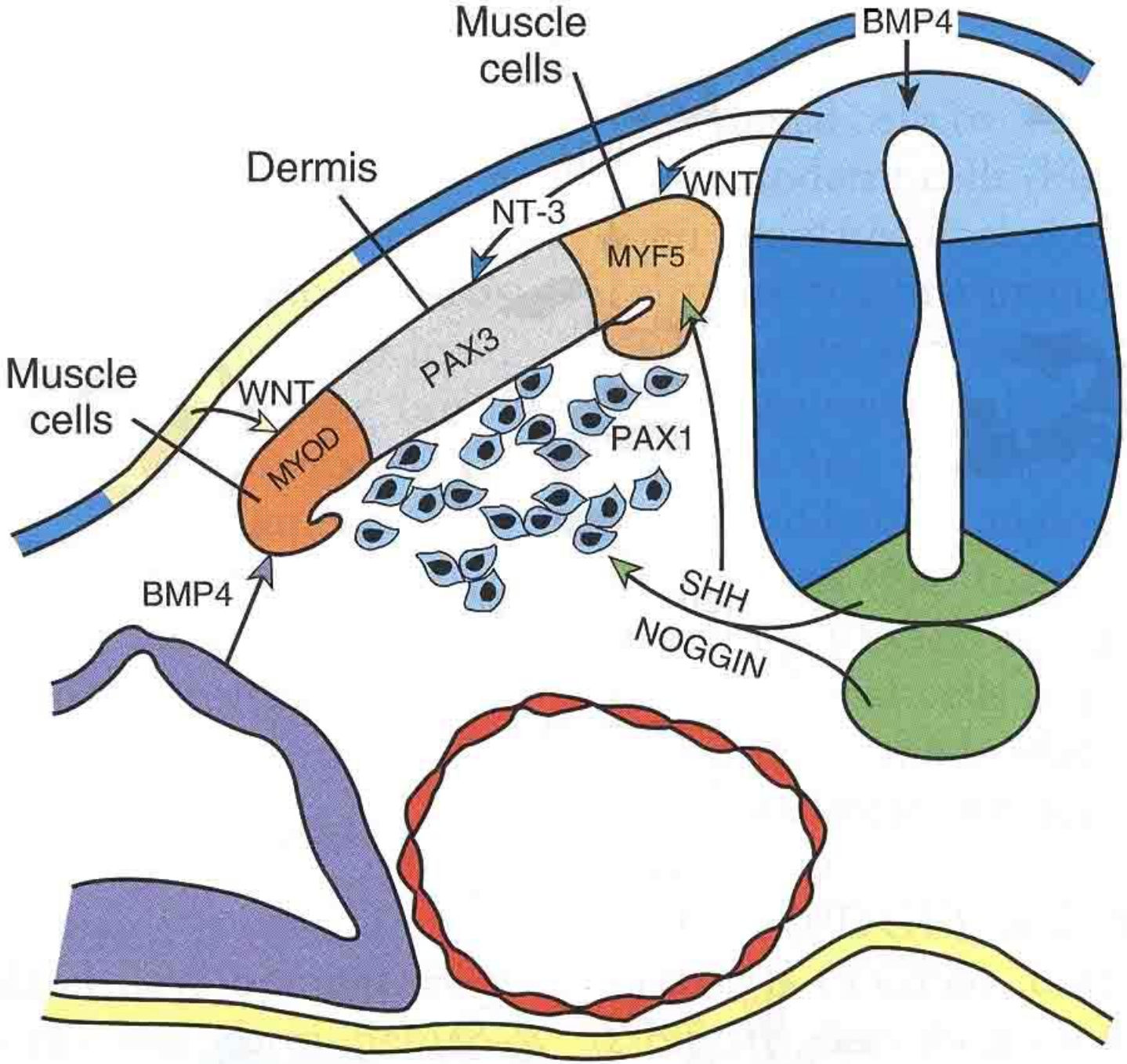




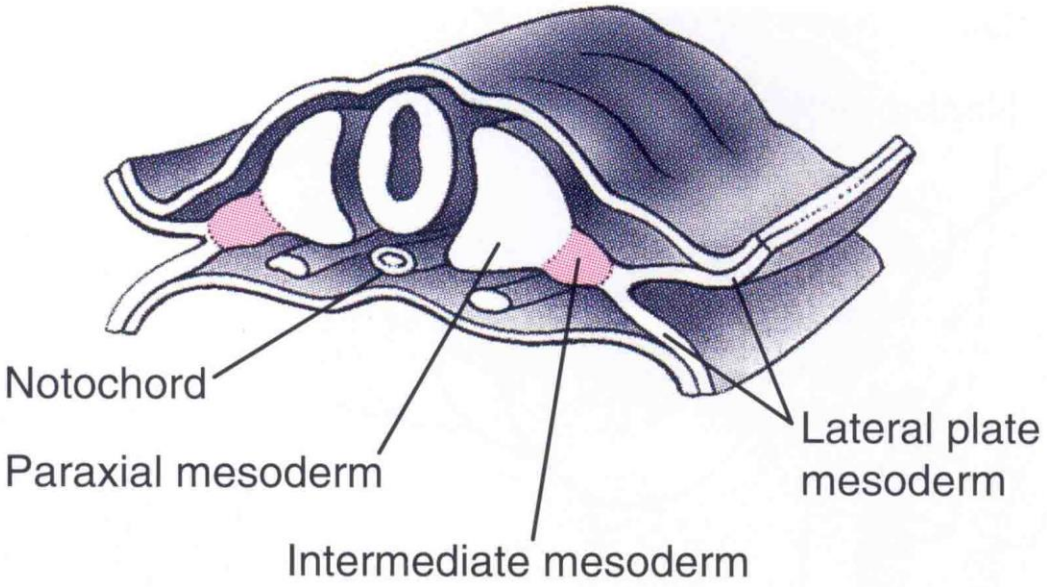
Somites

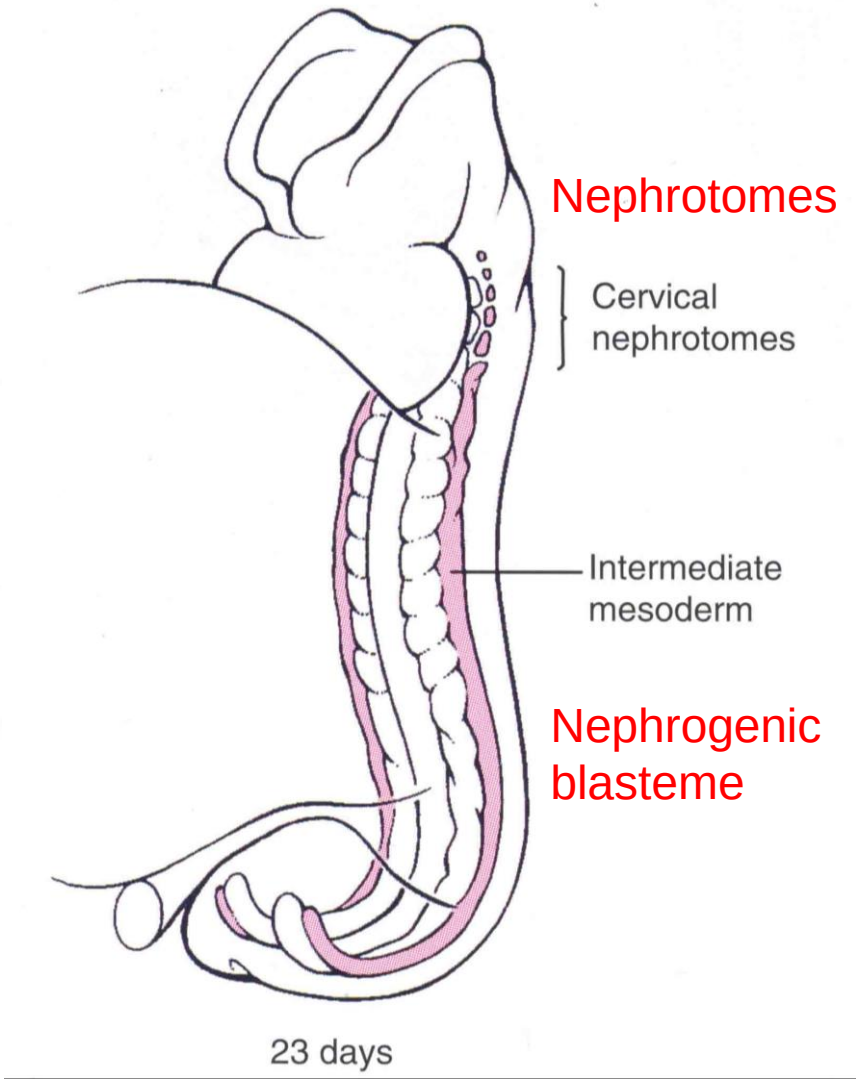




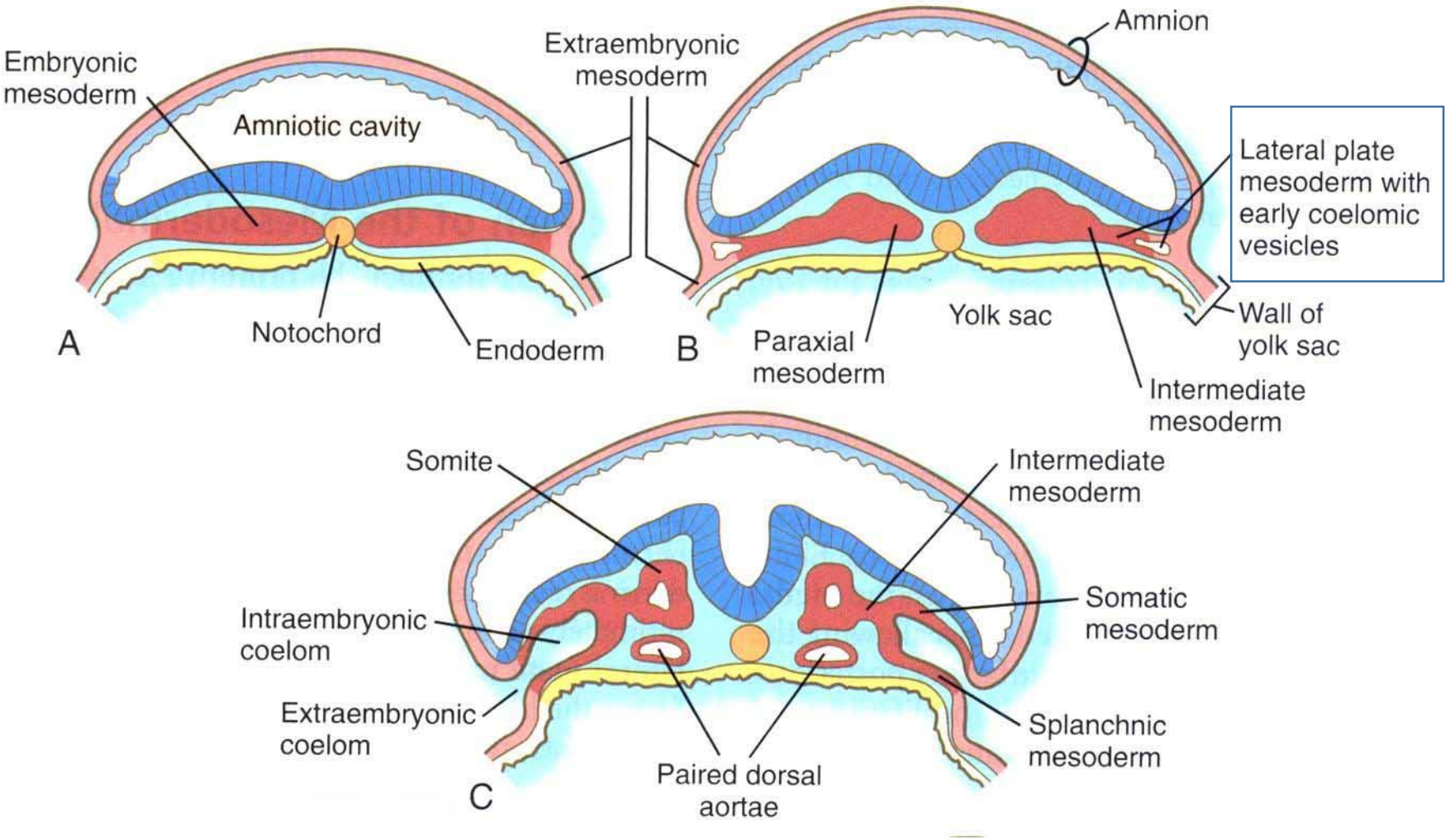

Muscle cells
BMP4
Dermis
WNT
NT-3
MYF5
PAX3
Muscle cells
WNT
MYOD
PAX1
BMP4
SHH
NOGGIN

Intermediate mesoderm





Mesoderm of the lateral plate



folding of the embryo