LECTURES 1, 2 and 3

Lecture 1 (40 minutes)

a. Introduction

b. Gametogenesis

c. Fertilization

d. Cleavage

Lecture 2 (40 minutes)

Gastrulation

Lecture 3 (40 minutes)

a. Neurulation

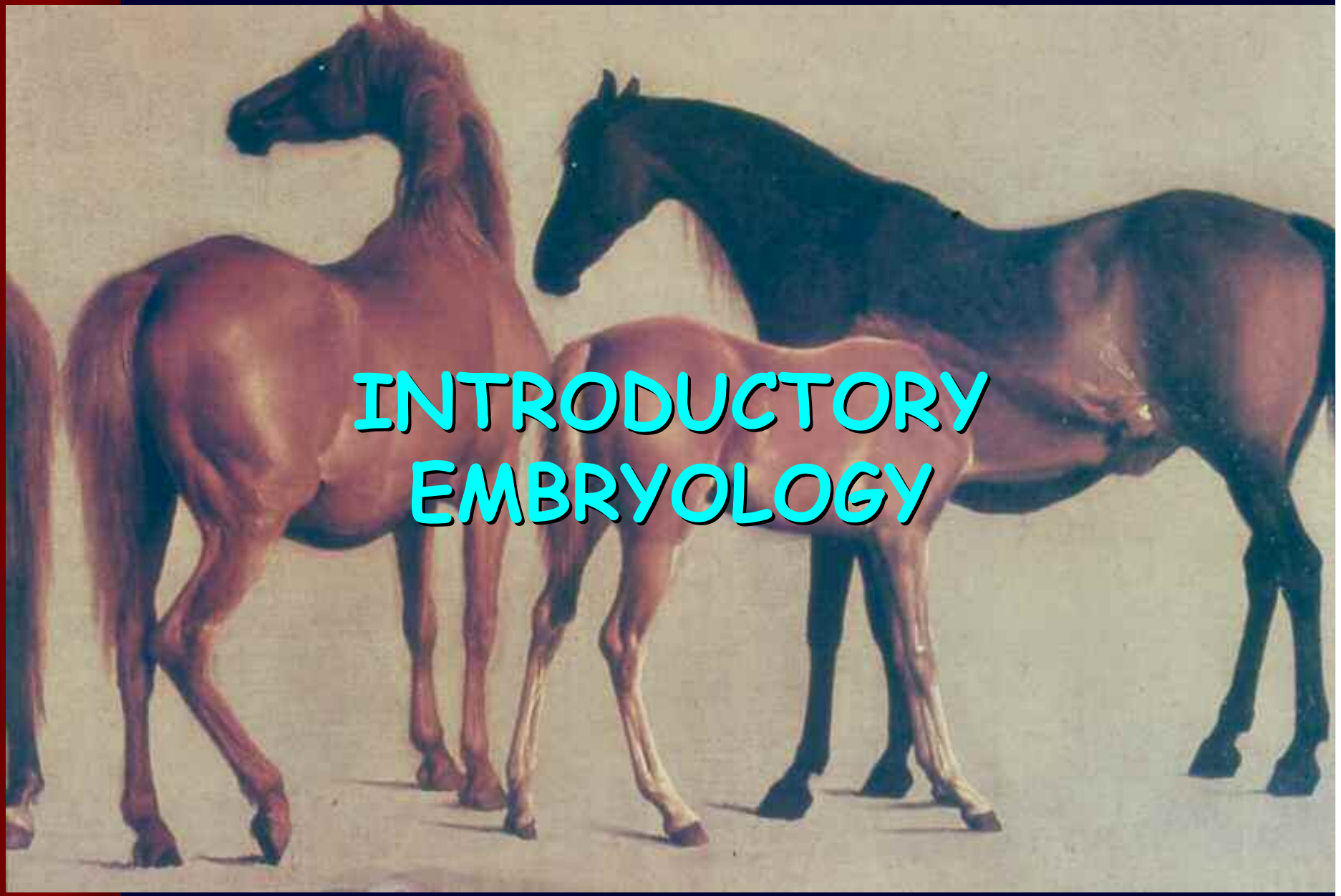
b. Mesodermal differentiation

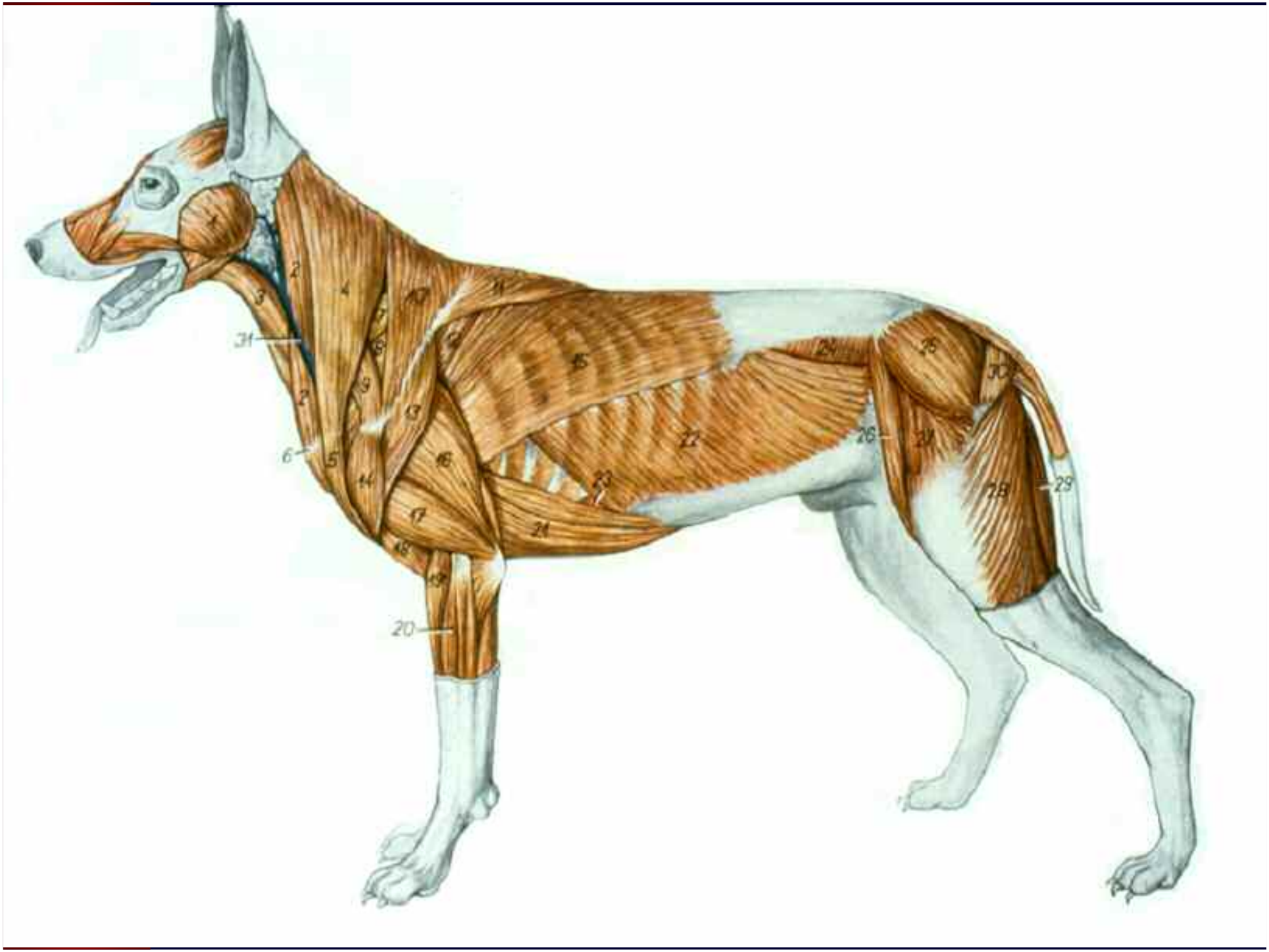
DE DO DO DO DE DA DA DA (THE POLICE - 1979)

DON'T THINK ME UNKIND
WORDS ARE HARD TO FIND
THEY'RE ONLY CHEQUES I'VE LEFT UNSIGNED
FROM THE BANKS OF CHAOS IN MY MIND
AND WHEN THEIR ELEQUENCE ESCAPES ME
THEIR LOGIC TIES ME UP AND RAPES ME

DE DO DO DO DE DA DA DA
IS ALL I WANT TO SAY TO YOU
DE DO DO DO DE DA DA DA
THEIR INNOCENCE WILL PULL ME THROUGH
DE DO DO DO DE DA DA DA
IS ALL I WANT TO SAY TO YOU
DE DO DO DO DE DA DA DA
THEY'RE MEANINGLESS AND ALL THAT'S TRUE

POETS, PRIESTS AND POLITICIANS
HAVE WORDS TO THANK FOR THEIR POSITIONS
WORDS THAT SCREAM FOR YOUR SUBMISSION
AND NO-ONE'S JAMMING THEIR TRANSMISSION
'COS WHEN THEIR ELOQUENCE ESCAPES YOU
THEIR LOGIC TIES YOU UP AND RAPES YOU


INTRODUCTORY
EMBRYOLOGY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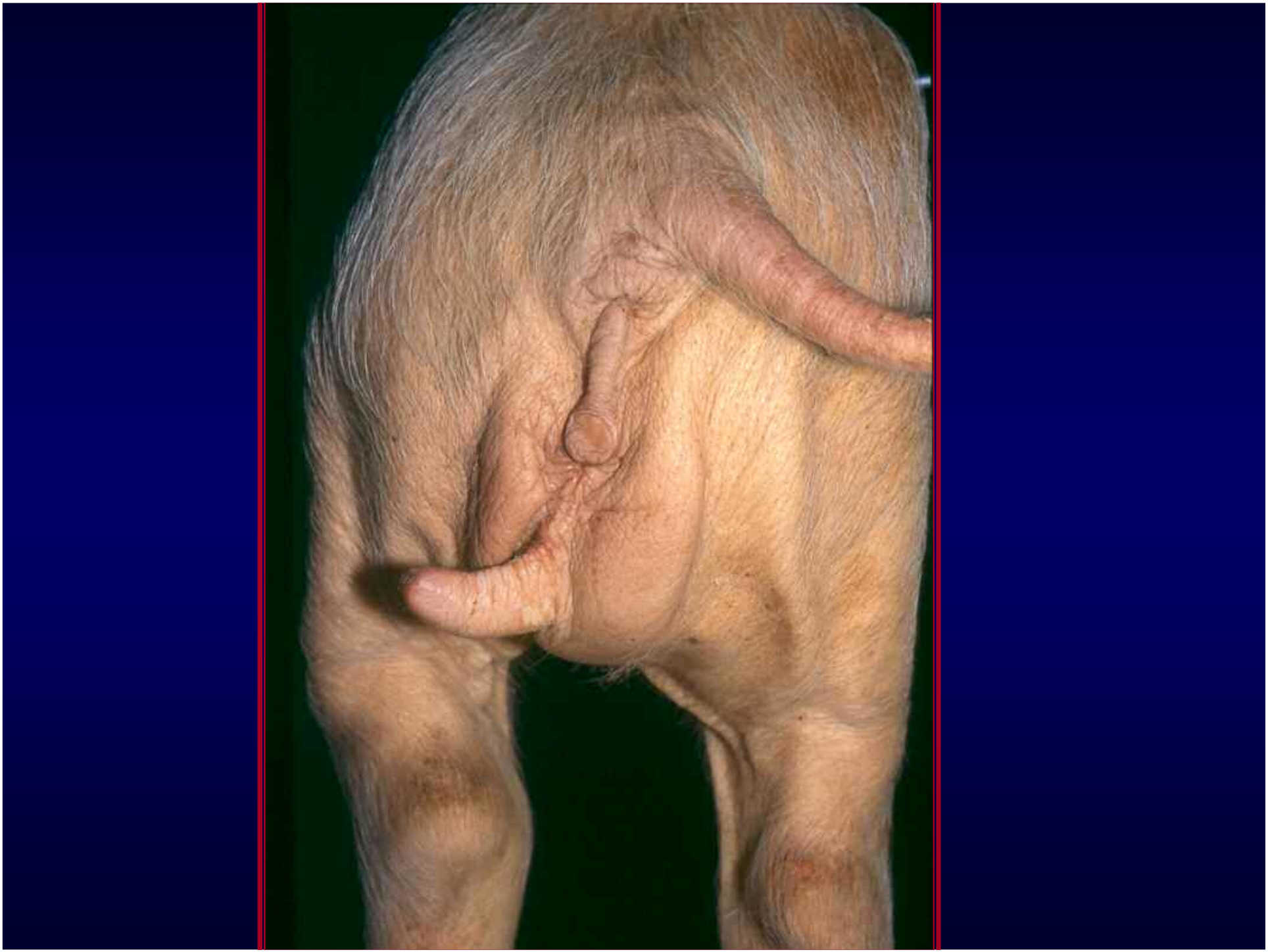


Gerneke, W.H. (1982) Veeartsenykundige Embriologie. Published and distributed by the author.

Noden, D.M. and De Lahunta, A. (1985) The Embryology of Domestic Animals. Williams and Wilkins, Baltimore.

Latshaw, W.K. (1987) Veterinary Developmental Anatomy. B.C. Decker Inc., Toronto.

Medical Embryology Texts eg.

Sadler, T.W. (1990) Langman's Medical Embryology, 6th Edition, Williams and Wilkins, Baltimore.

The process of development which an individual undergoes, from fertilization to death, is an uninterrupted, correlated series of changes referred to as its ontogenetic development or ontogeny.

- **Prenatal period**
- **Postnatal period**

Embryology confined to study of Prenatal Development

Pre-embryonic Phase

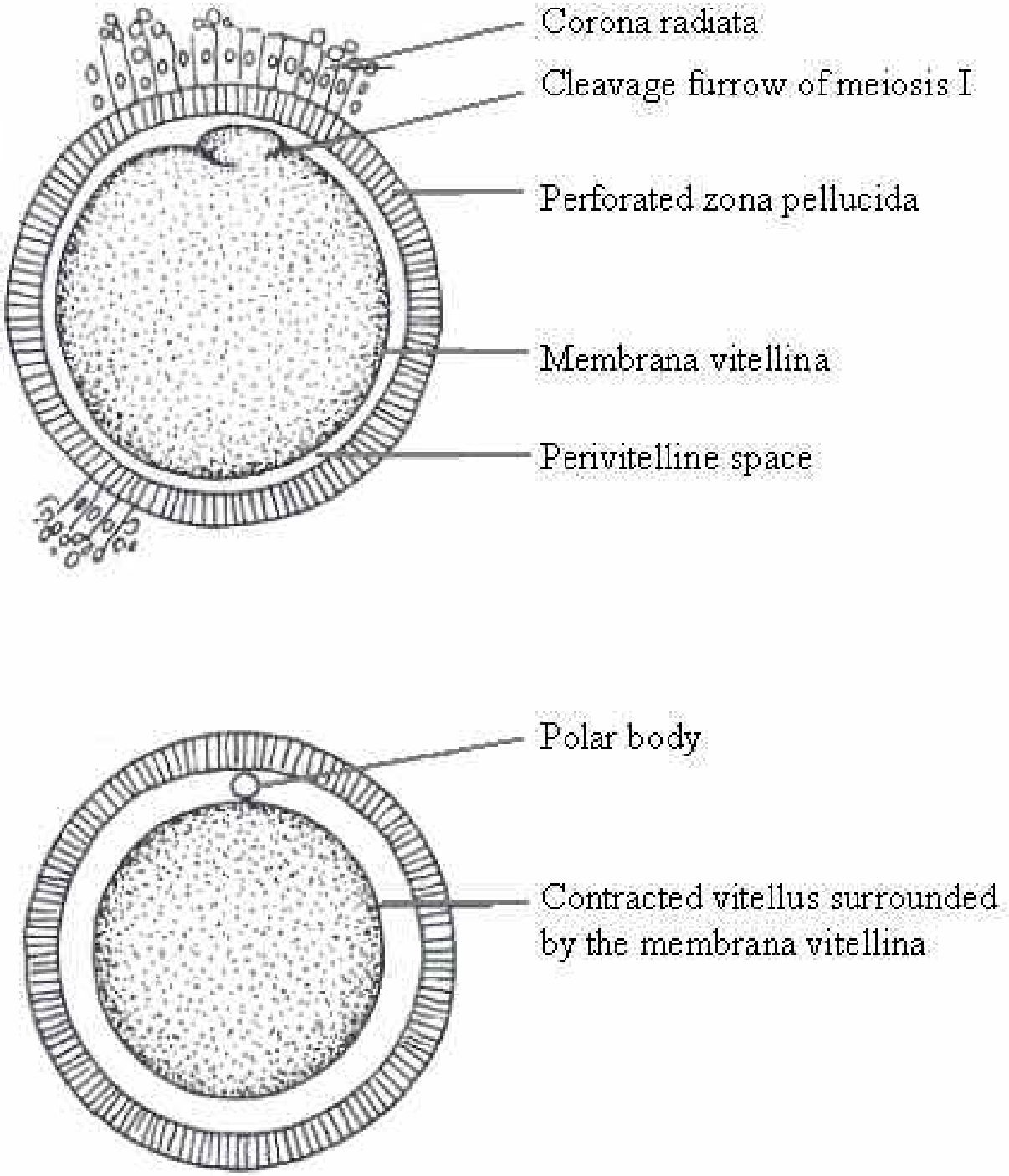
Embryonic Phase

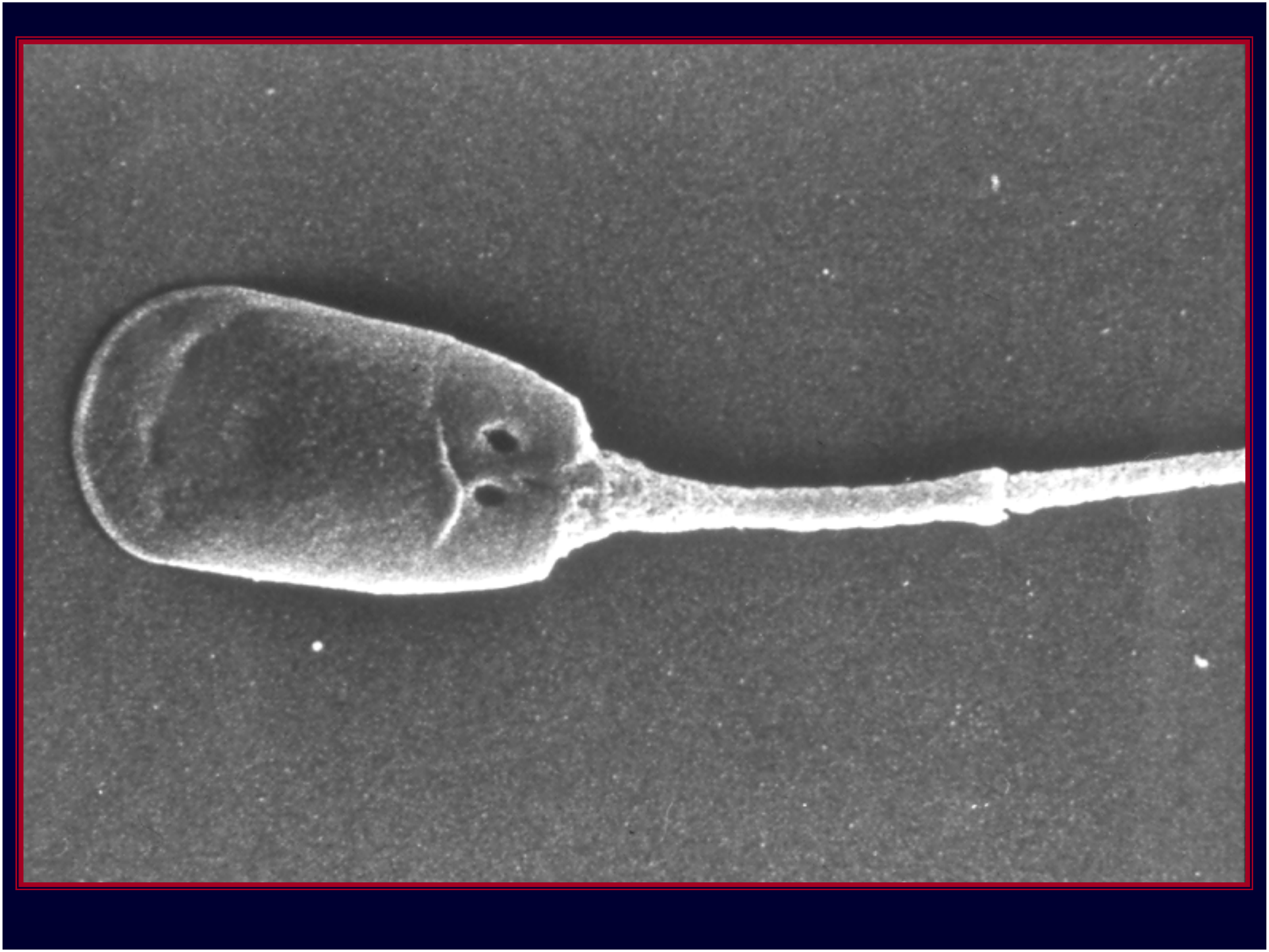
Fetal Phase

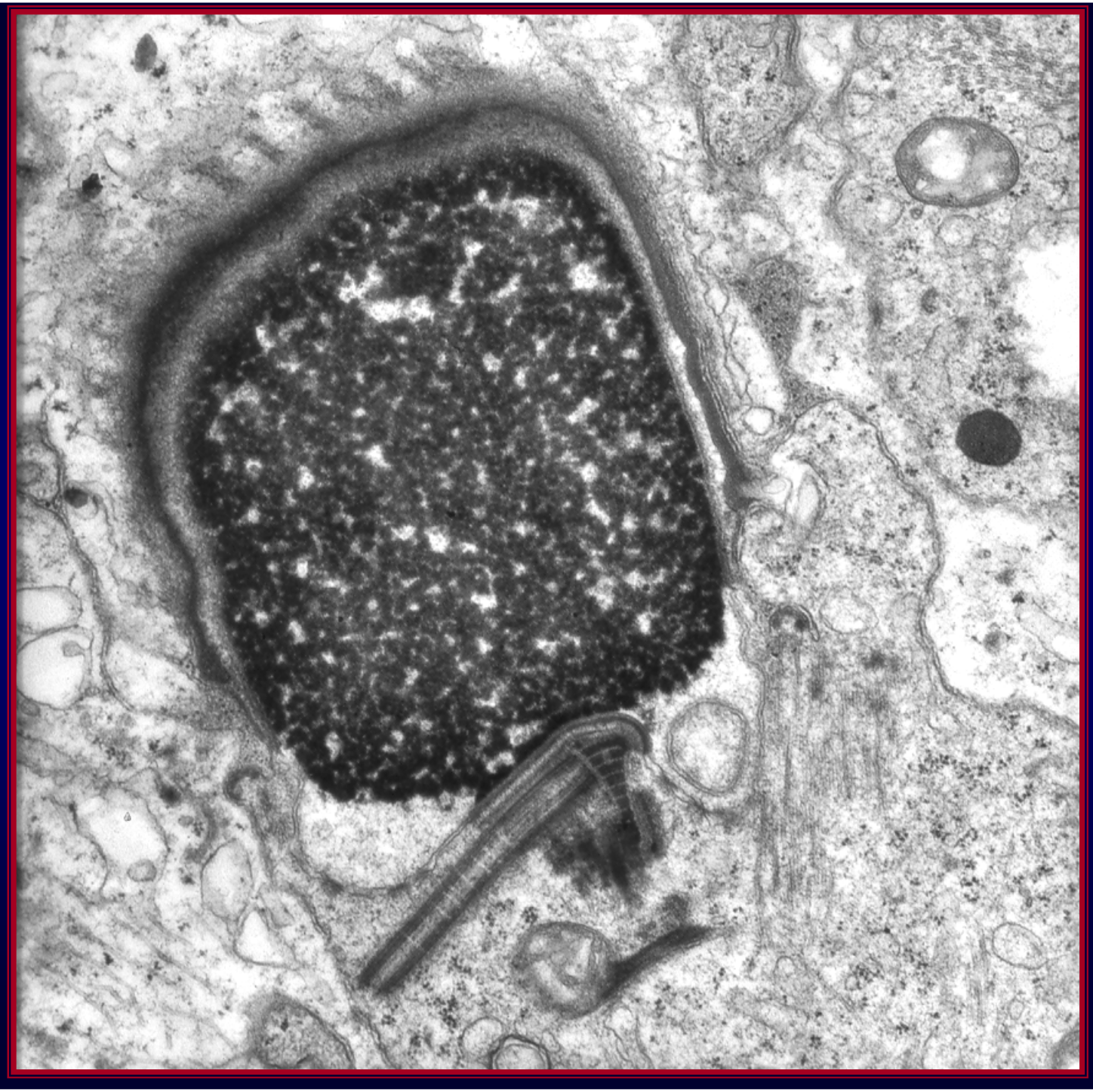
Pre-embryonic Phase

Study of Gametogenesis

Formation and Morphology of the male (sperm) and female (ovum) gametes


Corona radiata
Cleavage furrow of meiosis I
Perforated zona pellucida
Membrana vitellina
Perivitelline space
Polar body
Contracted vitellus surrounded by the membrana vitellina





Embryonic Phase (Four Stages)

A. Fertilization

B. Cleavage

C. Gastrulation

D. Development of Body Form

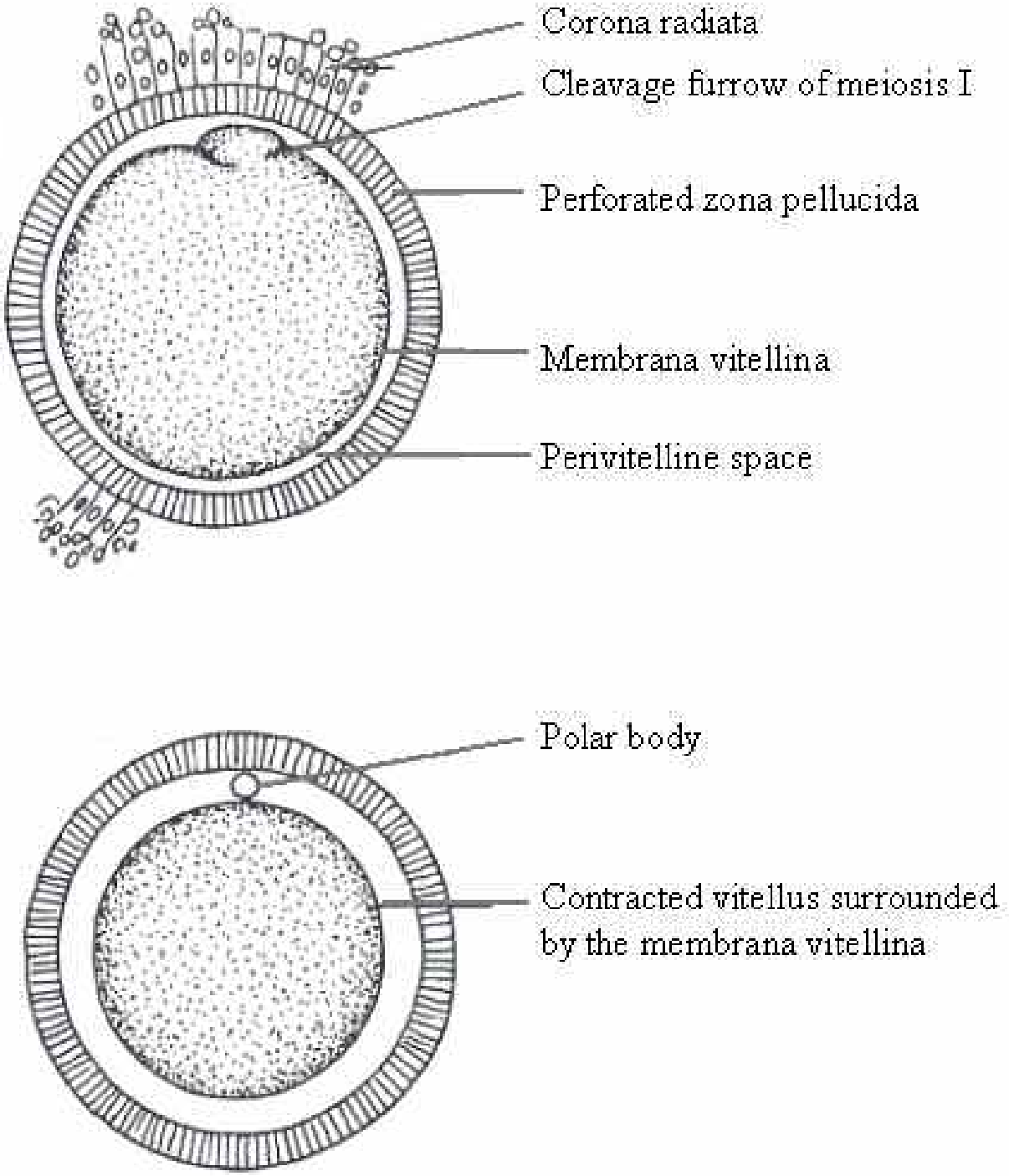
(Embryonic phase ends when organ primordia appear)

A. FERTILIZATION

At ovulation the ovum is surrounded by a *Zona pellucida* and the *Corona radiata*

- **Carnivores - ovulated ovum is a primary ovocyte**
- **Ungulates - ovulated ovum is a secondary ovocyte**

The fertilized ovum is known as a zygote


Corona radiata
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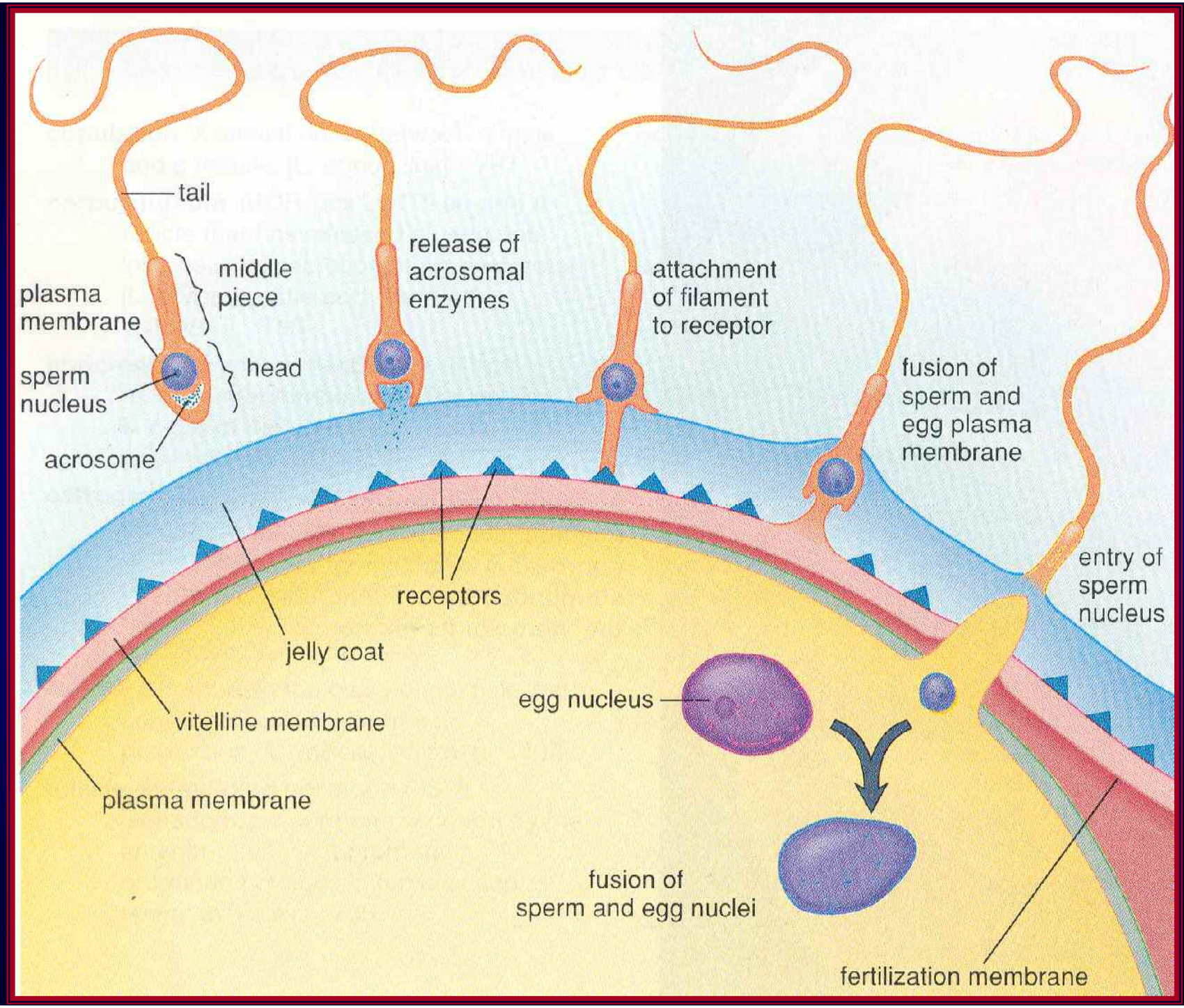
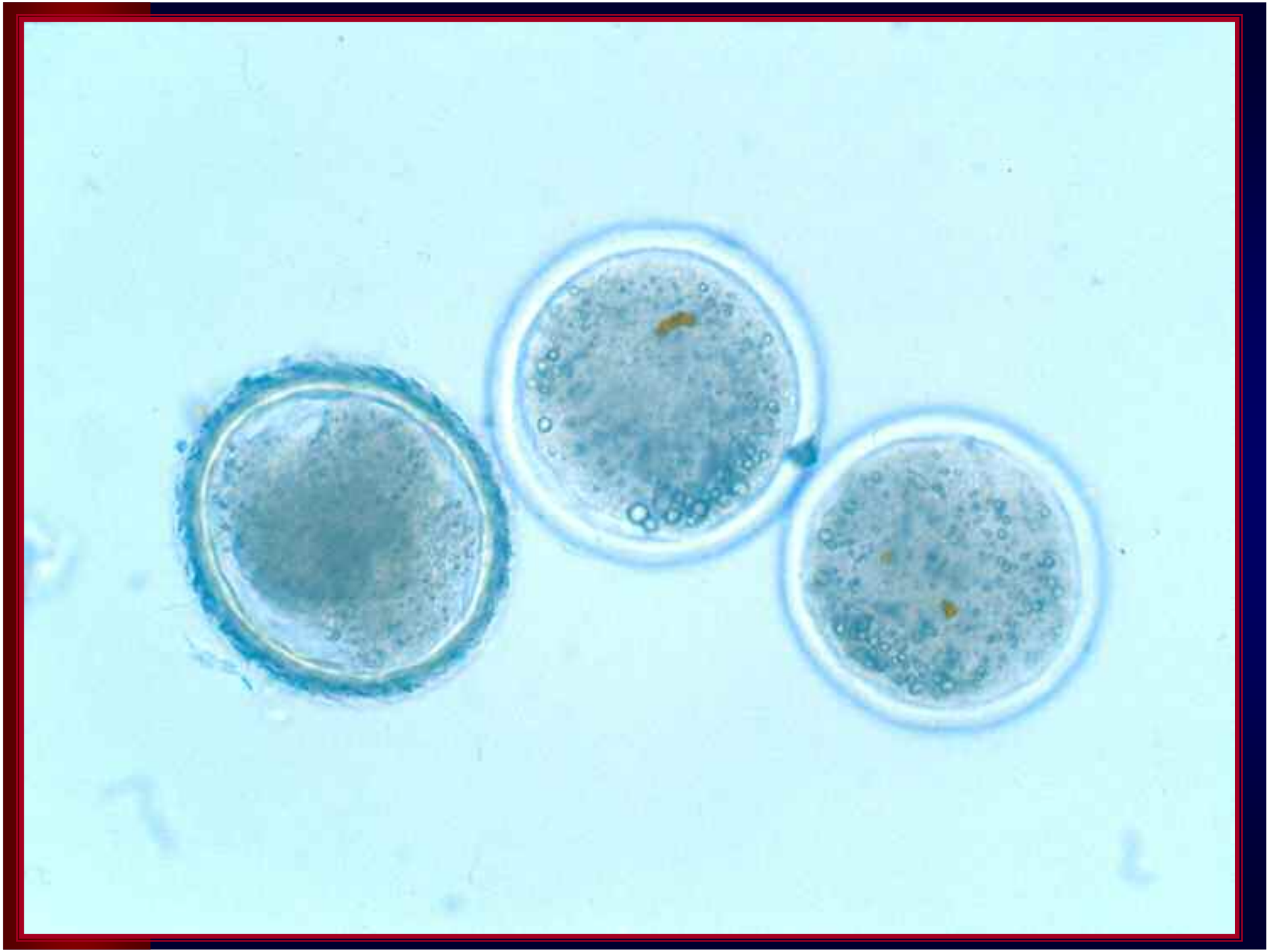
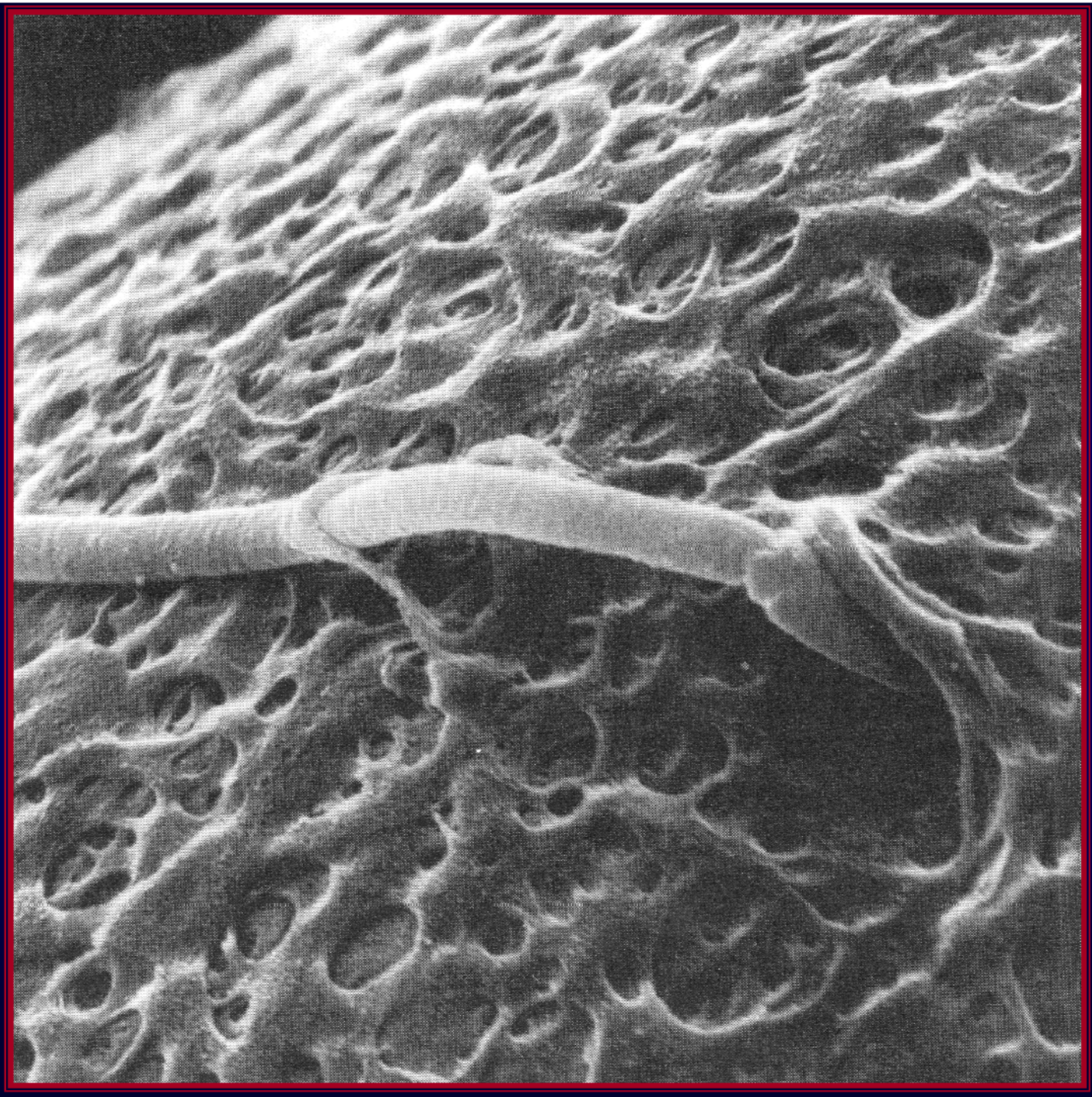
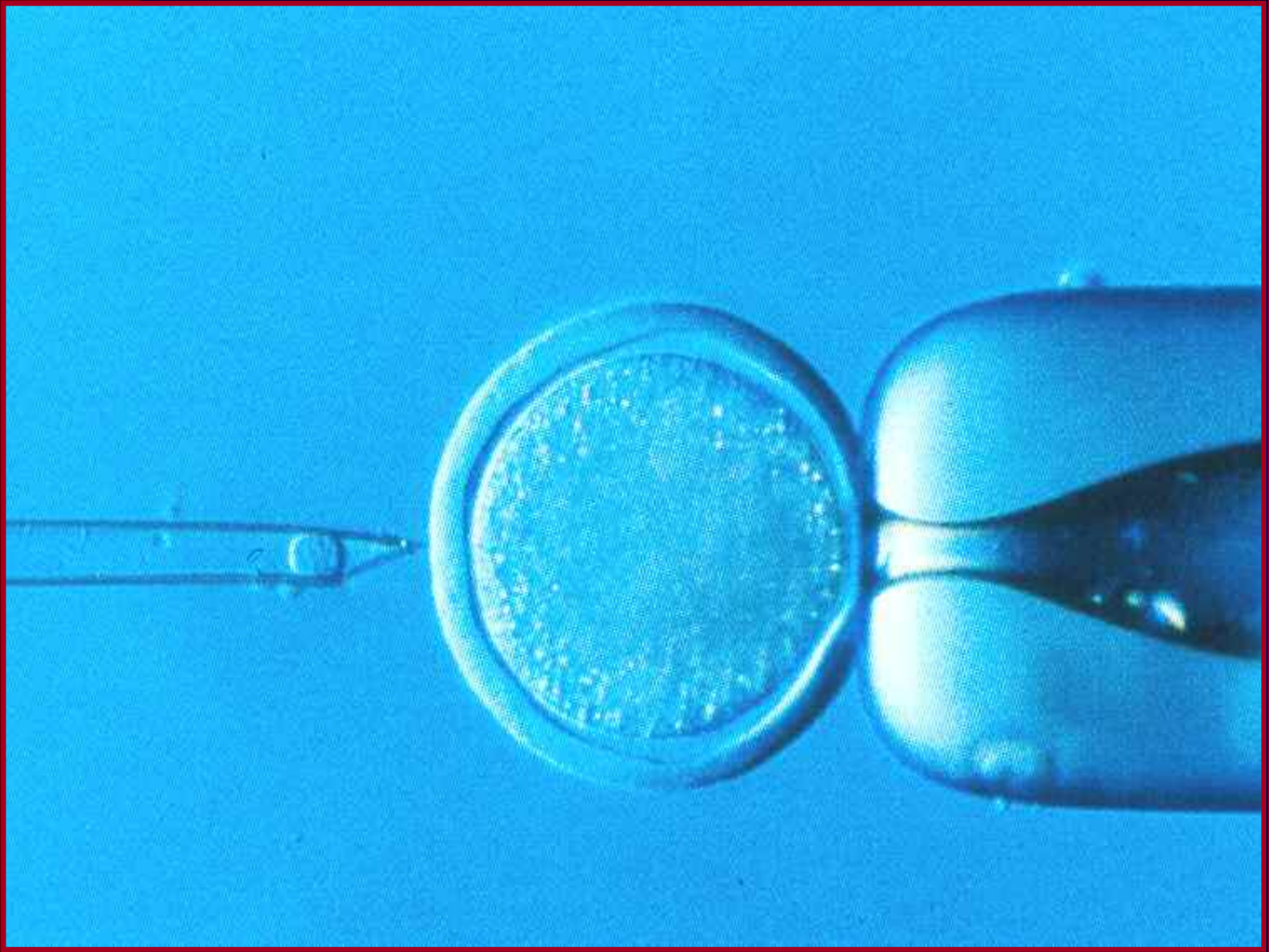

tail
middle piece
plasma membrane
head
sperm nucleus
acrosome
release of acrosomal enzymes
attachment of filament to receptor
fusion of sperm and egg plasma membrane
entry of sperm nucleus
receptors
jelly coat
vitelline membrane
plasma membrane
egg nucleus
fusion of sperm and egg nuclei
fertilization membrane



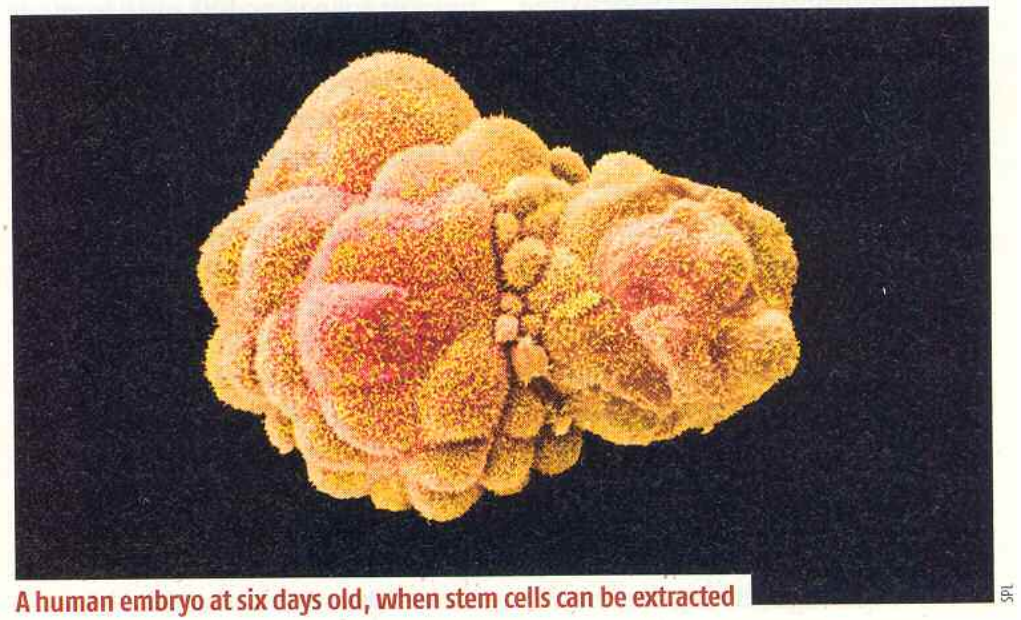




STEM CELLS

Virgin birth method could found stem cell dynasties

New Scientist – 26 April 2003



A human embryo at six days old, when stem cells can be extracted

SPL

PARTHENOGENESIS

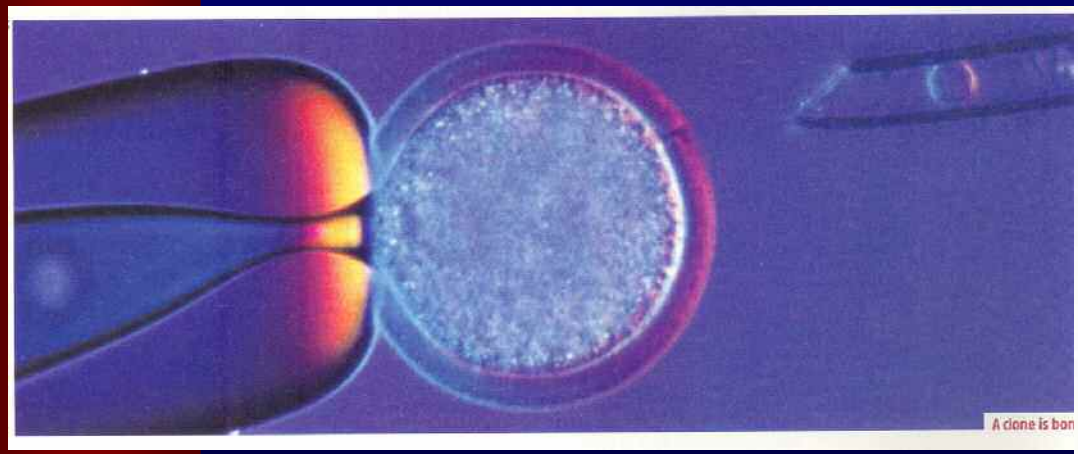
Unfertilised eggs have two complete sets of chromosomes

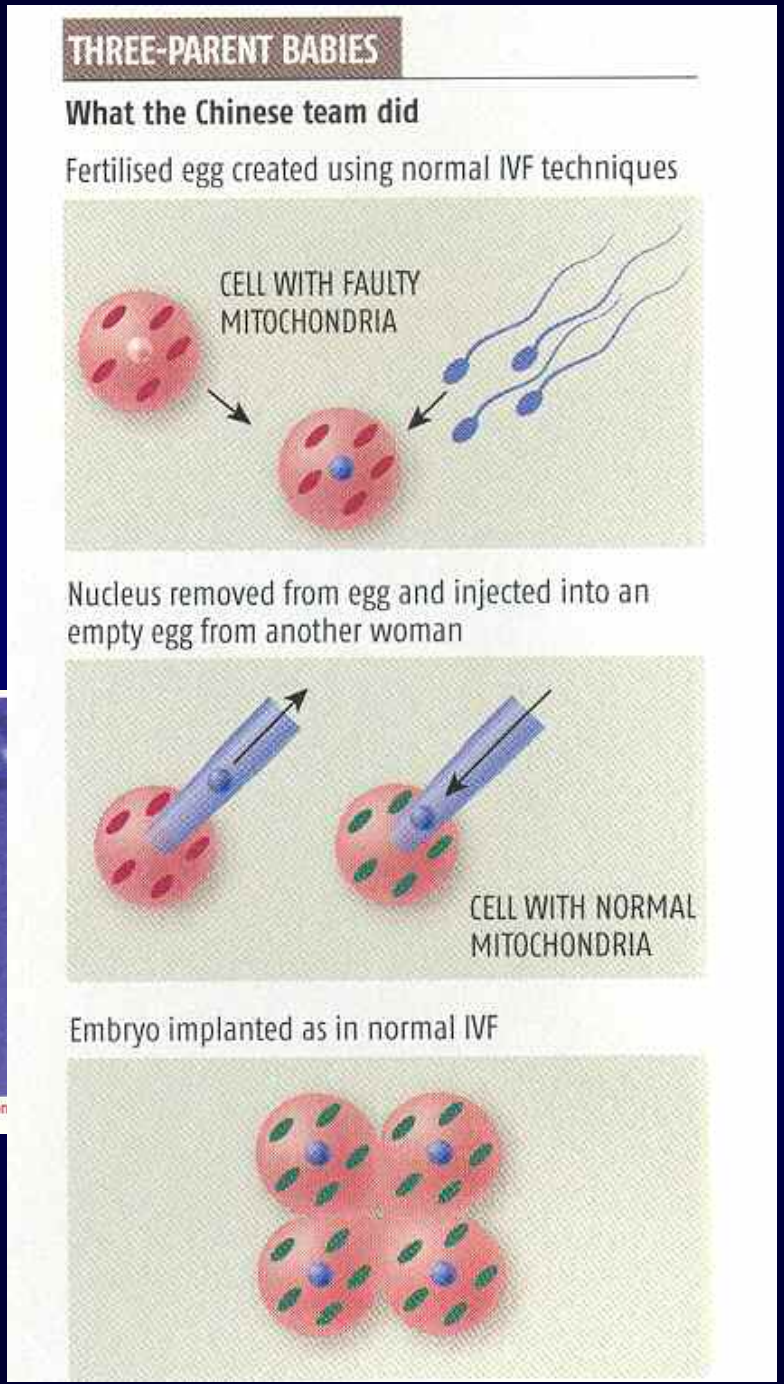
One set is expelled during fertilisation, but an electric or chemical shock can make the egg develop as if fertilised and retain the extra set

The resulting embryos usually die within days but stem cells can be extracted if they survive long enough

IVF creates fetuses with three parents

New Scientist – 18 October 2003



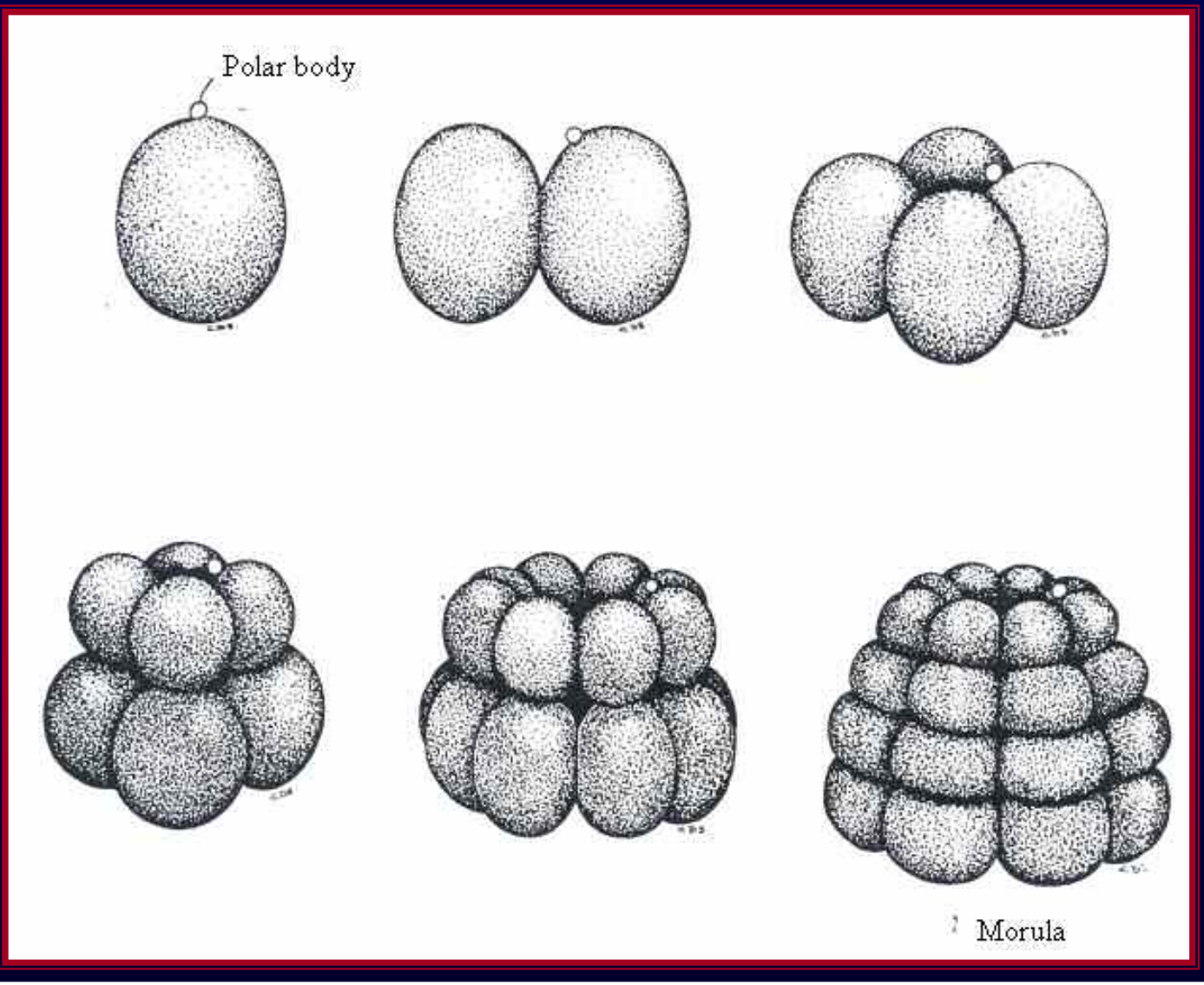


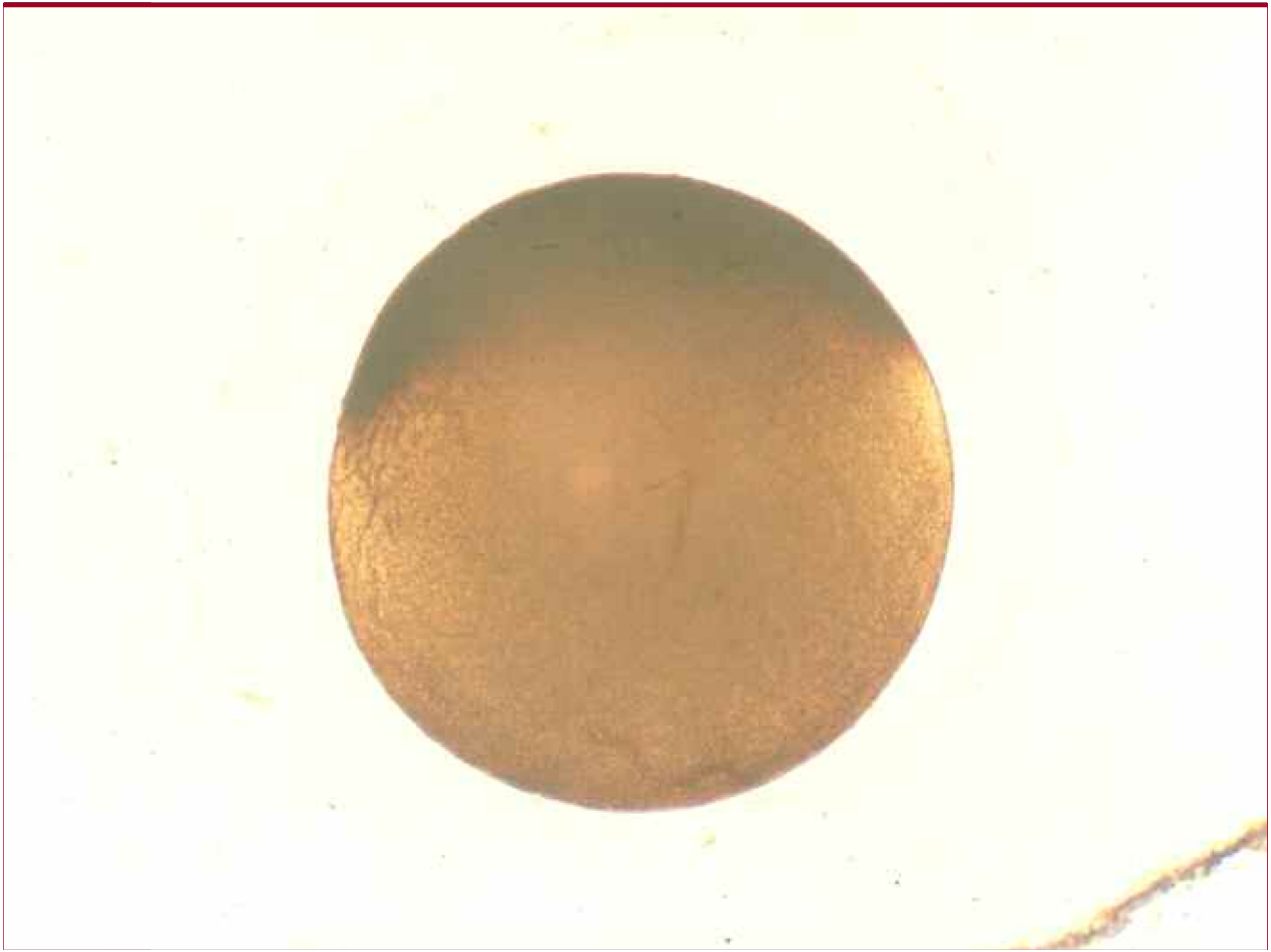
B. CLEAVAGE

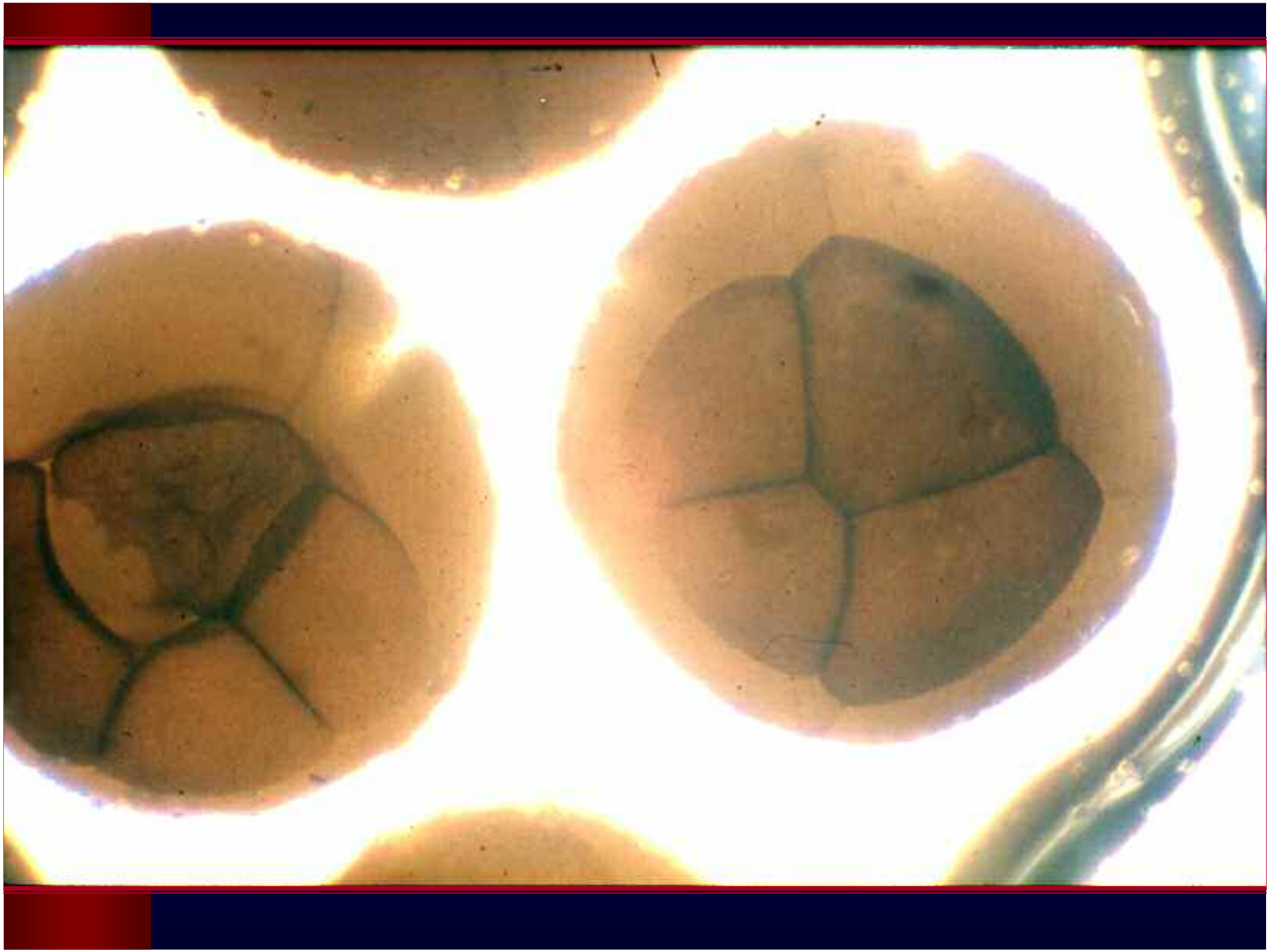
Involves division of zygote (mitosis) to form an embryo

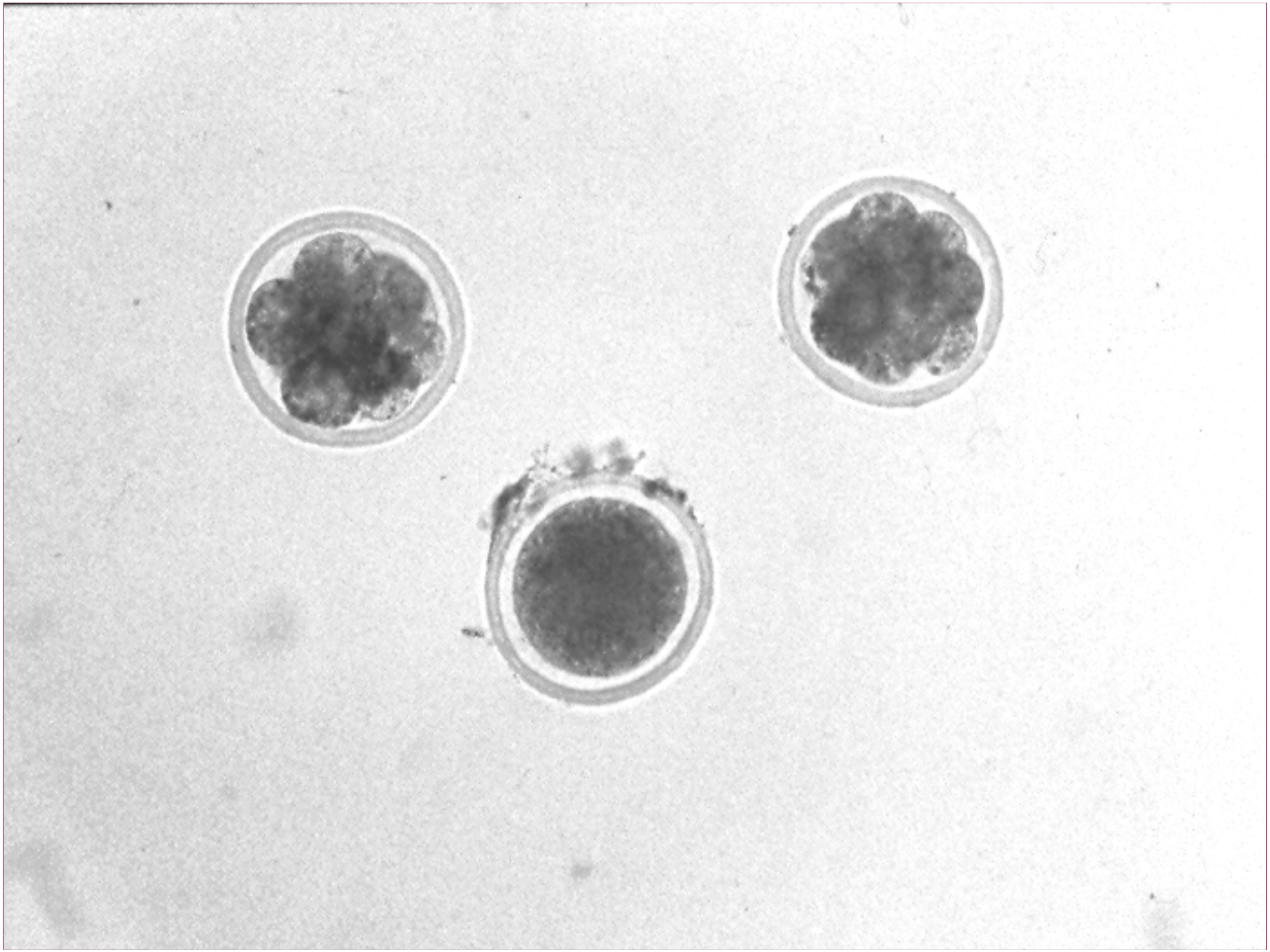
- **Mammalian ova are oligolecithal (small amount of yolk) and isolecithal (yolk evenly distributed. Cleavage is thus equal and holoblastic**
- **Ova of birds, reptiles, higher fishes are polylecithal (abundant yolk) and telolecithal (yolk concentrated at vegetal pole). Cleavage is thus partial or meroblastic**

During cleavage vertical and horizontal divisions occur until the 16 – 64 cell stage is reached. Embryo now has a mulberry-like appearance (referred to as a morula)





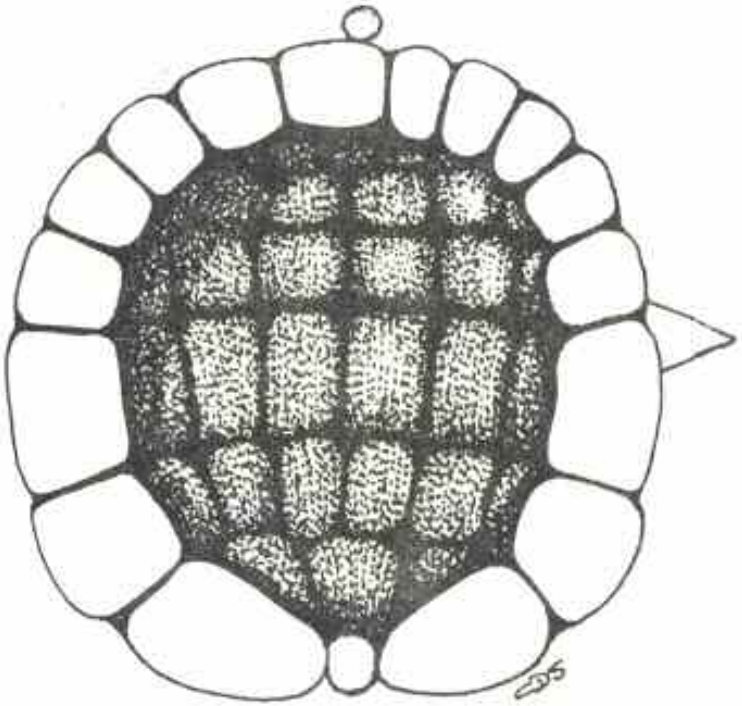




Transformation of morula to a blastocyst

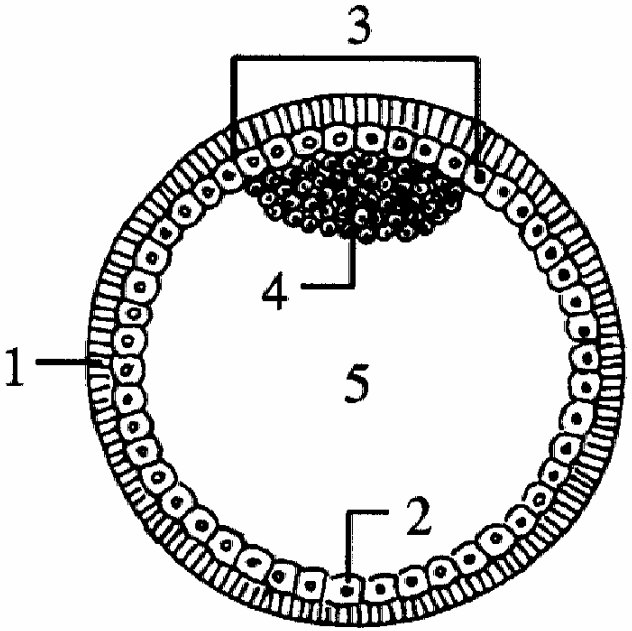
Formation of fluid-filled spaces between the cells of the morula

Spaces coalesce to form large fluid-filled cavity, the blastocyst cavity



Blastomeres form the blastoderm which encloses the blastocoele

Blastula



1. *Zona pellucida*
2. Trophoblast
3. Covering layer of Rauber
4. Embryoblast
5. Blastocyst cavity

Mammalian blastocyst – transverse section

Bovine blastocyst – about 13 days old. NB! Differs in shape in various animals

GASTRULATION

Formation (Differentiation) of the 3 basic germ layers:

Ectoderm - receive stimuli, protection

Mesoderm - support, movement, excretion, reproduction

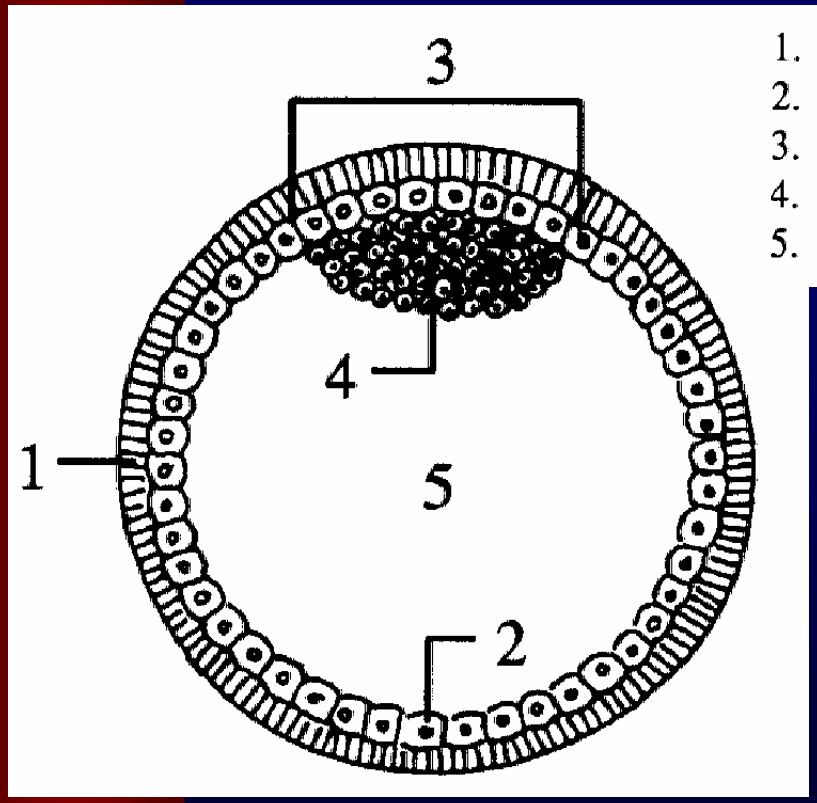
Endoderm - digestion, respiration

Gastrulation is divided into 3 stages:

Stage I

A. Hypoblast formation - delamination of embryoblast cells

B. Embryonal disc formation



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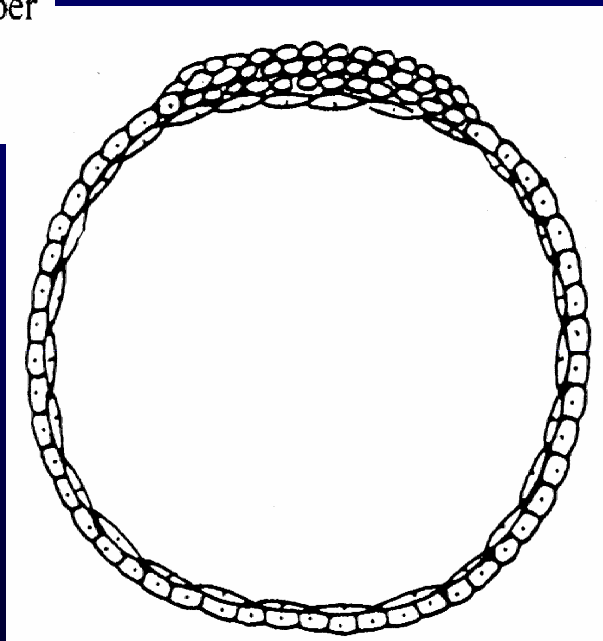
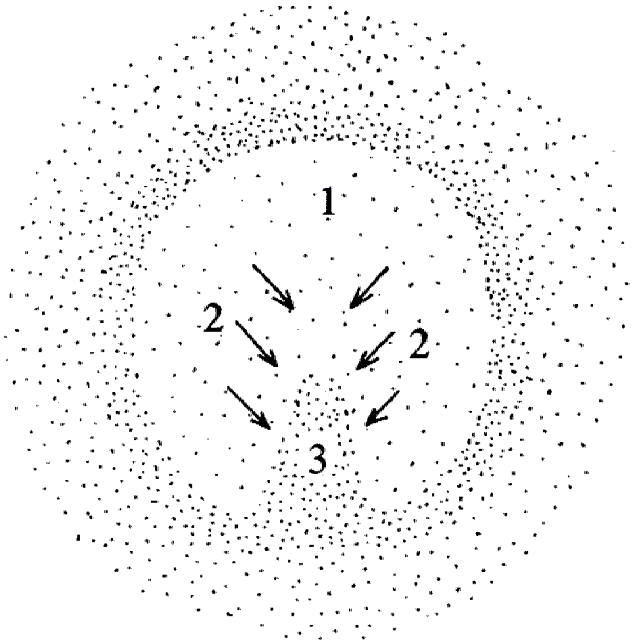
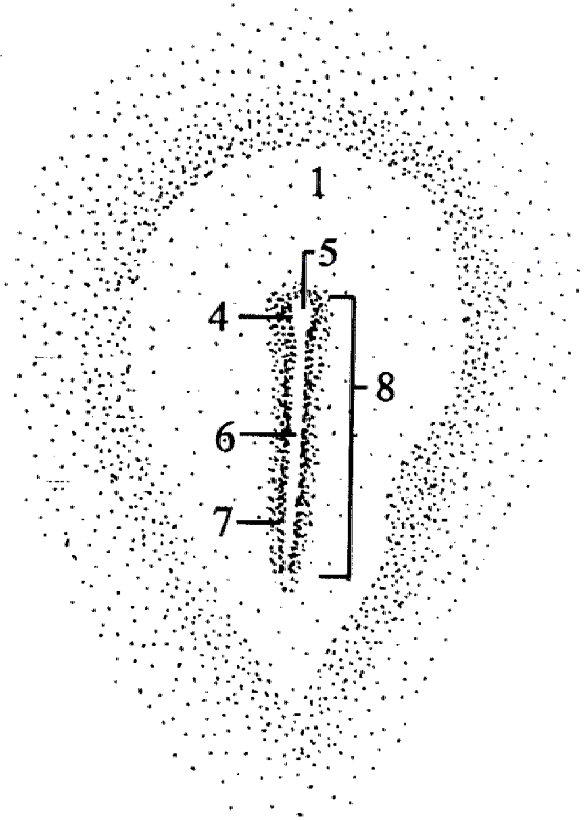


Stage II

Primitive Streak Formation (PSF)

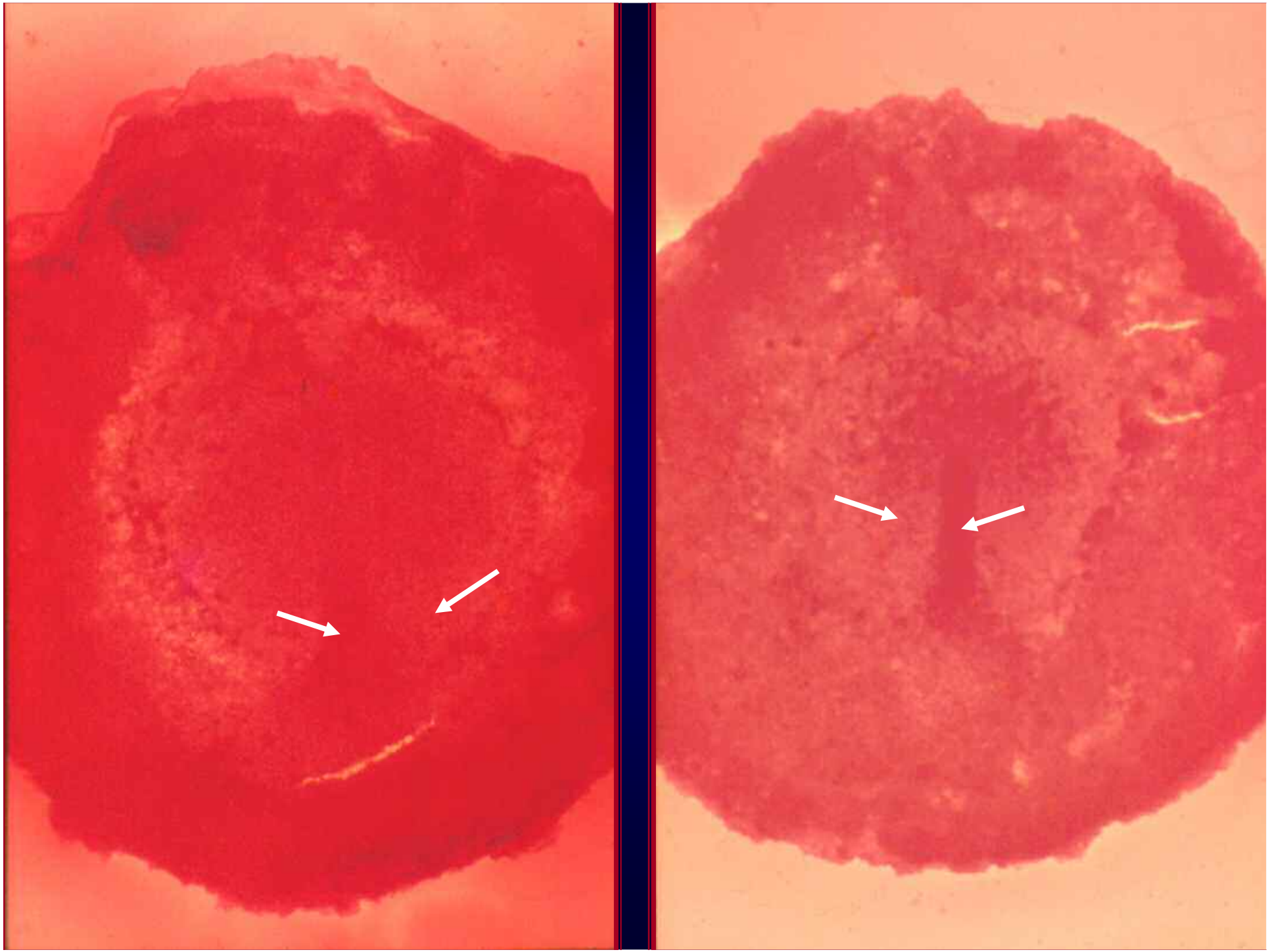


Development initiated



Development completed

1. Embryonal disc
2. Direction of migration of epiblast cells
3. Beginning of primitive streak
4. Primitive node
5. Primitive pit
6. Primitive groove
7. Primitive fold
8. Primitive streak



Stage III (essentially a continuation of PSF)

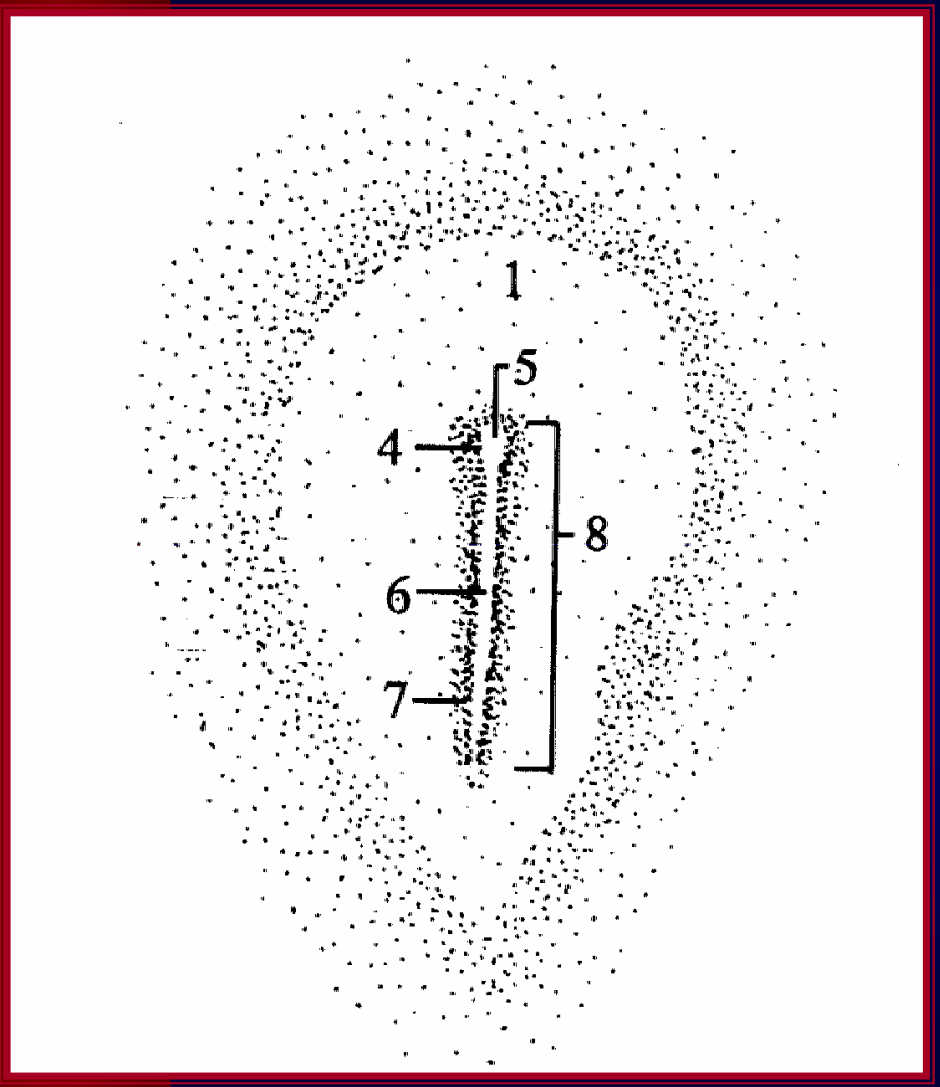
Involves the involution (moving inwards) of cells and formation of the notochord:

A. Cell involution

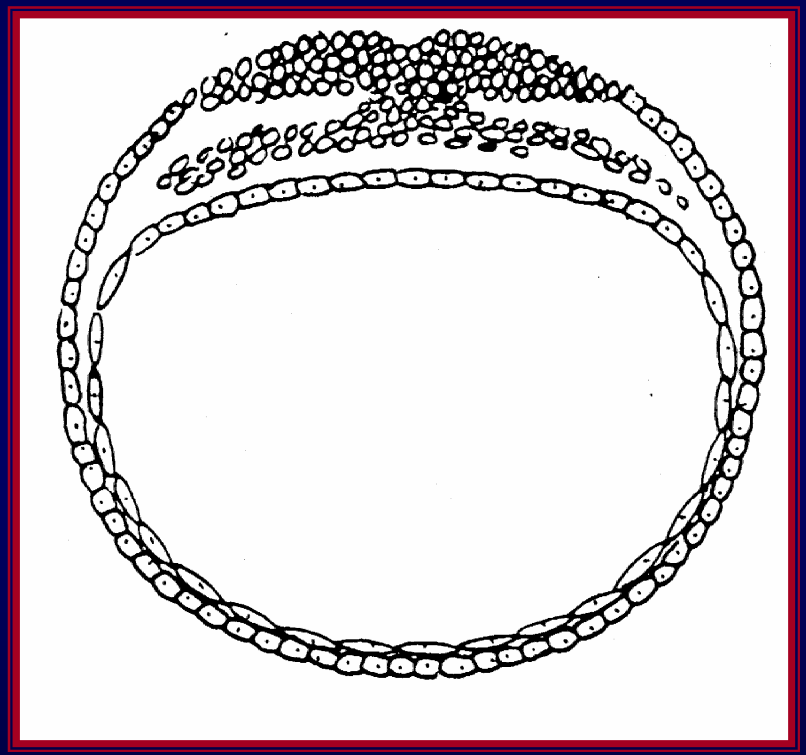
1. Endoderm formation

2. Mesoderm formation

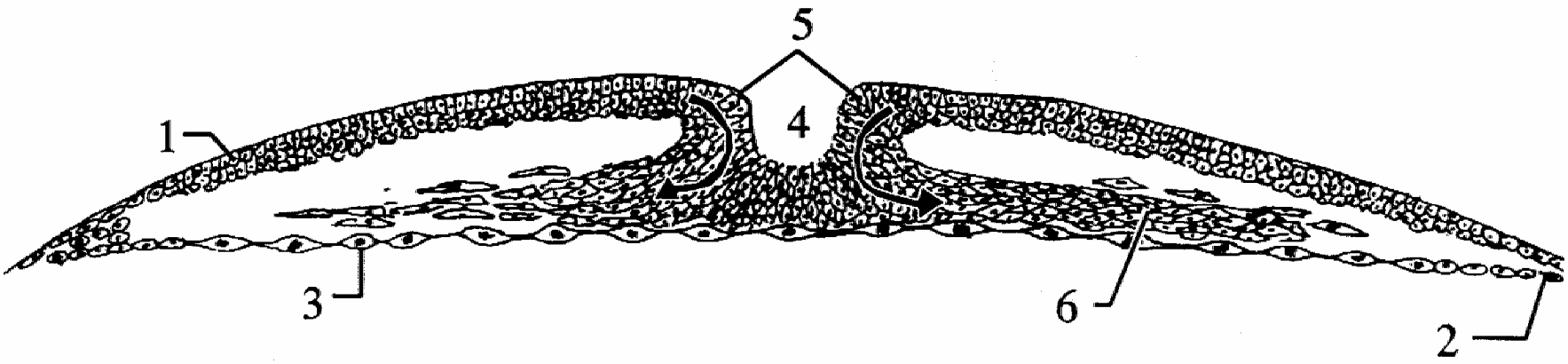
Primitive streak formation



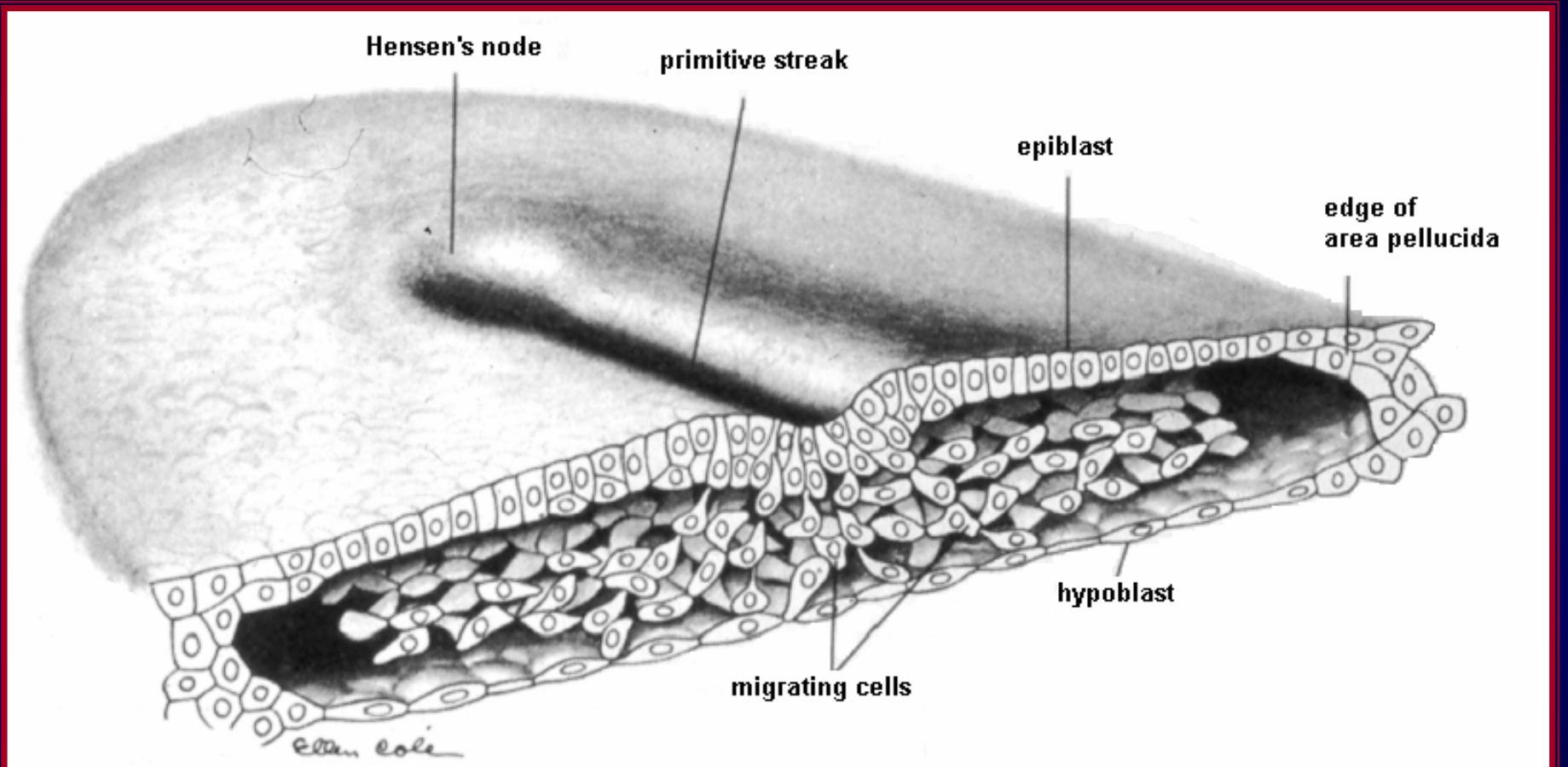
Surface view

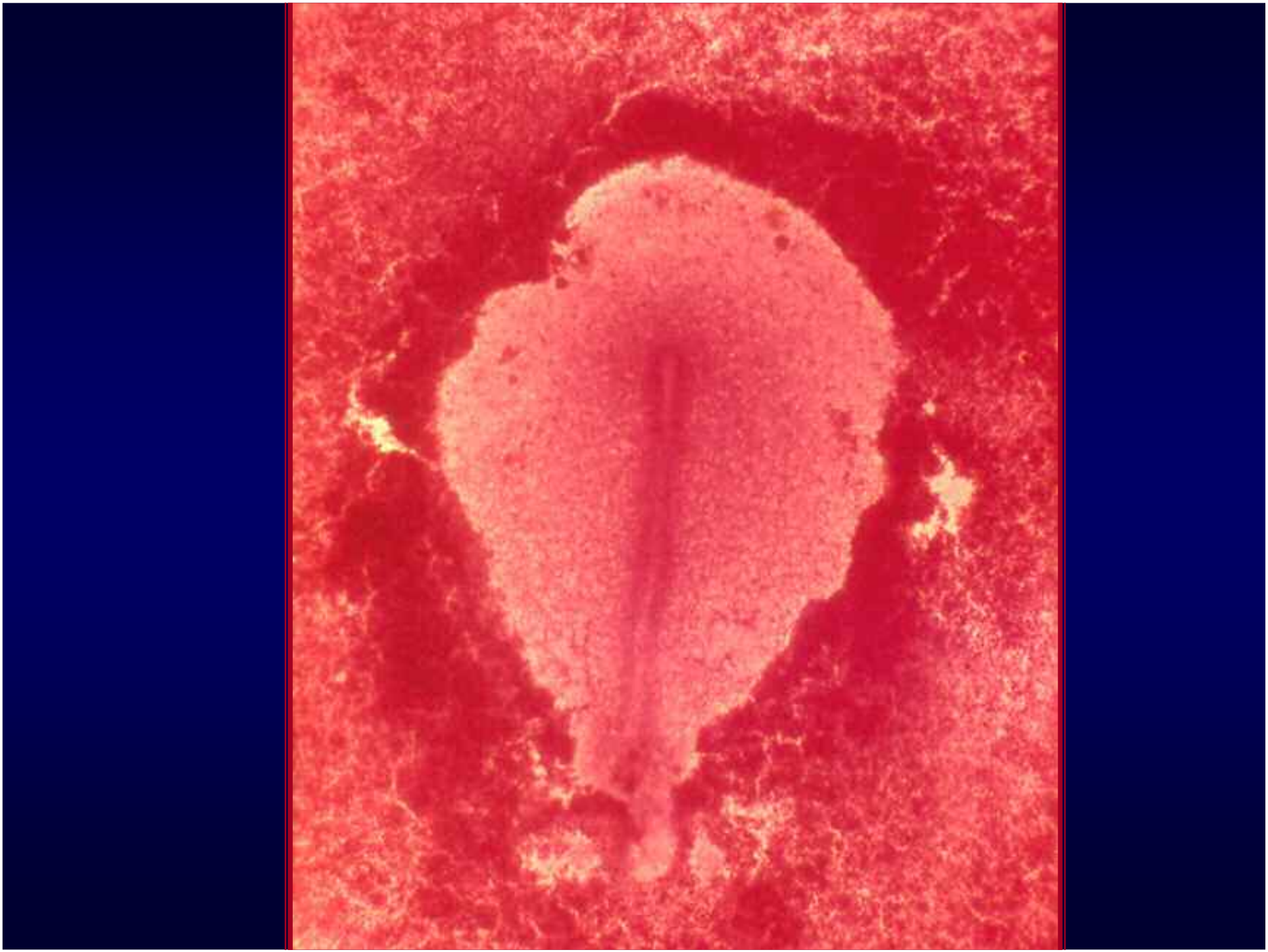


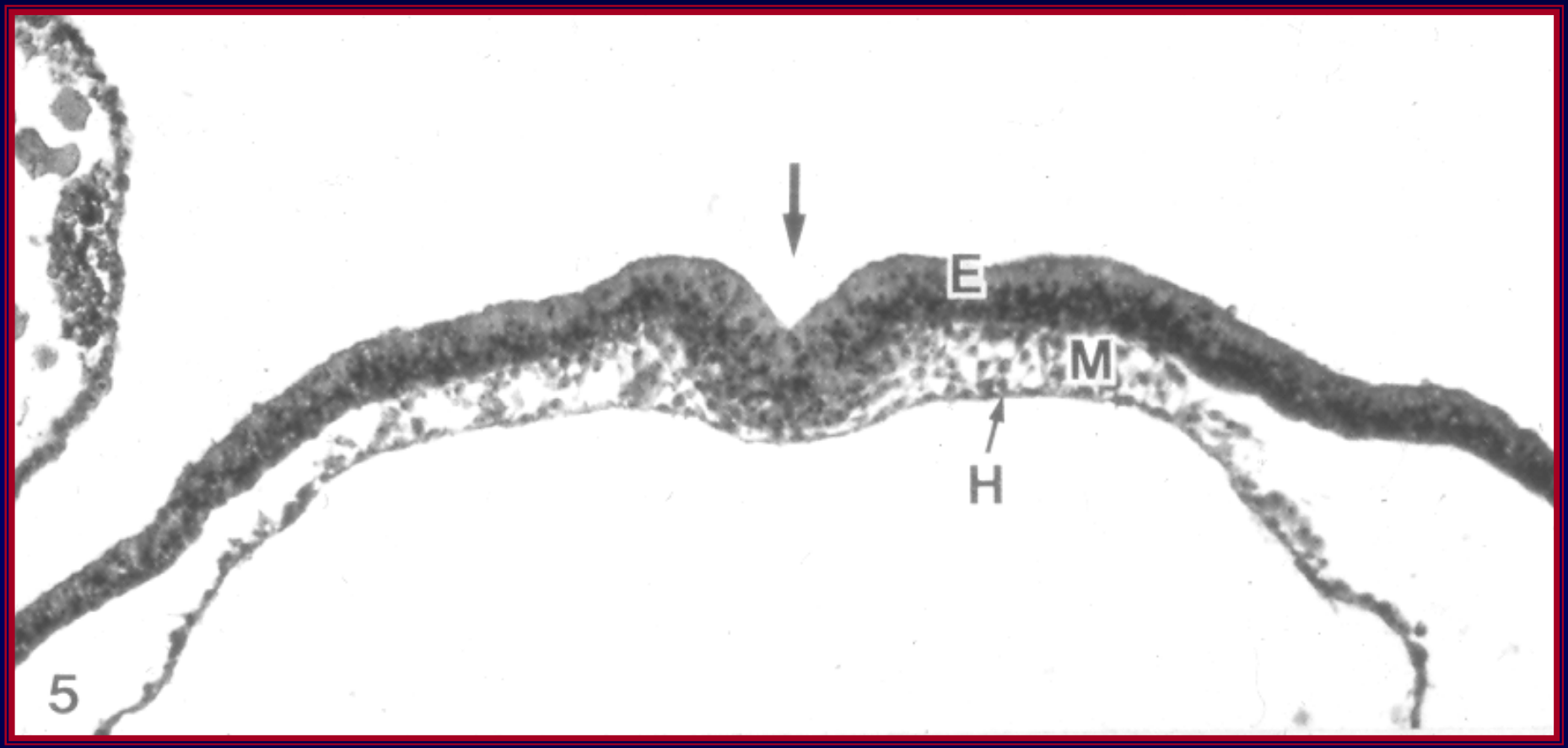
Cross-sectional view



1. Epiblast
2. Hypoblast
3. Endoderm
4. Primitive groove
5. Primitive folds
6. Mesoderm


Hensen's node
primitive streak
epiblast
edge of
area pellucida
hypoblast
migrating cells

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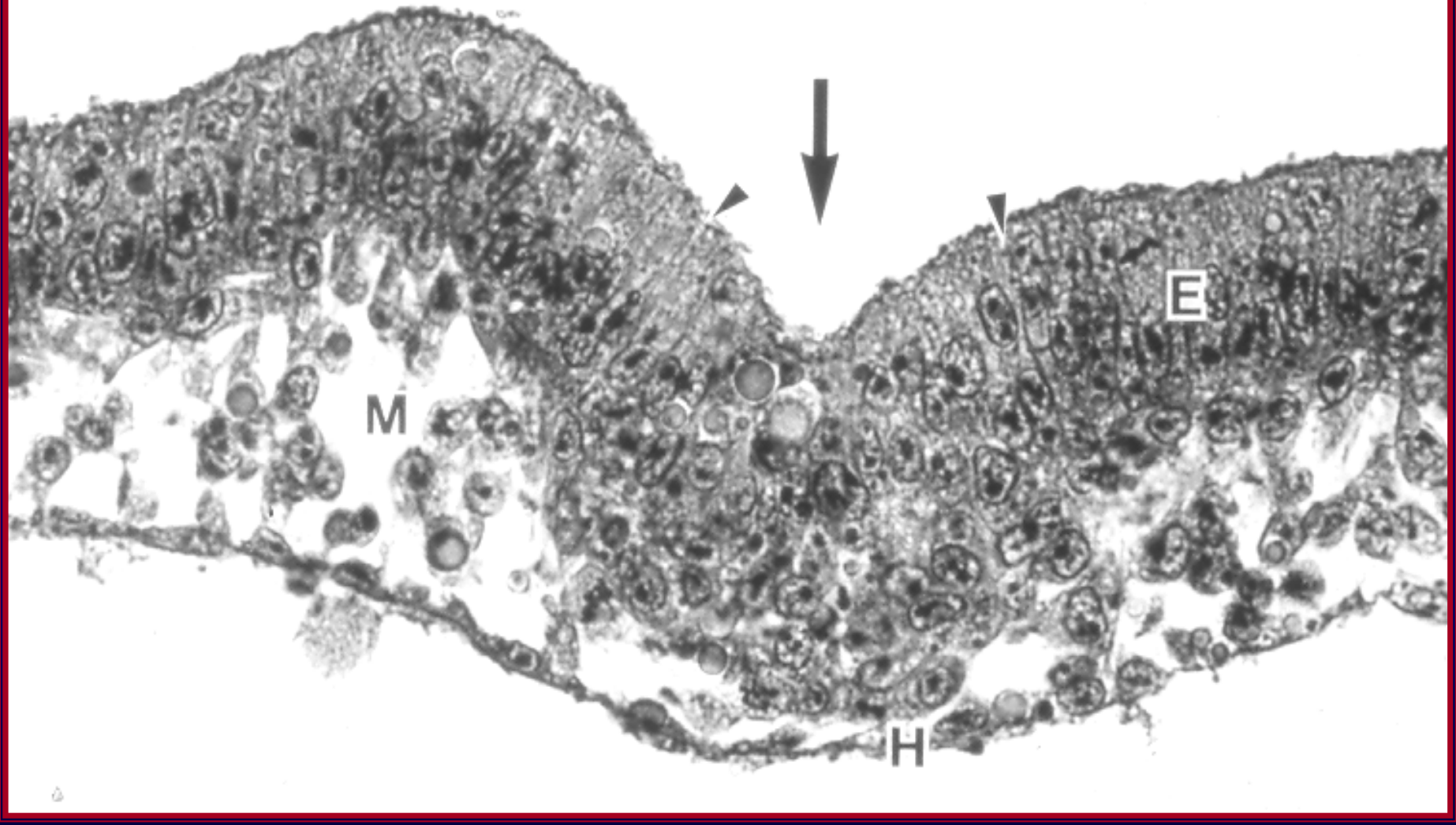
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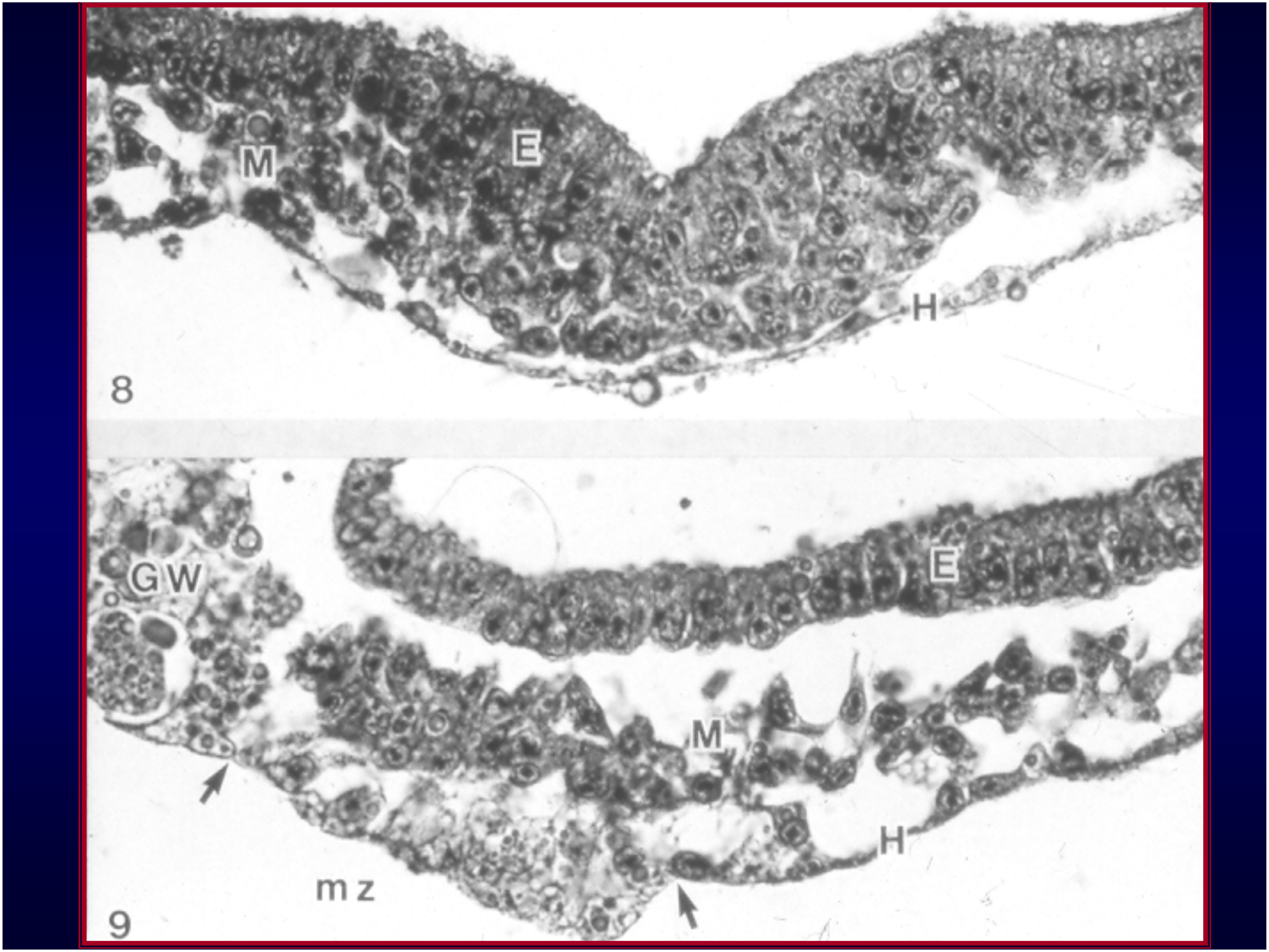
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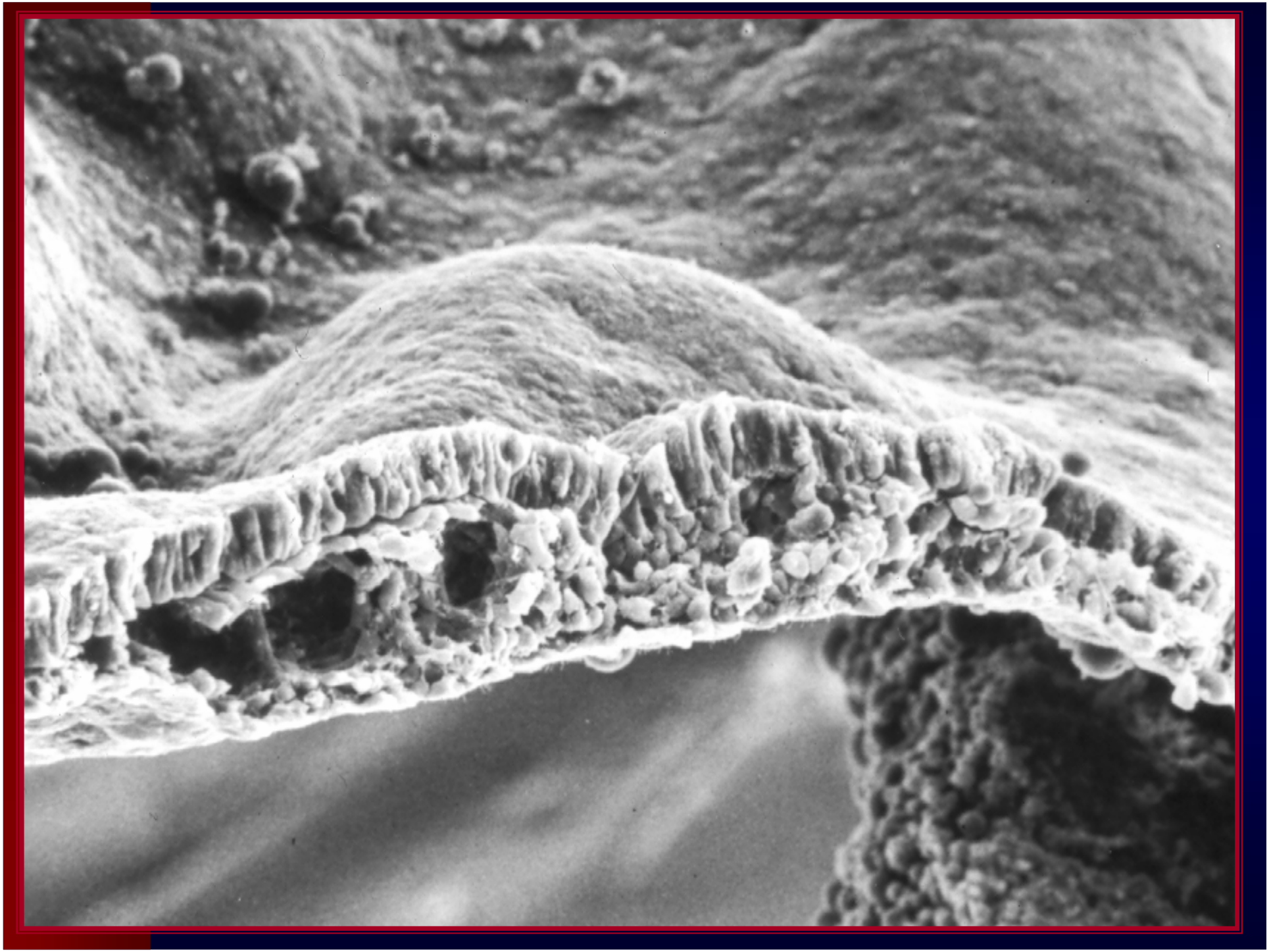

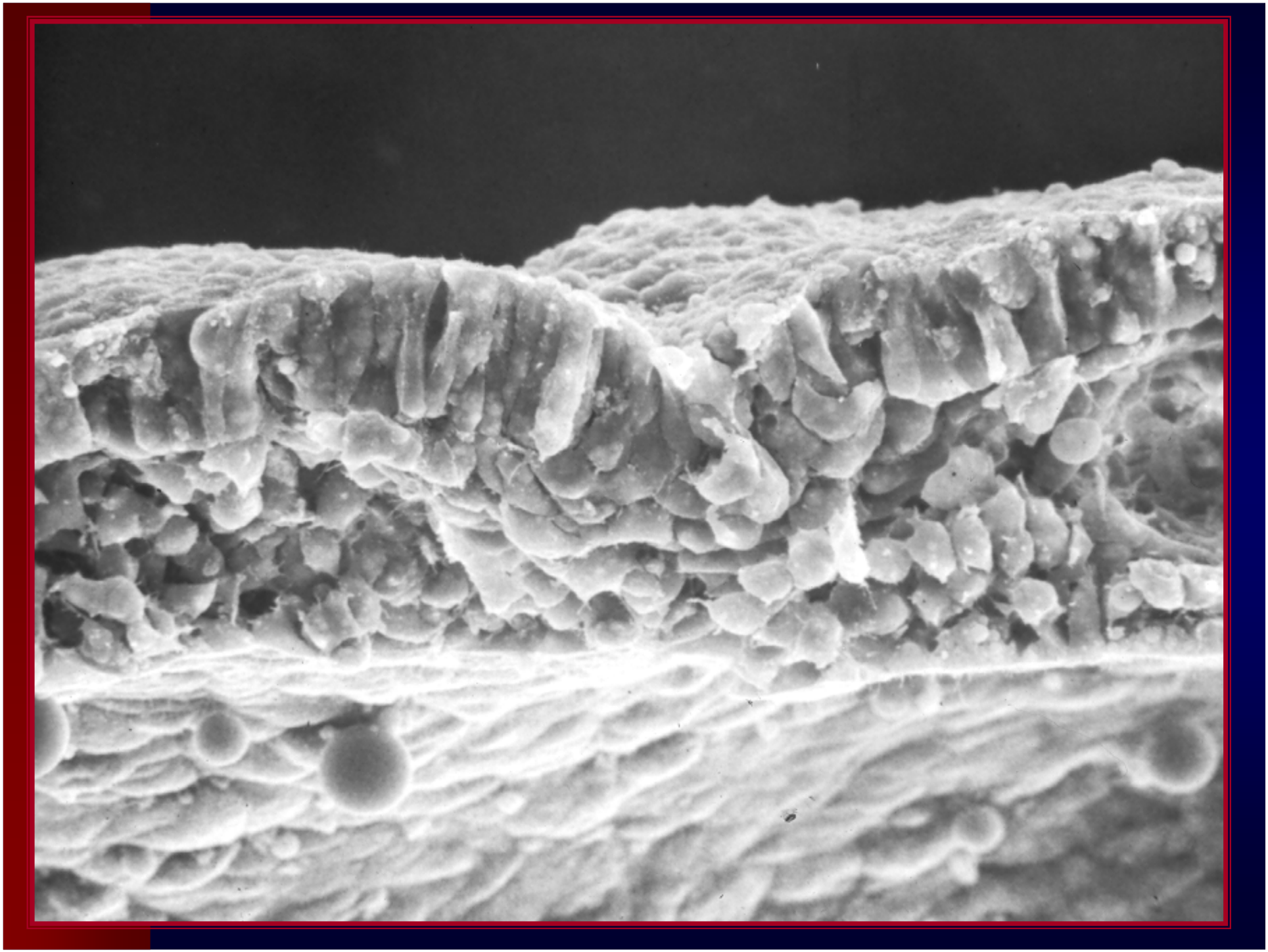

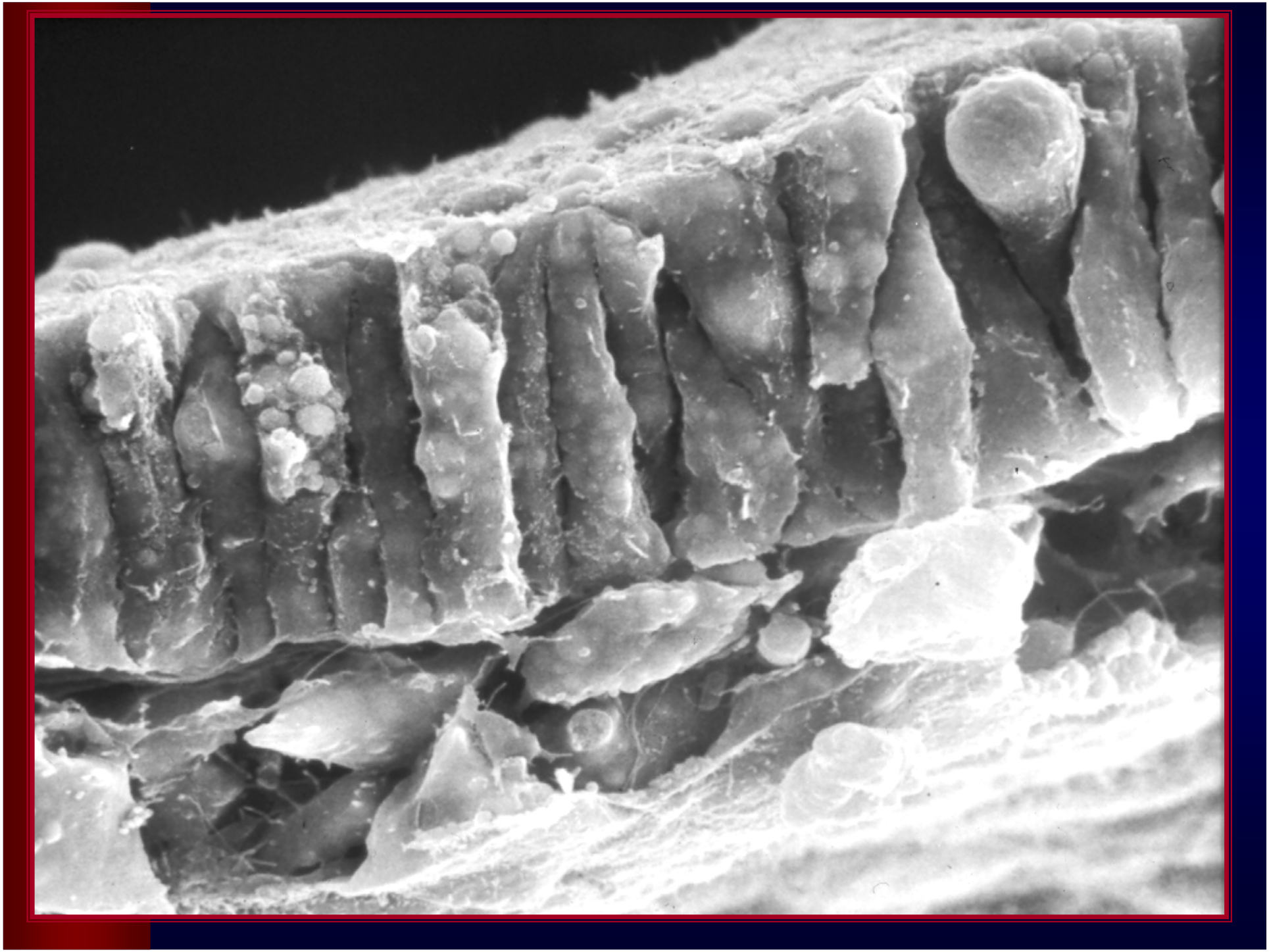

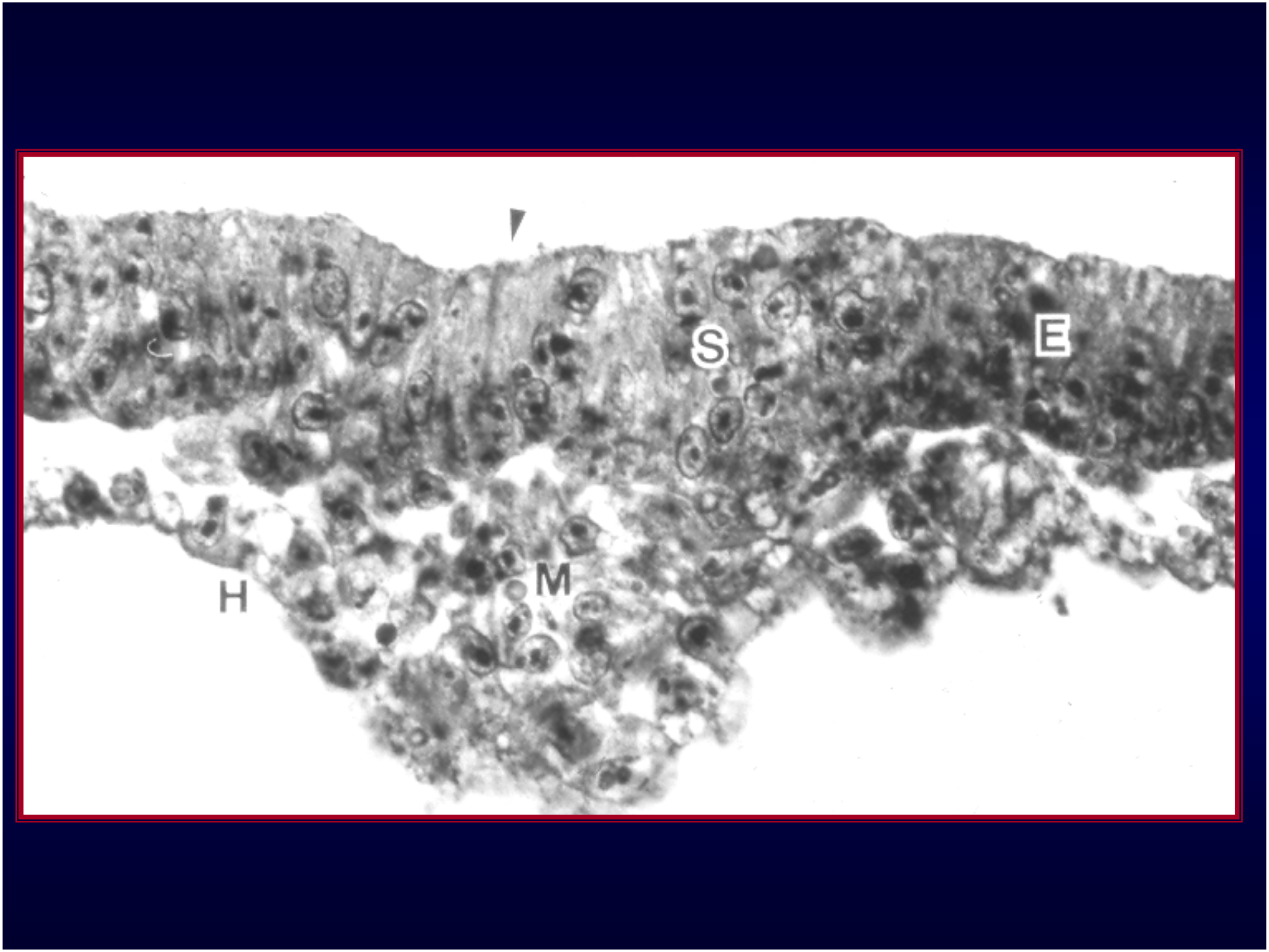
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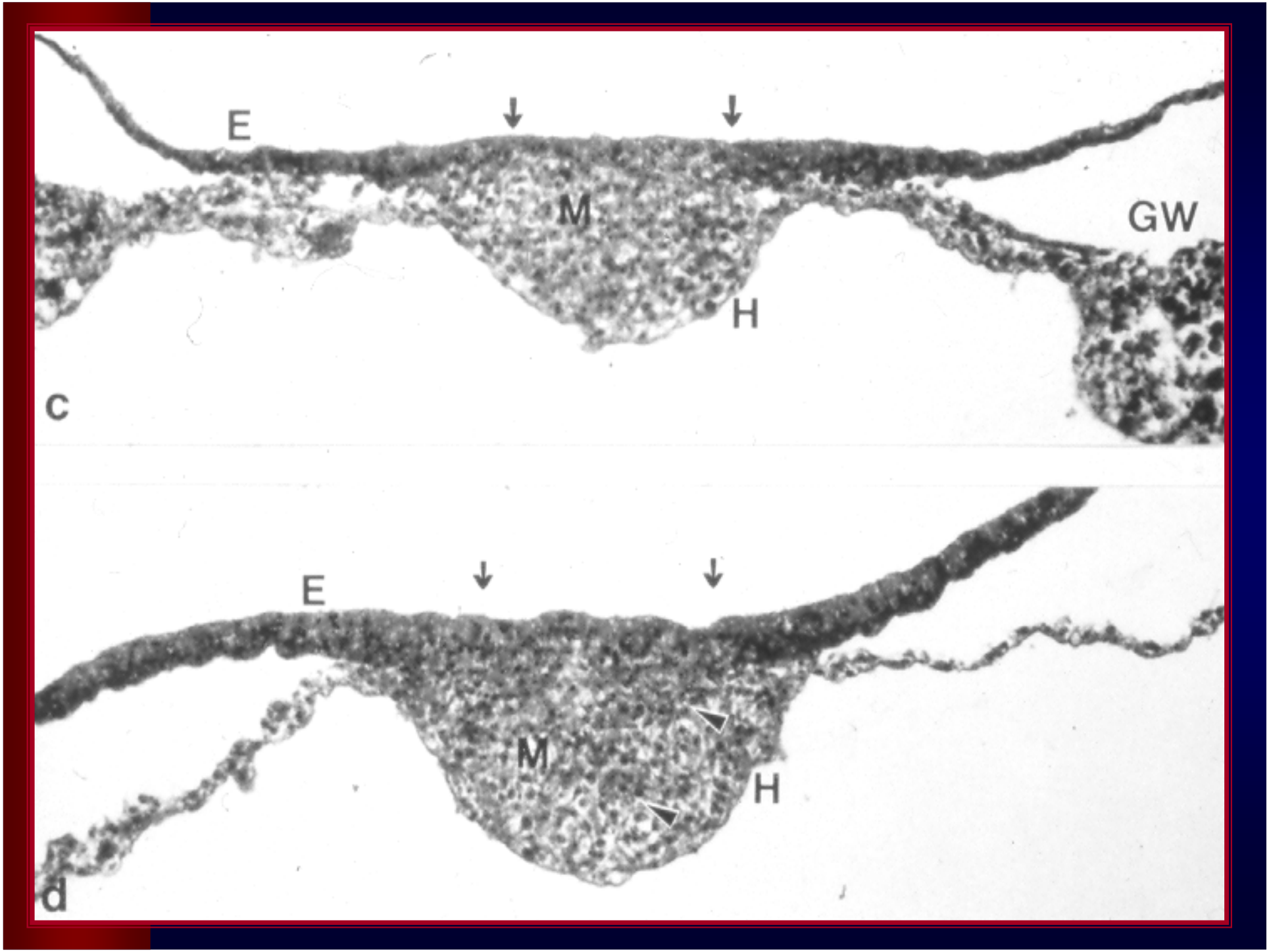
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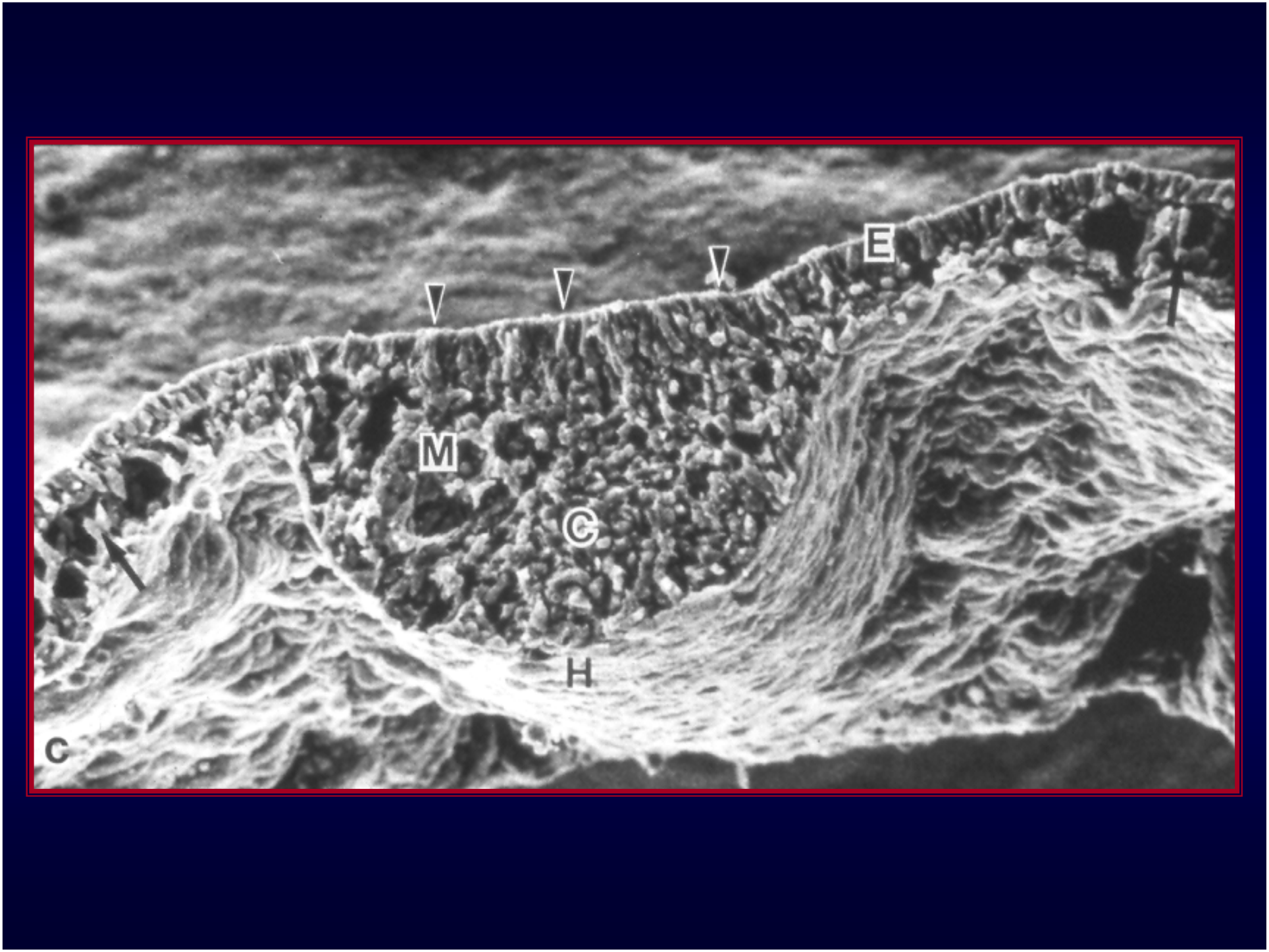
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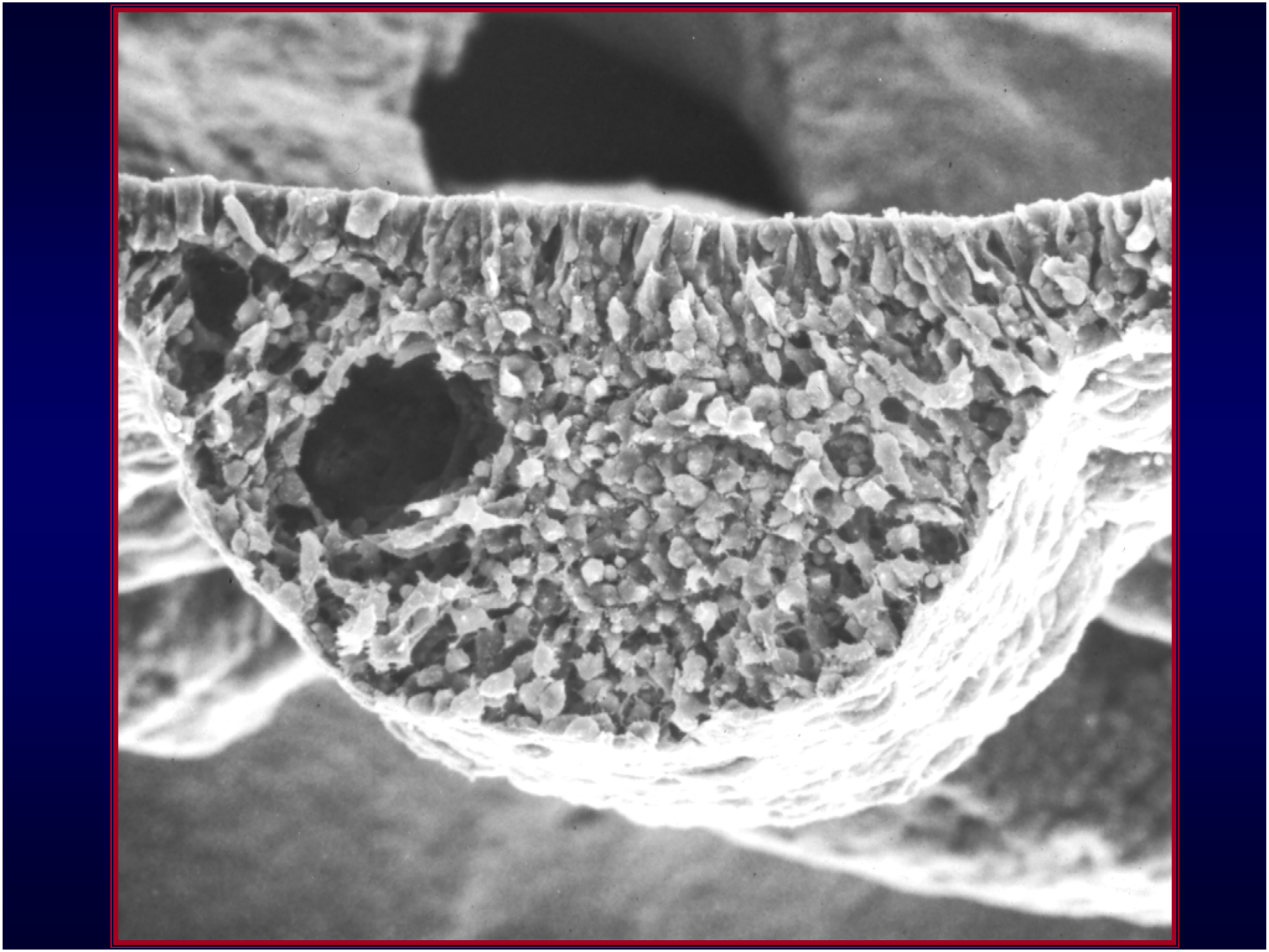

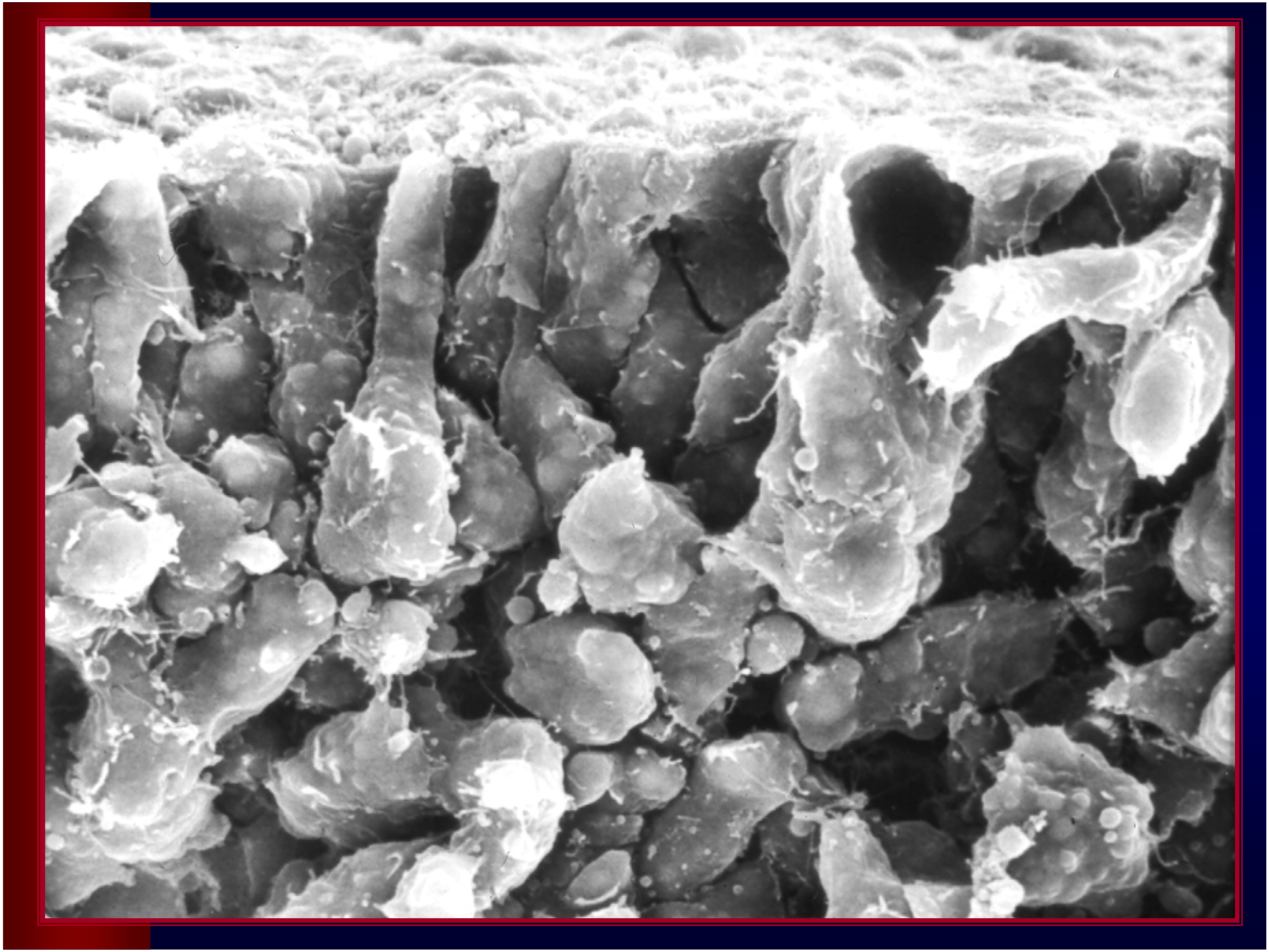

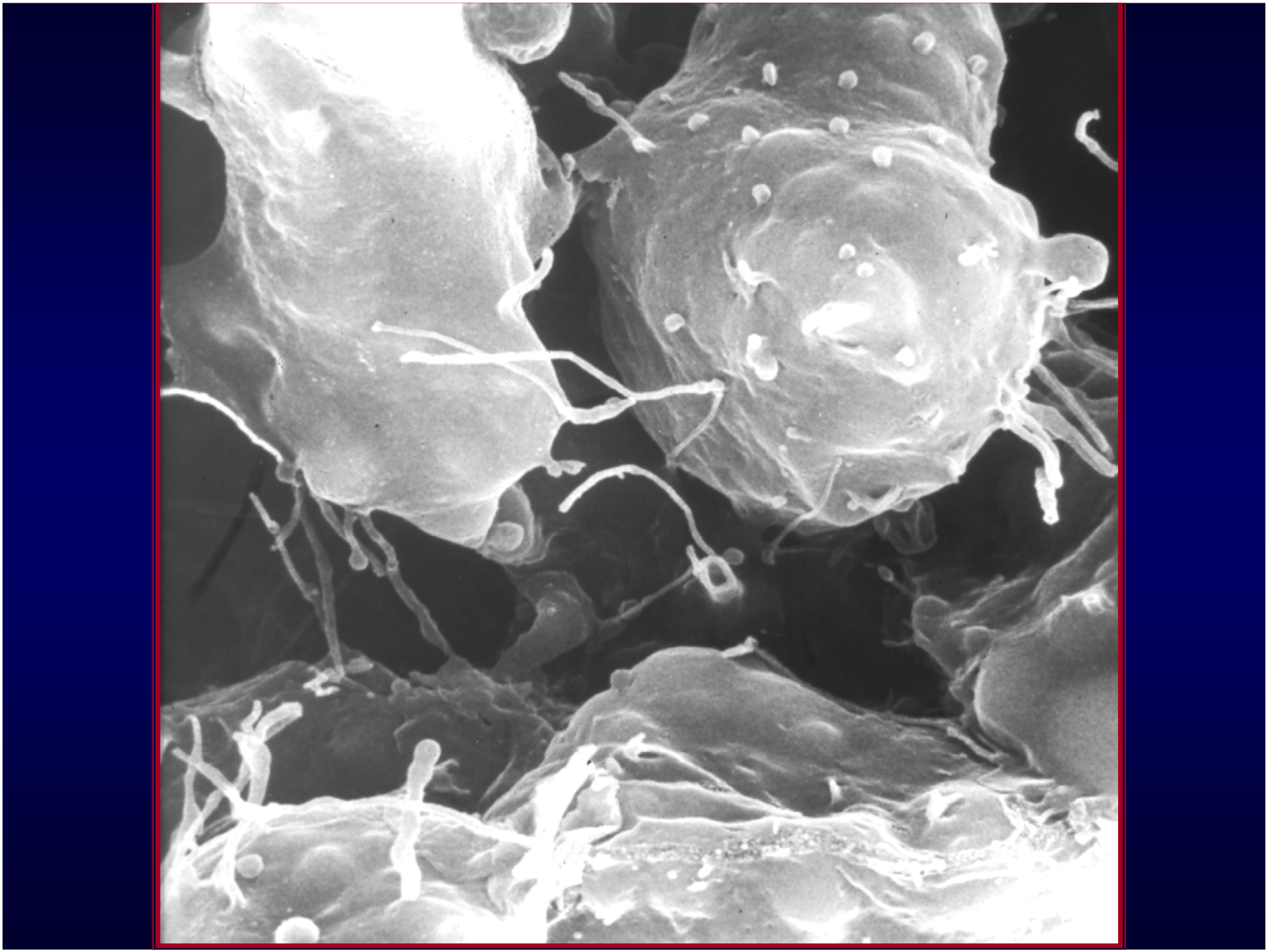

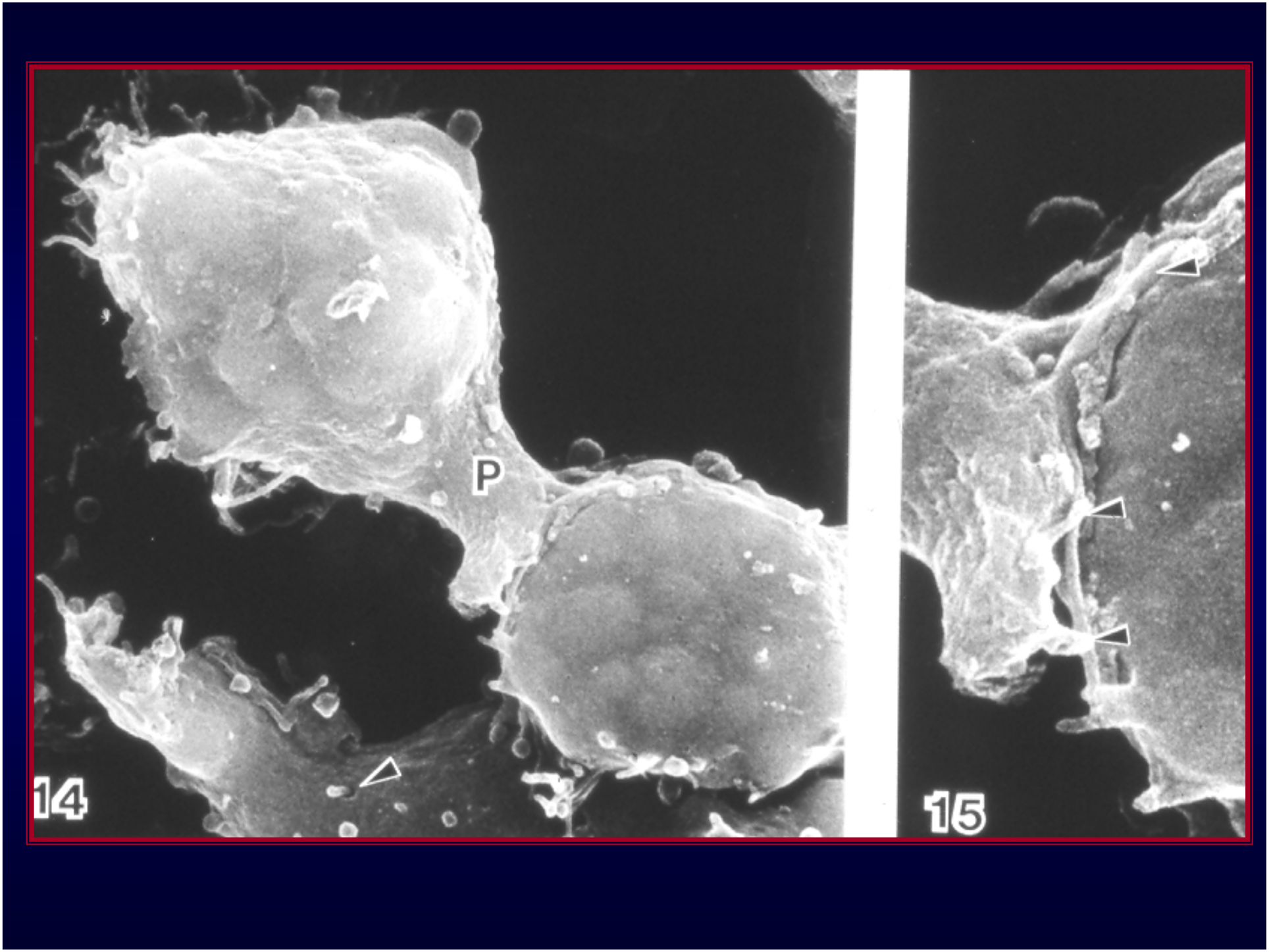
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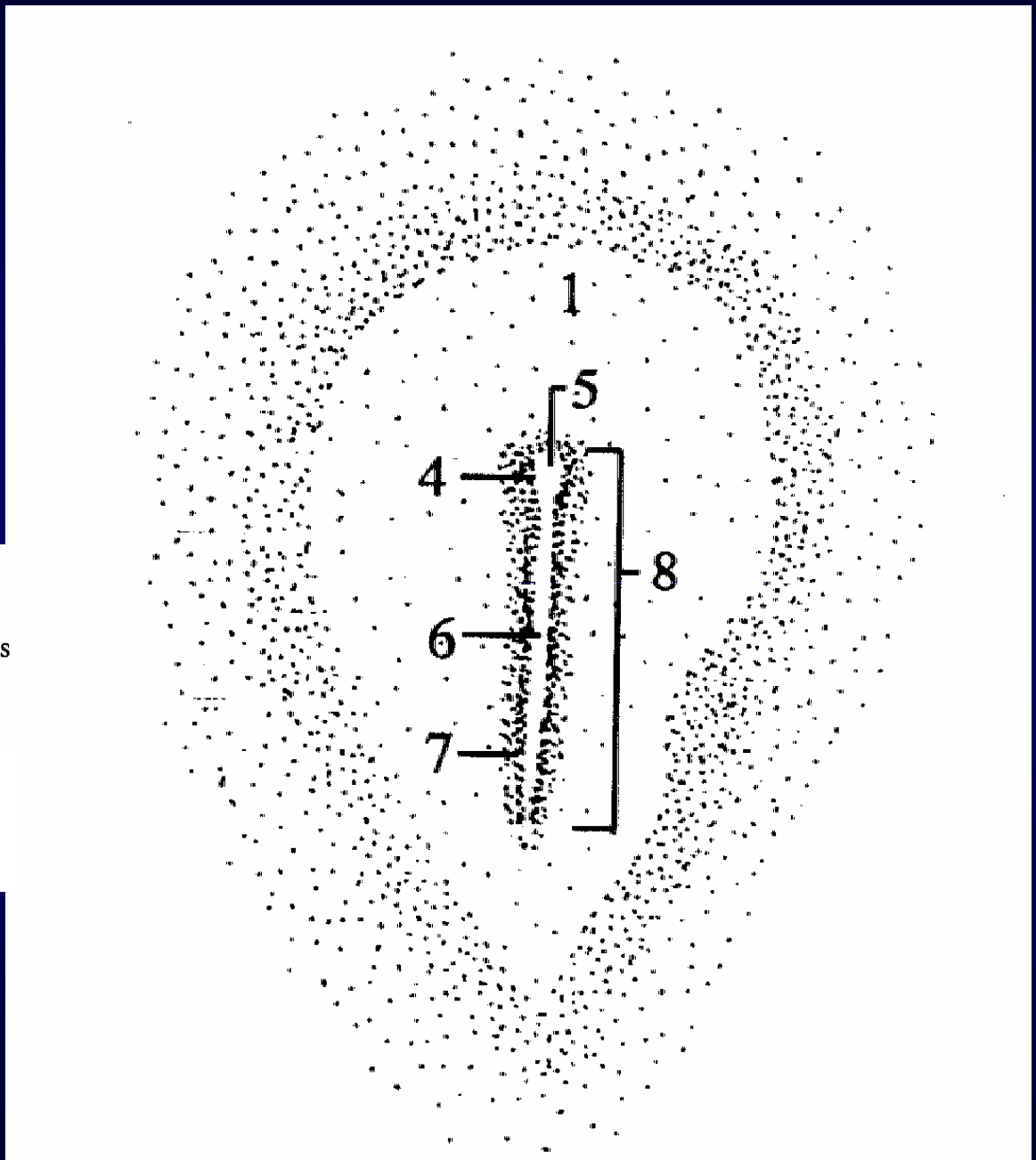
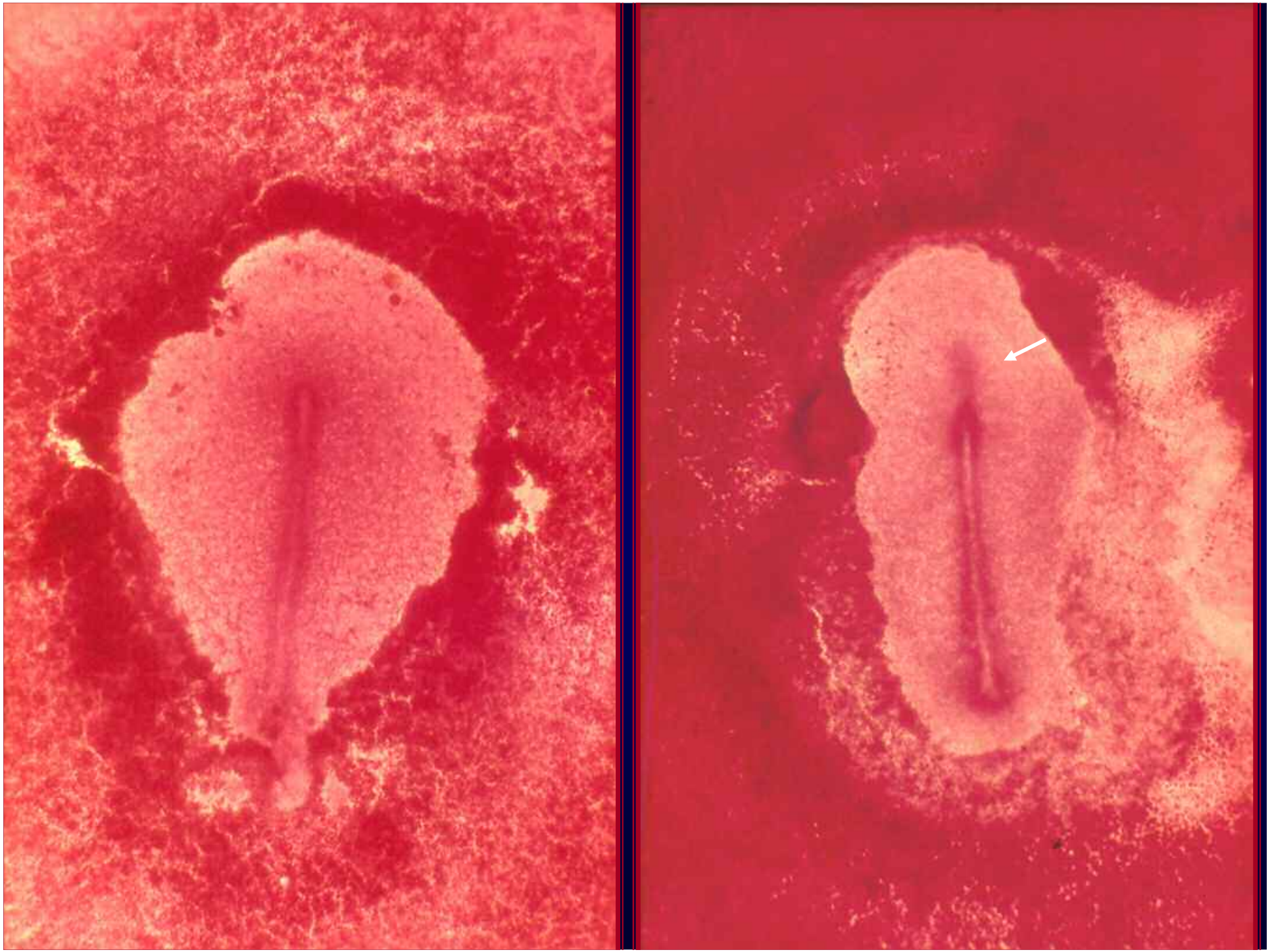
Stage III
(essentially a continuation of PSF)

B. Notochord formation

1. Embryonal disc
2. Direction of migration of epiblast cells
3. Beginning of primitive streak
4. Primitive node
5. Primitive pit
6. Primitive groove
7. Primitive fold
8. Primitive streak





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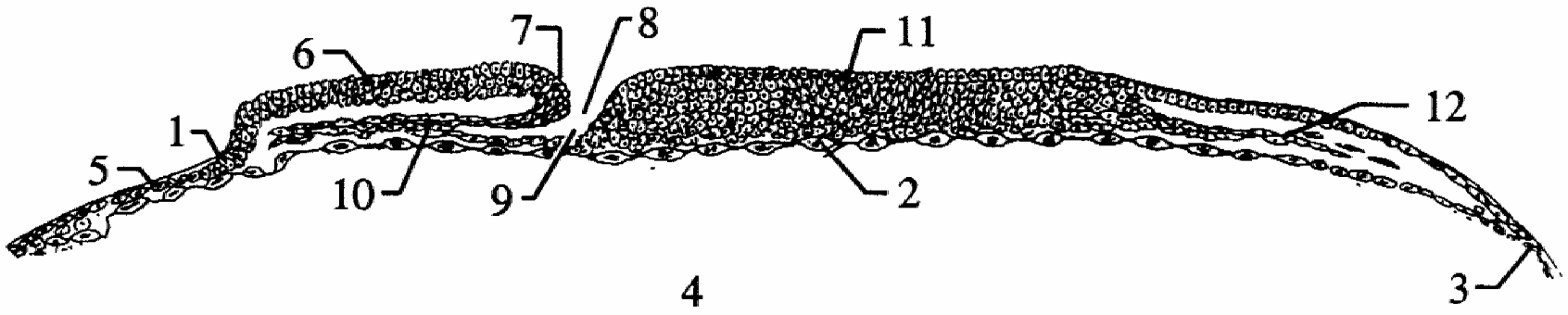
B. Notochord formation



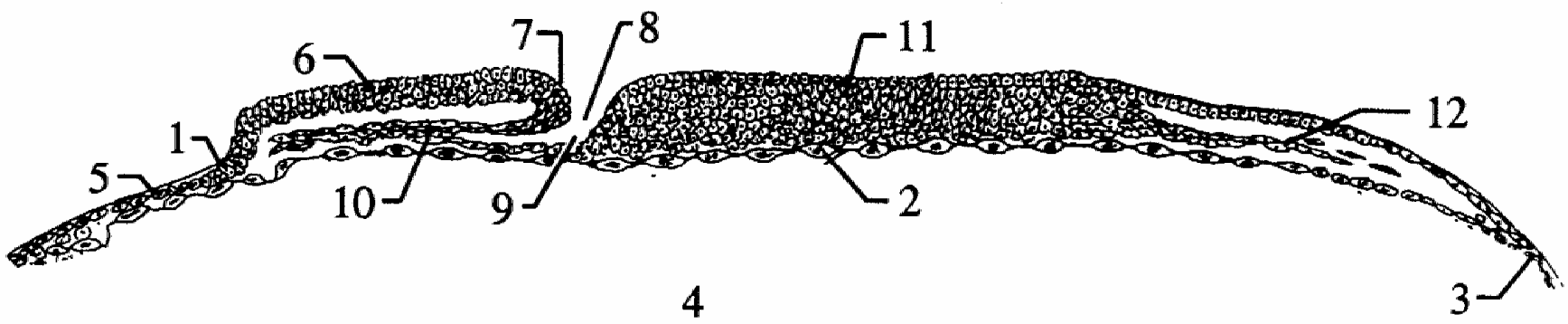
1. Epiblast
2. Embryonic endoderm
3. Extra-embryonic endoderm
4. Yolk sac
5. Pre-chordal plate
6. Neural plate
7. Primitive node
8. Primitive pit
9. Blastopore
10. Notochordal process
11. Primitive groove
12. Mesoderm

Stage IV

Simultaneous differentiation of the mesoderm and neurulation

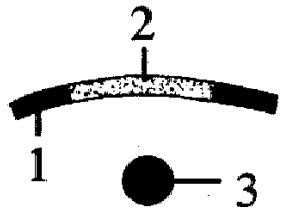
1. Neurulation

Formation of the neural tube under the inductive influence of the notochord

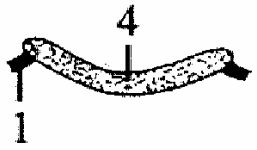


1. Epiblast
2. Embryonic endoderm
3. Extra-embryonic endoderm
4. Yolk sac
5. Pre-chordal plate
6. Neural plate
7. Primitive node
8. Primitive pit
9. Blastopore
10. Notochordal process
11. Primitive groove
12. Mesoderm

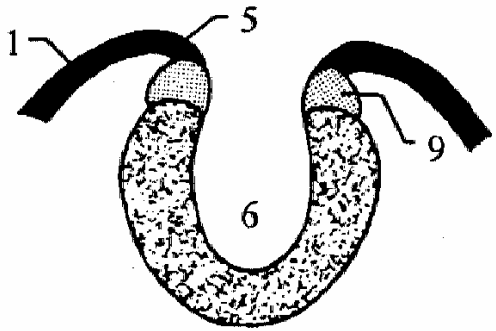
1. Ectoderm
2. Neuro-ectoderm
3. Notochord
4. Neural plate
5. Neural fold
6. Neural groove
7. Neural tube
8. Neural canal
9. Neural crest
10. *Sulcus limitans*



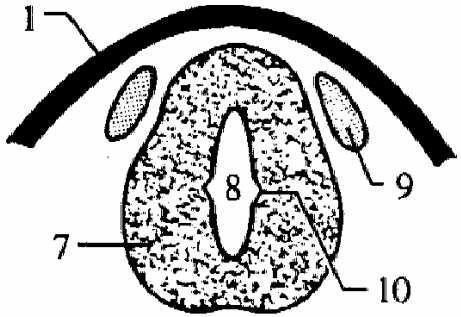
a.



b.



c.

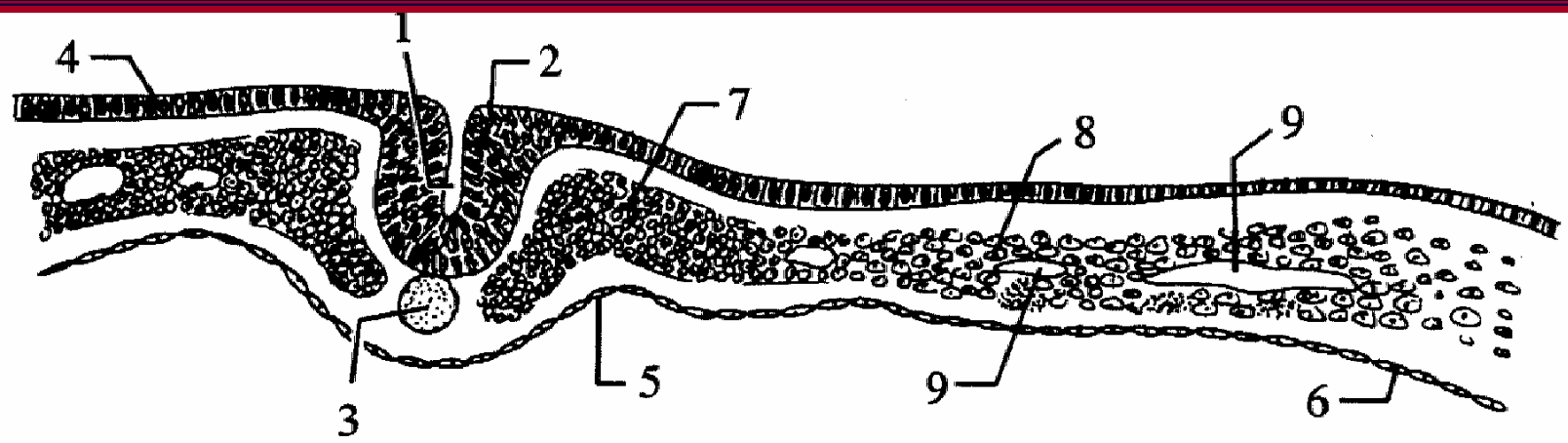


d.

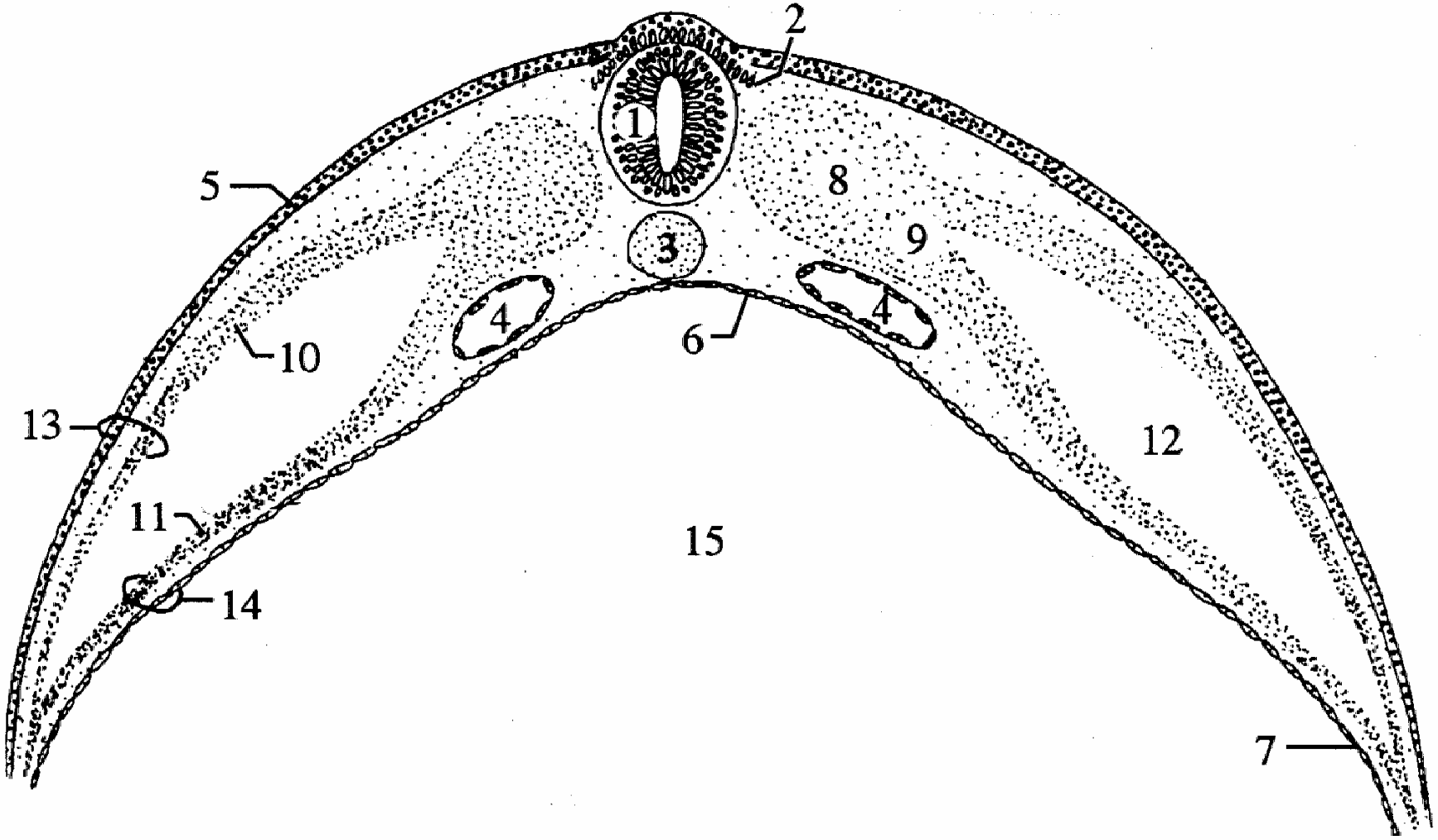
Stage IV

2. Initial differentiation of the mesoderm

- **Paraxial mesoderm - Somites**
- **Lateral mesoderm - Splanchnic and somatic**
- **Head mesoderm - U-tube (pleuropericardial coelom) formation**



1. Neural groove	4. Ectoderm	7. Paraxial mesoderm
2. Neural fold	5. Embryonic endoderm	8. Lateral mesoderm
3. Notochord	6. Extra-embryonic endoderm	9. Mesodermal cavities



1. Neural tube
2. Neural crest cells
3. Notochord
4. Dorsal aorta
5. Ectoderm
6. Embryonic endoderm
7. Extra-embryonic endoderm
8. Paraxial mesoderm
9. Nephrotome
10. Somatic mesoderm
11. Splanchnic mesoderm
12. Coelom
13. Somatopleure
14. Splanchnopleure
15. Yolk sac

LECTURES 4, 5 and 6 (3 X 40 min)

Development of body form

a. Body and amnion folds (chorio-amniotic folds)

b Nervous system

c. Cardio-vascular system

d. Digestive system

e. Uro-genital system

f. Head and face development

g. Tail and limb formation

D. Development of body form

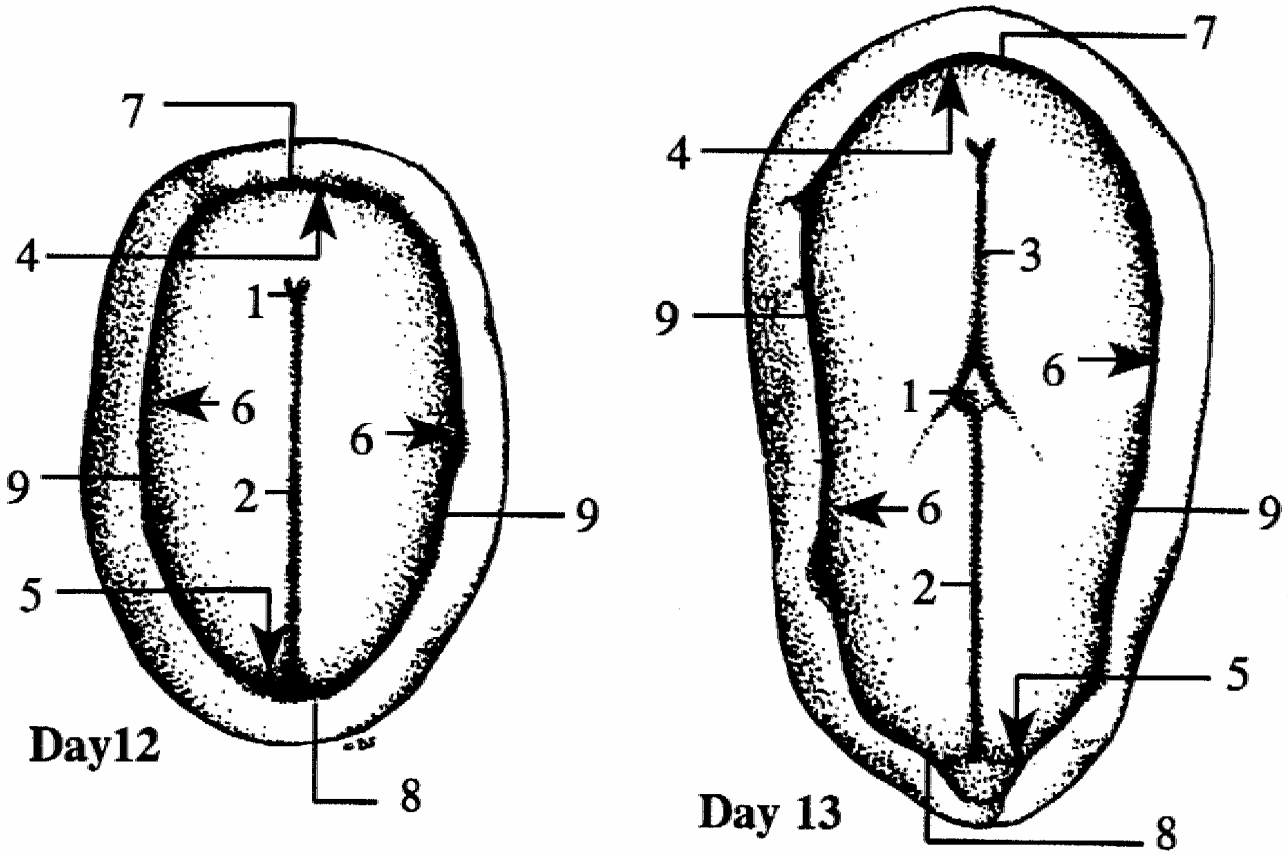
Appearance of organ primordia - marks transition from embryonal phase to fetal phase.

1. Cylindrical Body Formation

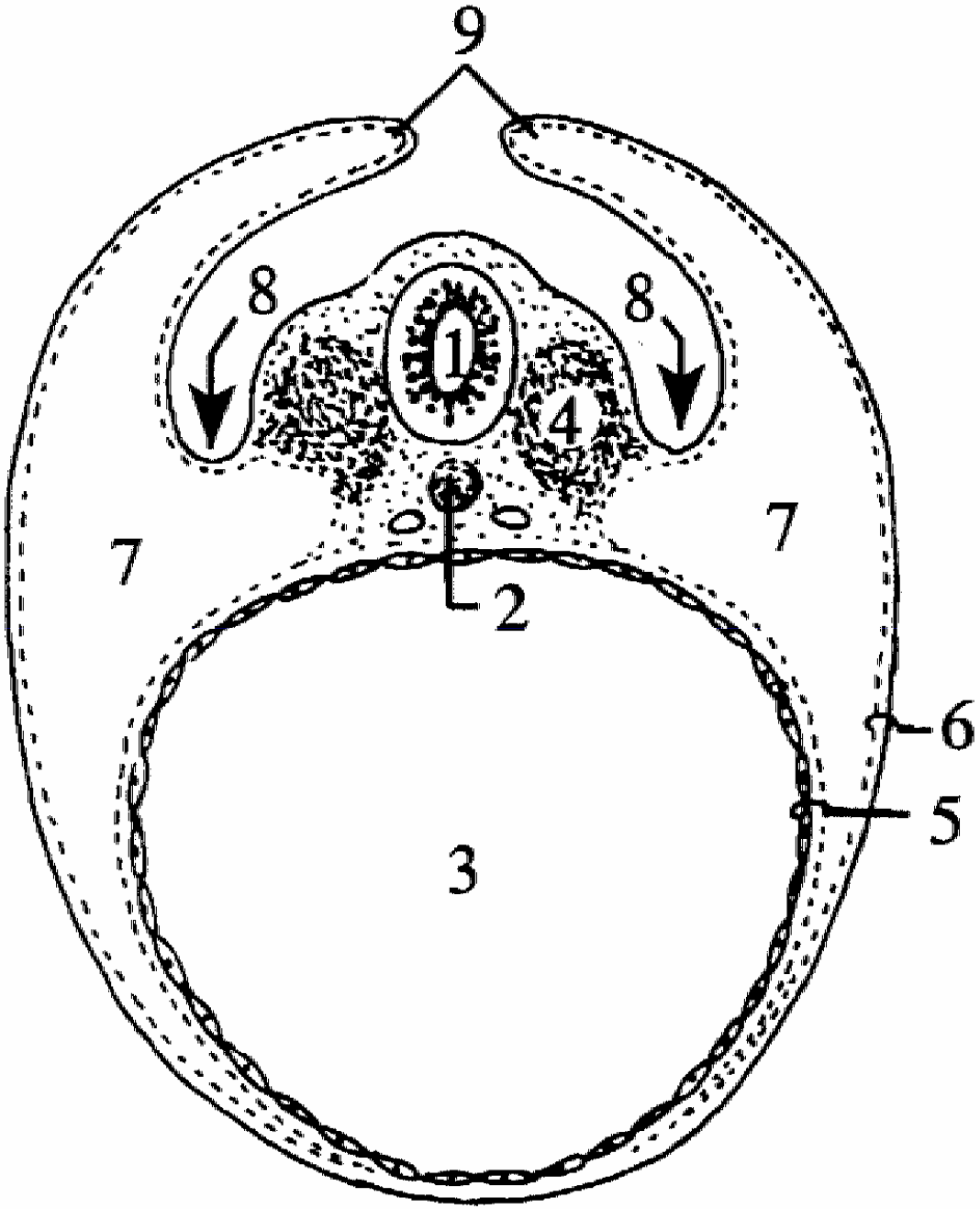
- Rapid growth of embryonal tissues
- Formation of body folds (+ amniotic folds)

Results in:

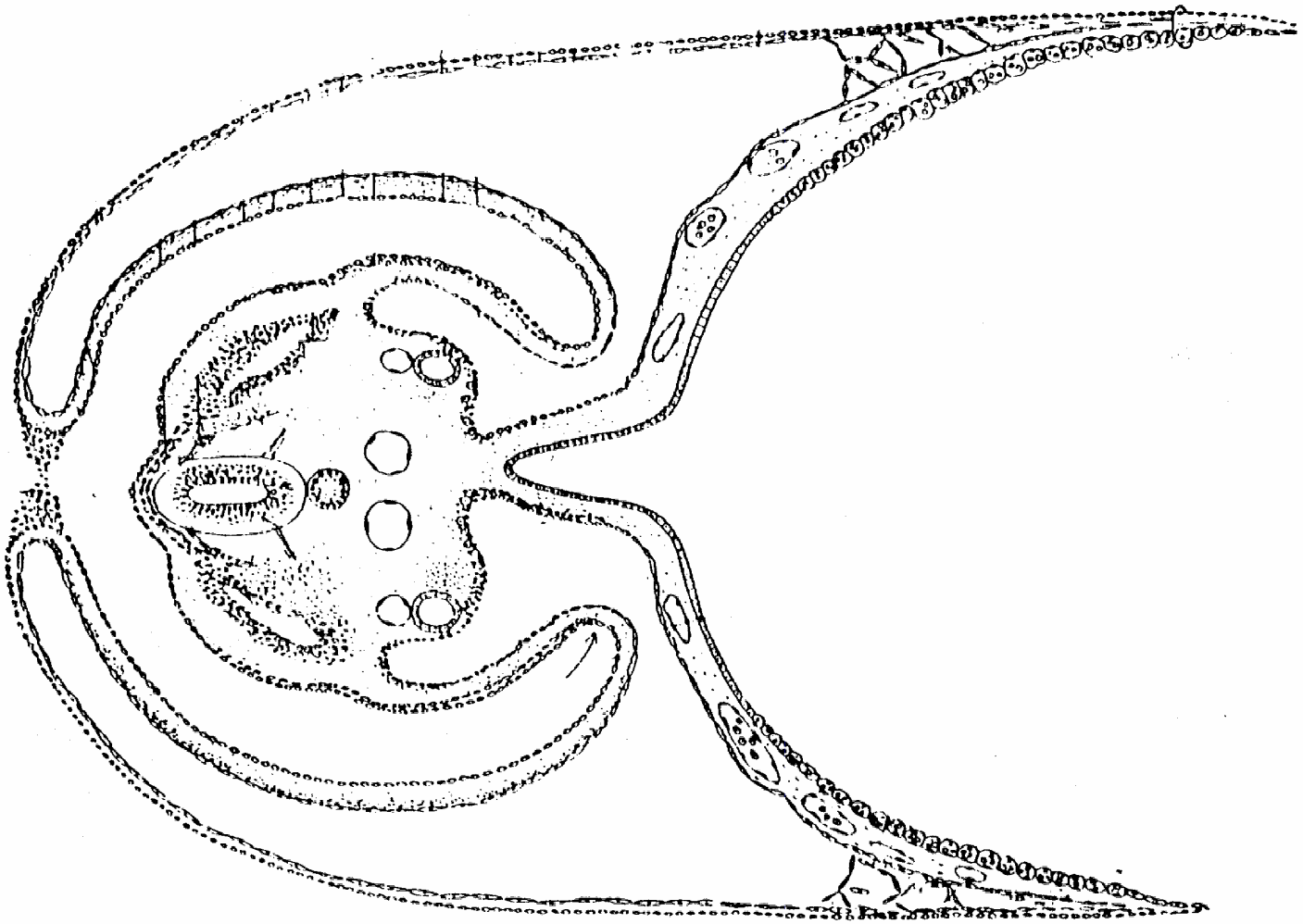
- Defining cylindrical shape of body
- Formation of primitive gut
- Formation of umbilical cord
- Correct positioning of heart, oropharyngeal and cloacal membranes
- Formation of chorion and amnion

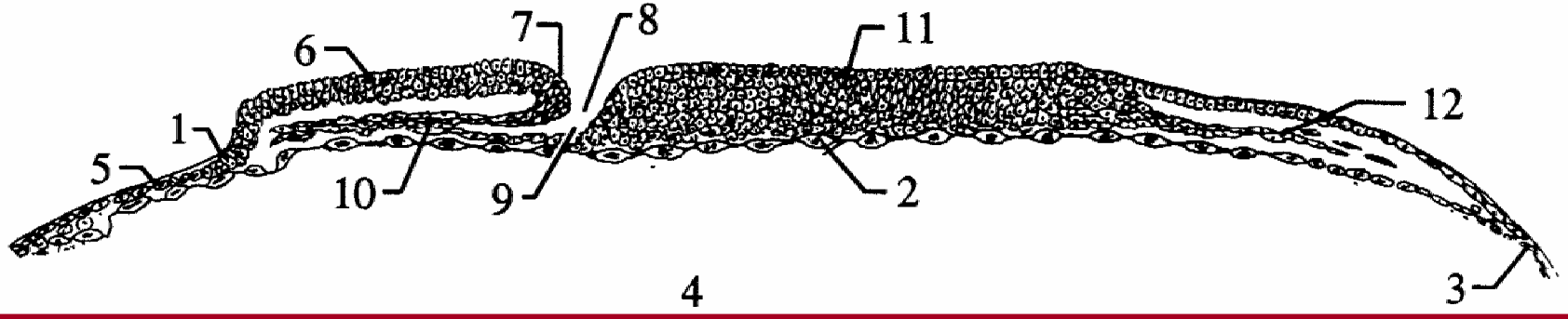


1. Primitive node
2. Primitive streak
3. Neural groove
4. Head fold
5. Tail fold
6. Lateral body fold
7. Cranial chorioamniotic fold
8. Caudal chorioamniotic fold
9. Lateral chorioamniotic fold



1. Neural tube
2. Notochord
3. Yolk sac
4. Paraxial mesoderm
5. Splanchnopleure
6. Somatopleure
7. Exocoelom
8. Lateral body fold
9. Chorioamniotic folds

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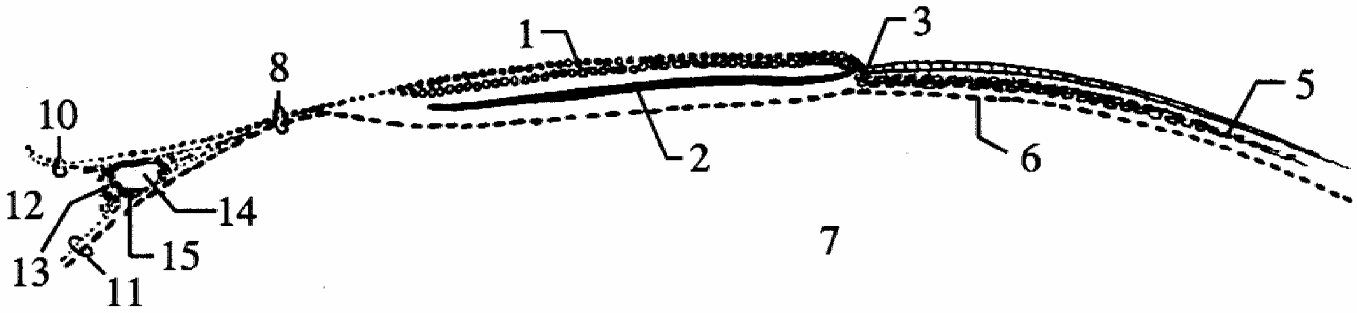
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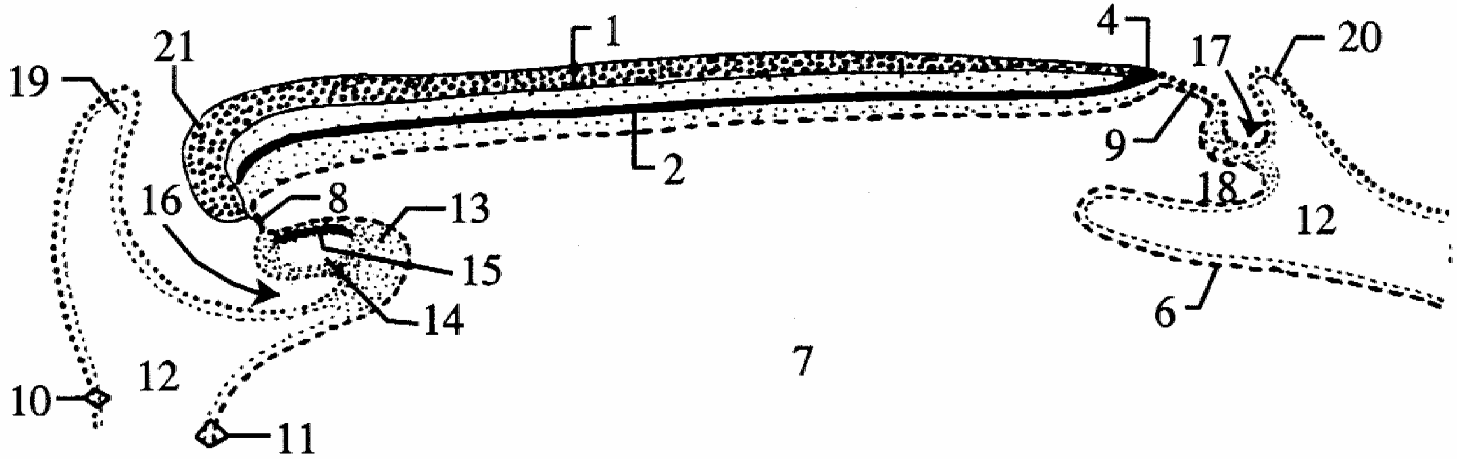
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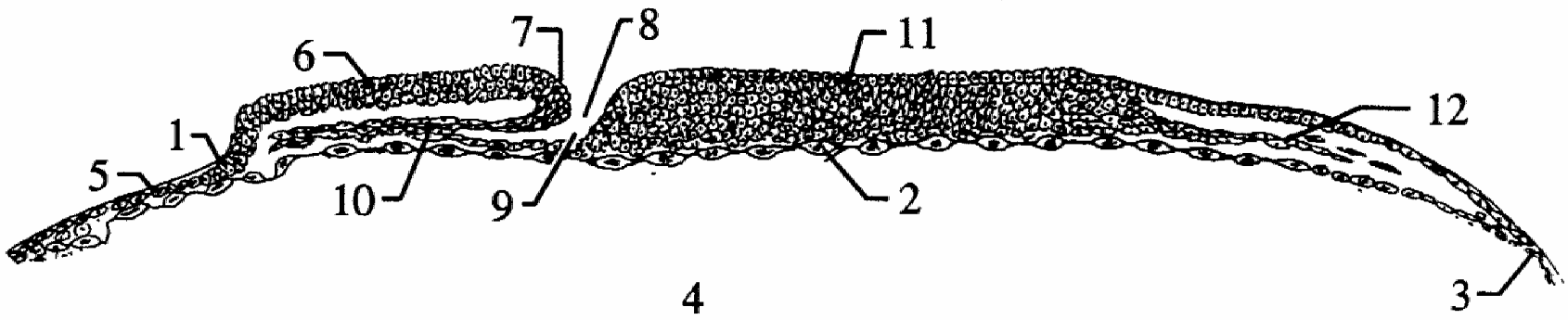
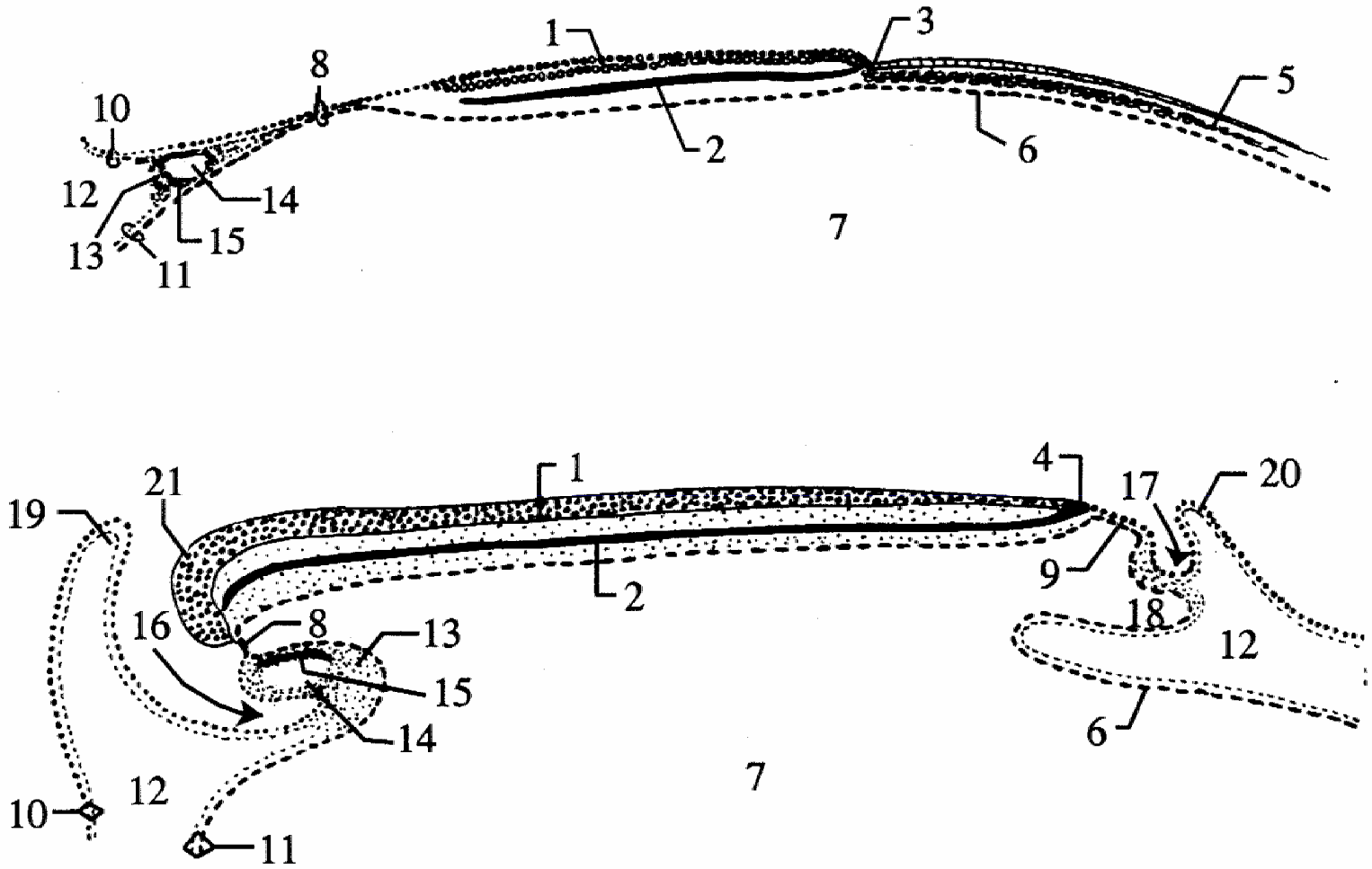
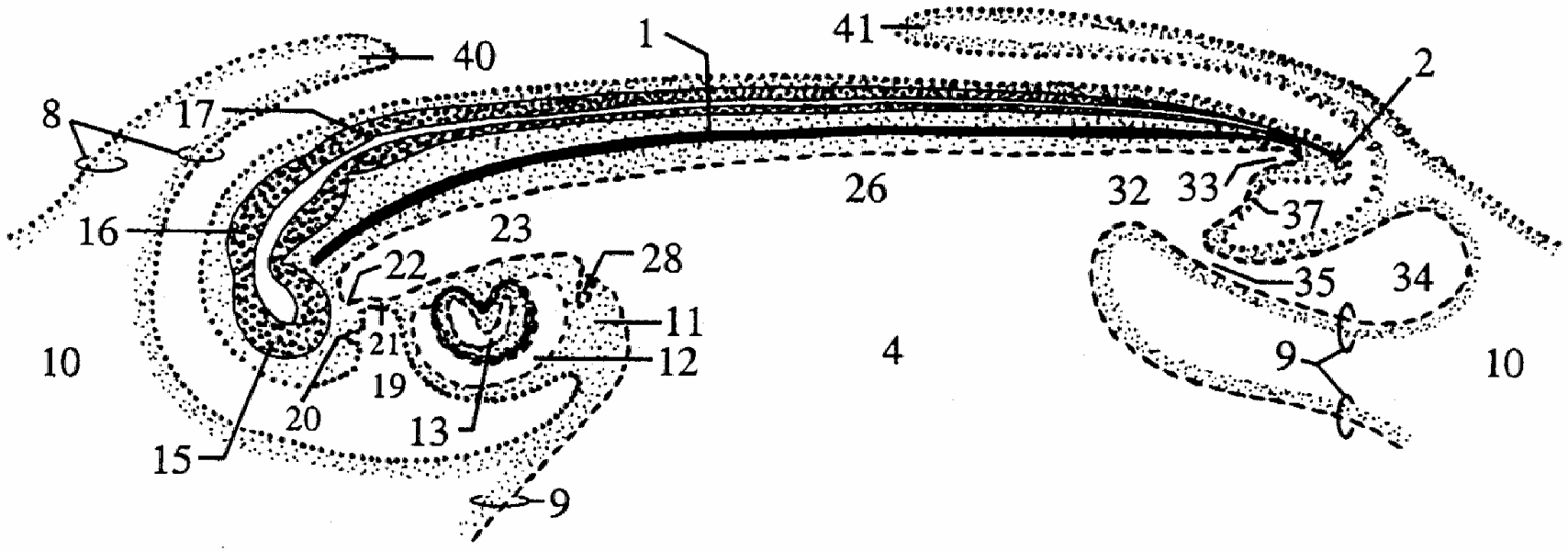


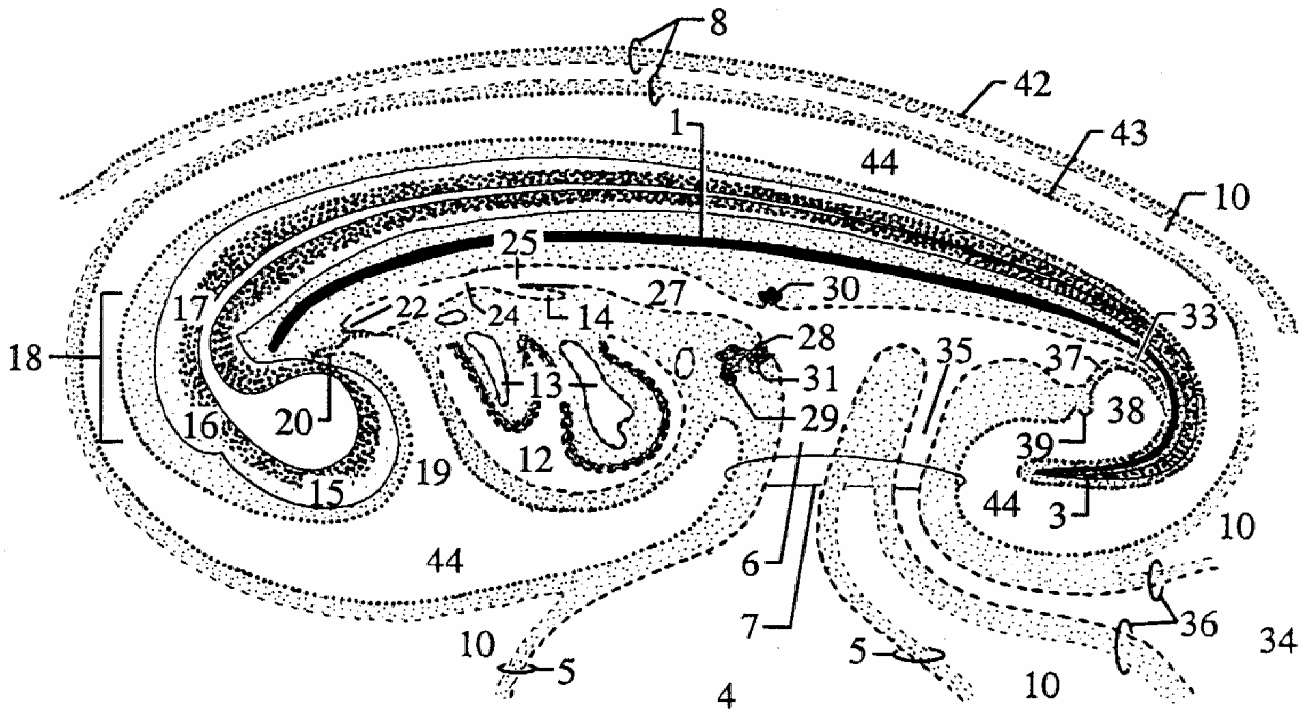
1. Epiblast
2. Embryonic endoderm
3. Extra-embryonic endoderm
4. Yolk sac
5. Pre-chordal plate
6. Neural plate
7. Primitive node
8. Primitive pit
9. Blastopore
10. Notochordal process
11. Primitive groove
12. Mesoderm



1. Neural plate
2. Notochord
3. Primitive pit
4. End bud
5. Extra-embryonic mesoderm
6. Extra-embryonic endoderm
7. Yolk sac
8. Oropharyngeal membrane
9. Cloacal membrane
10. Somatopleure
11. Splanchnopleure
12. Exocoelom
13. *Septum transversum*
14. Pleuropericardial coelom
15. Cardiogenic plate
16. Head fold
17. Tail fold
18. Allantois
19. Cranial chorioamniotic fold
20. Caudal chorioamniotic fold
21. Cephalic flexure



1. Notochord
2. Tail bud
3. Tail
4. Yolk sac
5. Yolk sac splanchnopleure
6. Vitelline duct
7. Umbilical cord
8. Somatopleure
9. Splanchnopleure
10. Exocoelom
11. *Septum transversum*
12. Pericardial cavity
13. Heart
14. Lung primordium
15. Prosencephalon
16. Mesencephalon
17. Rhombencephalon
18. Cephalic flexure
19. Stomodeum
20. Rathke's pouch
21. Oropharyngeal membrane
22. Seessel's pouch
23. Pre-enteron
24. Pharynx
25. Esophagus
26. Mesenteron
27. Stomach
28. Liver primordium
29. Gall bladder
30. Dorsal pancreas
31. Ventral pancreas
32. Metenteron
33. Tail gut
34. Allantois
35. Allantoic duct
36. Allantoic splanchnopleure
37. Cloacal membrane
38. Proctodeum
39. Phallus
40. Cranial chorioamniotic fold
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity



1. Notochord
2. Tail bud
3. Tail
4. Yolk sac
5. Yolk sac splanchnopleure
6. Vitelline duct
7. Umbilical cord
8. Somatopleure
9. Splanchnopleure
10. Exocoelom
11. *Septum transversum*
12. Pericardial cavity
13. Heart
14. Lung primordium
15. Prosencephalon
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17. Rhombencephalon
18. Cephalic flexure
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20. Rathke's pouch
21. Oropharyngeal membrane
22. Seessel's pouch
23. Pre-enteron
24. Pharynx
25. Esophagus
26. Mesenteron
27. Stomach
28. Liver primordium
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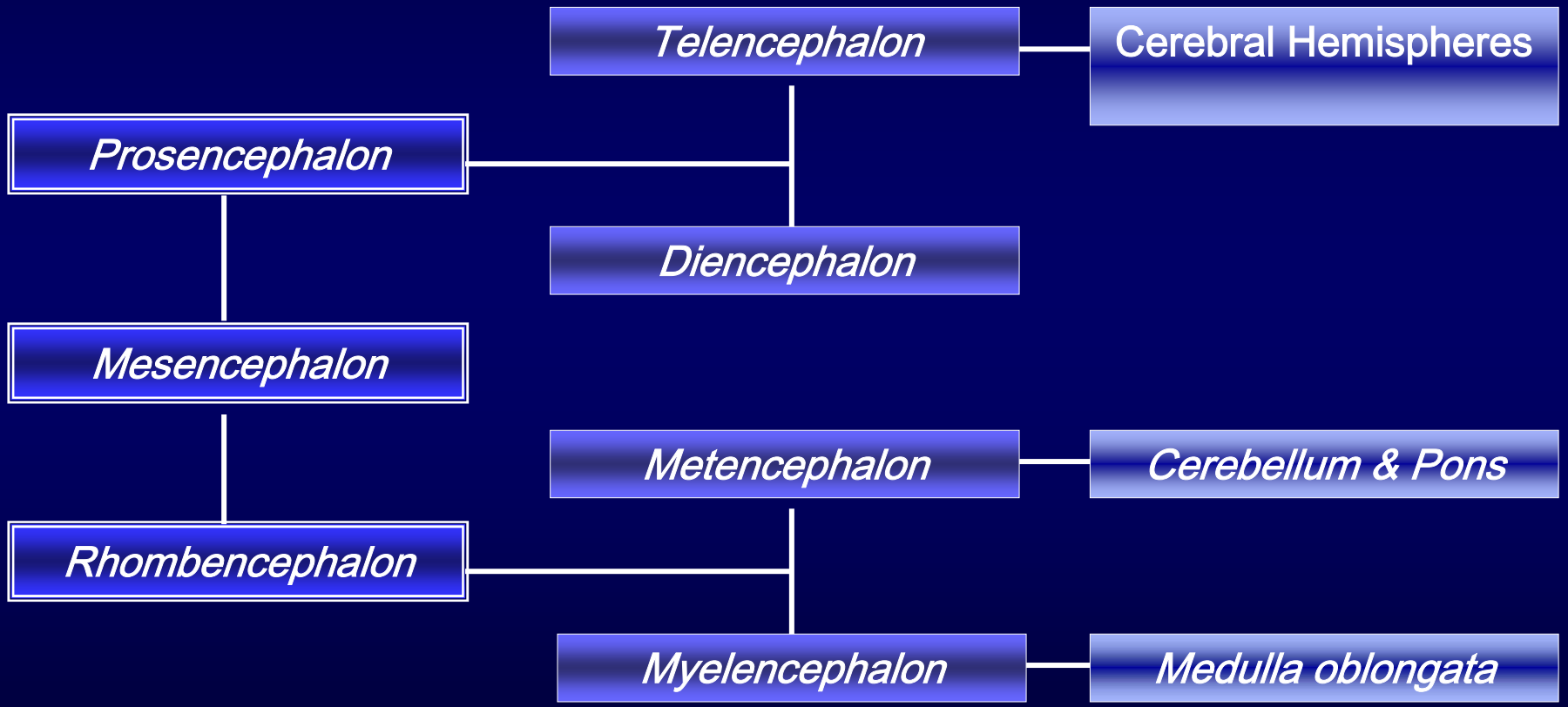
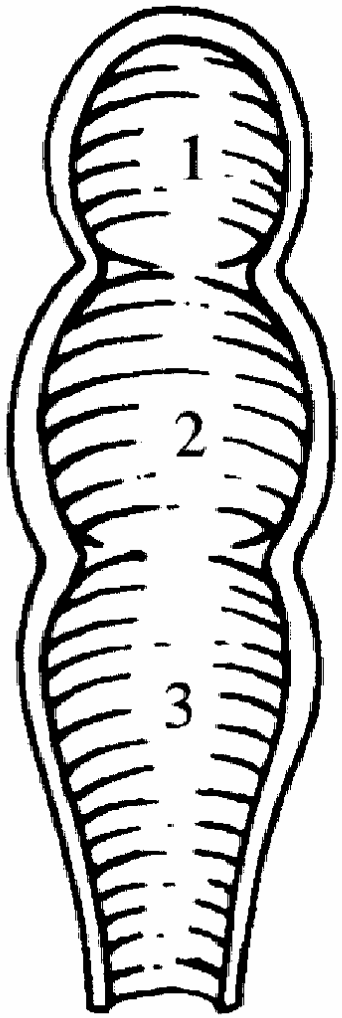
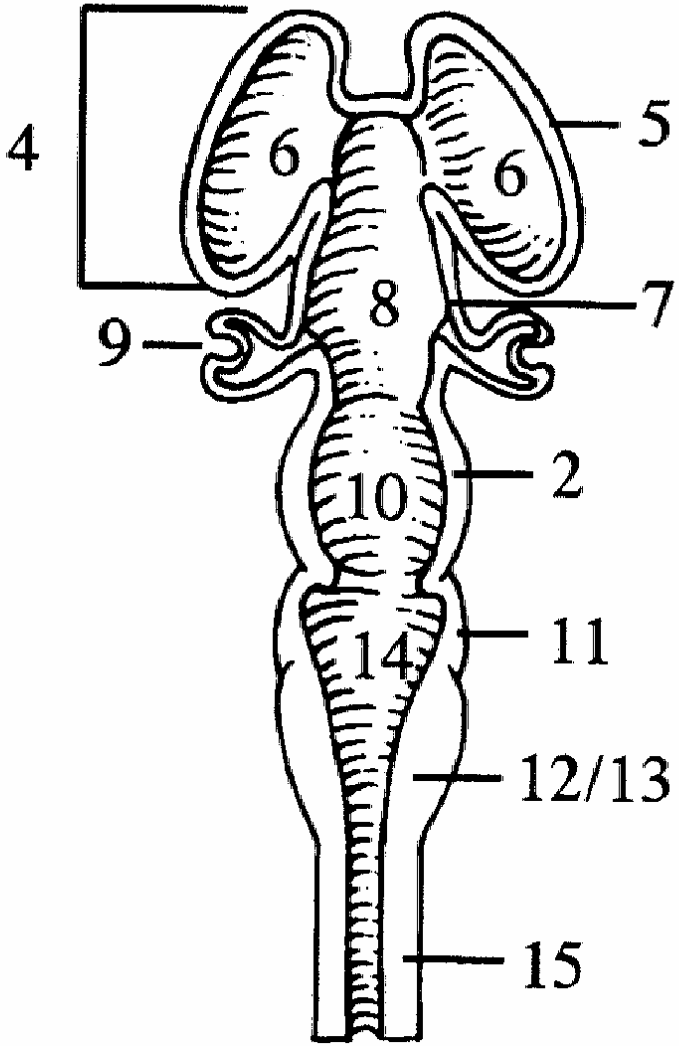
32. Metenteron
33. Tail gut
34. Allantois
35. Allantoic duct
36. Allantoic splanchnopleure
37. Cloacal membrane
38. Proctodeum
39. Phallus
40. Cranial chorioamniotic fold
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity

Further development of the Nervous System

Development of the Brain: Summary

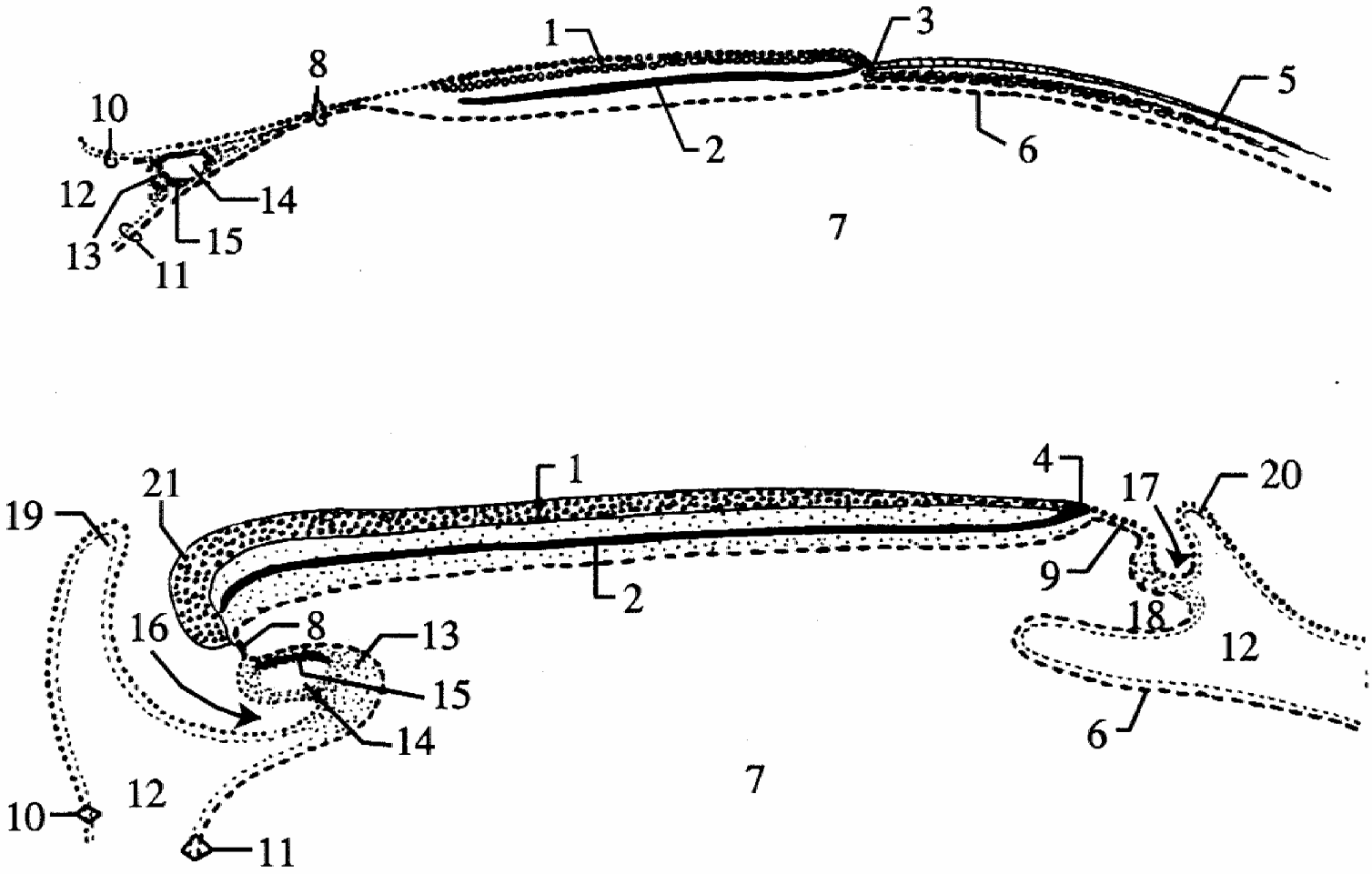




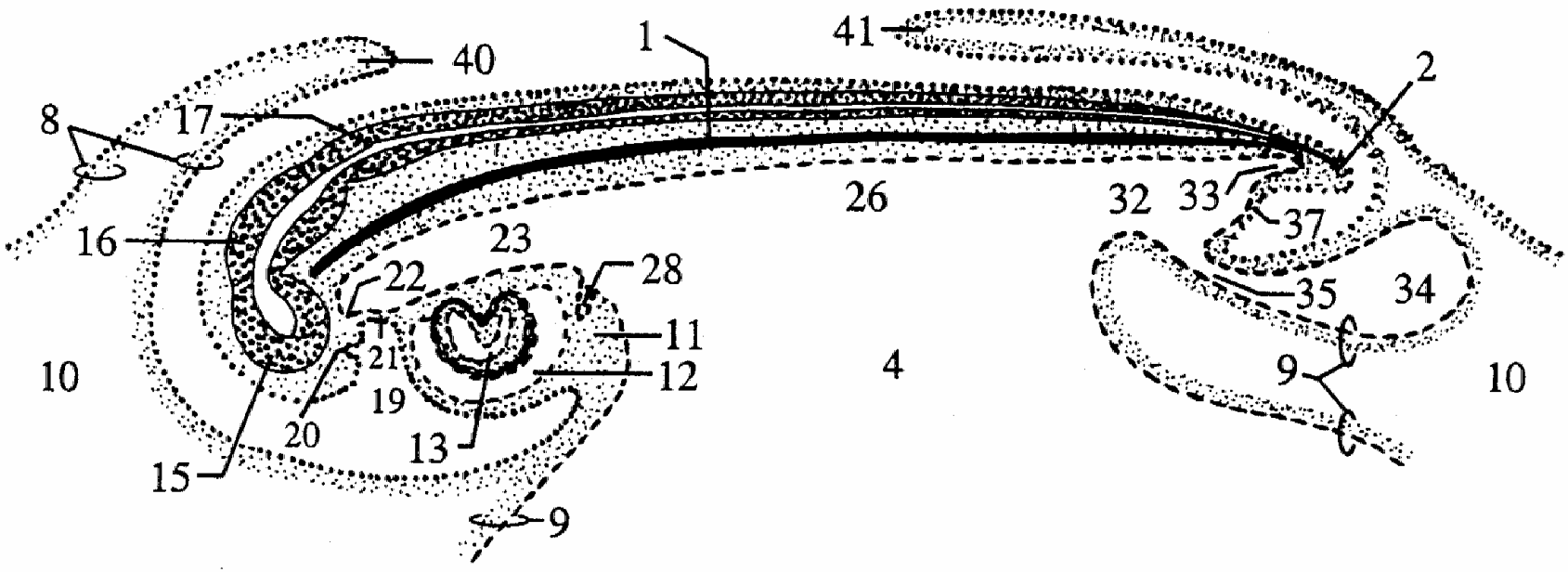


1. *Prosencephalon*
2. *Mesencephalon*
3. *Rhombencephalon*
4. *Telencephalon*
5. Cerebral hemisphere
6. Lateral ventricle
7. *Diencephalon*
8. Third ventricle
9. Optic cup
10. Mesencephalic aqueduct
11. *Metencephalon*
12. *Myelencephalon*
13. *Medulla oblongata*
14. Fourth ventricle
15. Spinal cord

Initial development of Cardio-Vascular System



1. Neural plate
2. Notochord
3. Primitive pit
4. End bud
5. Extra-embryonic mesoderm
6. Extra-embryonic endoderm
7. Yolk sac
8. Oropharyngeal membrane
9. Cloacal membrane
10. Somatopleure
11. Splanchnopleure
12. Exocoelom
13. *Septum transversum*
14. Pleuropericardial coelom
15. Cardiogenic plate
16. Head fold
17. Tail fold
18. Allantois
19. Cranial chorioamniotic fold
20. Caudal chorioamniotic fold
21. Cephalic flexure



1. Notochord
2. Tail bud
3. Tail
4. Yolk sac
5. Yolk sac splanchnopleure
6. Vitelline duct
7. Umbilical cord
8. Somatopleure
9. Splanchnopleure
10. Exocoelom
11. *Septum transversum*
12. Pericardial cavity
13. Heart
14. Lung primordium
15. Prosencephalon
16. Mesencephalon
17. Rhombencephalon
18. Cephalic flexure
19. Stomodeum
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30. Dorsal pancreas
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32. Metenteron
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35. Allantoic duct
36. Allantoic splanchnopleure
37. Cloacal membrane
38. Proctodeum
39. Phallus
40. Cranial chorioamniotic fold
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity

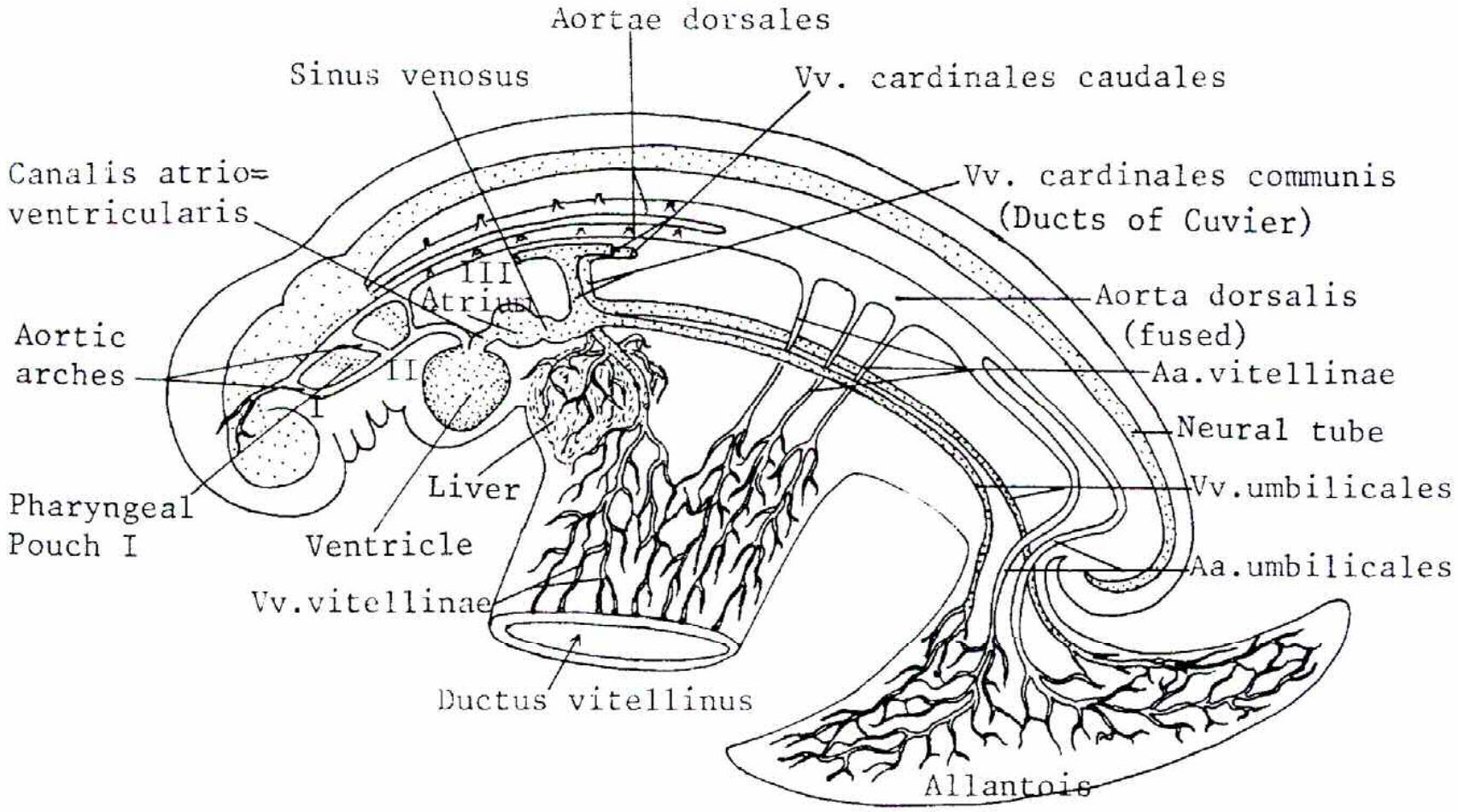
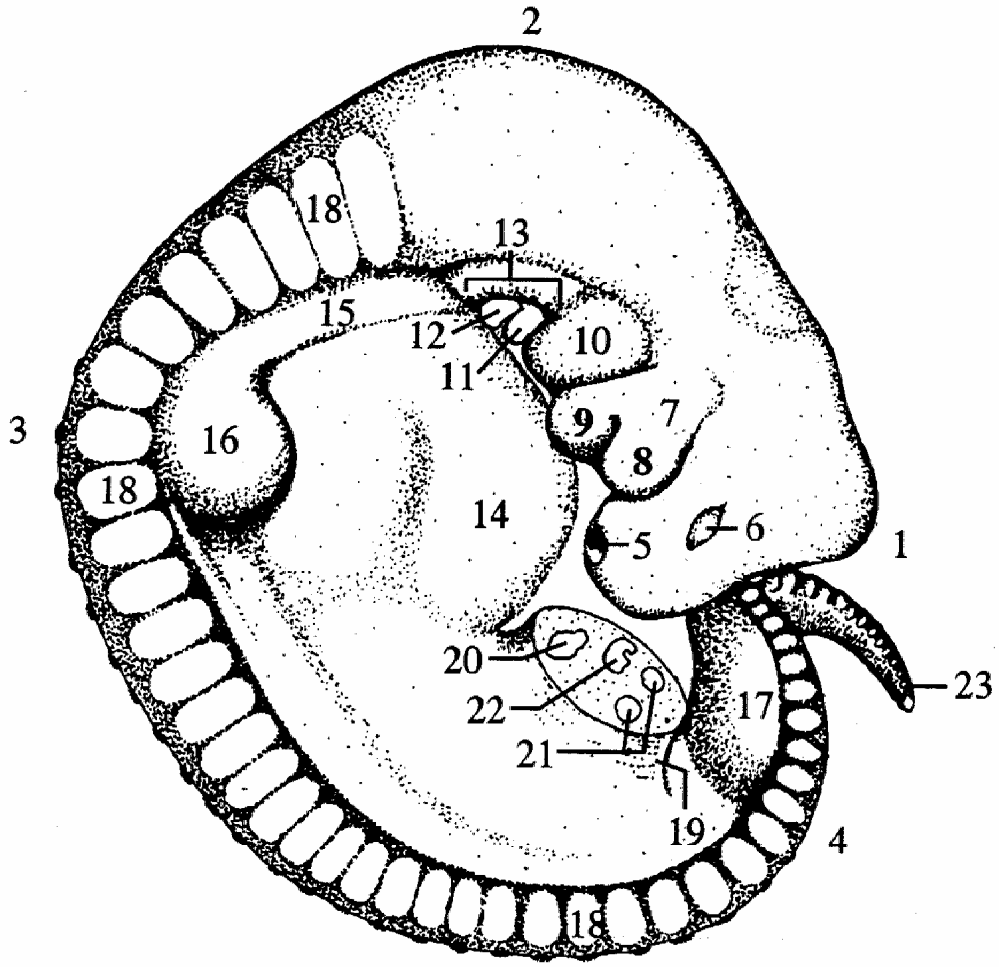


Fig. 6.1. A schematic representation of the vascular system in a pig embryo of ± 17 days.

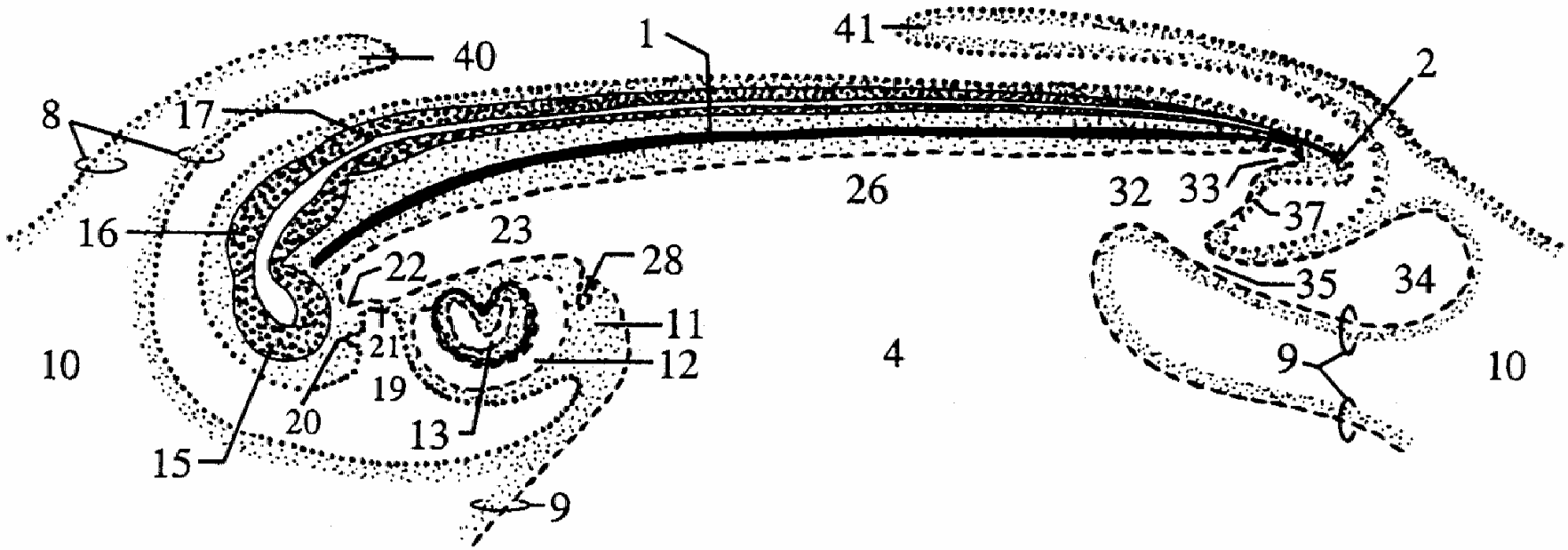


1. Cephalic flexure
2. Cervical flexure
3. Dorsal flexure
4. Sacral flexure
5. Nostril
6. Eye
7. Pharyngeal arch I
8. Maxillary prominence
9. Mandibular prominence
10. Pharyngeal arch II
11. Pharyngeal arch III
12. Pharyngeal arch IV
13. *Sinus cervicalis*
14. Heart & liver bulge
15. Wolffian ridge
16. Thoracic limb bud
17. Pelvic limb bud
18. Somites
19. Umbilical cord (transected)
20. Allantoic duct
21. Umbilical arteries
22. Umbilical vein (left)
23. Tail

Further development of the Digestive System

Stomodeum (Oral cavity)

Proctodeum (Anal canal)



1. Notochord
2. Tail bud
3. Tail
4. Yolk sac
5. Yolk sac splanchnopleure
6. Vitelline duct
7. Umbilical cord
8. Somatopleure
9. Splanchnopleure
10. Exocoelom
11. *Septum transversum*
12. Pericardial cavity
13. Heart
14. Lung primordium
15. Prosencephalon
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17. Rhombencephalon
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39. Phallus
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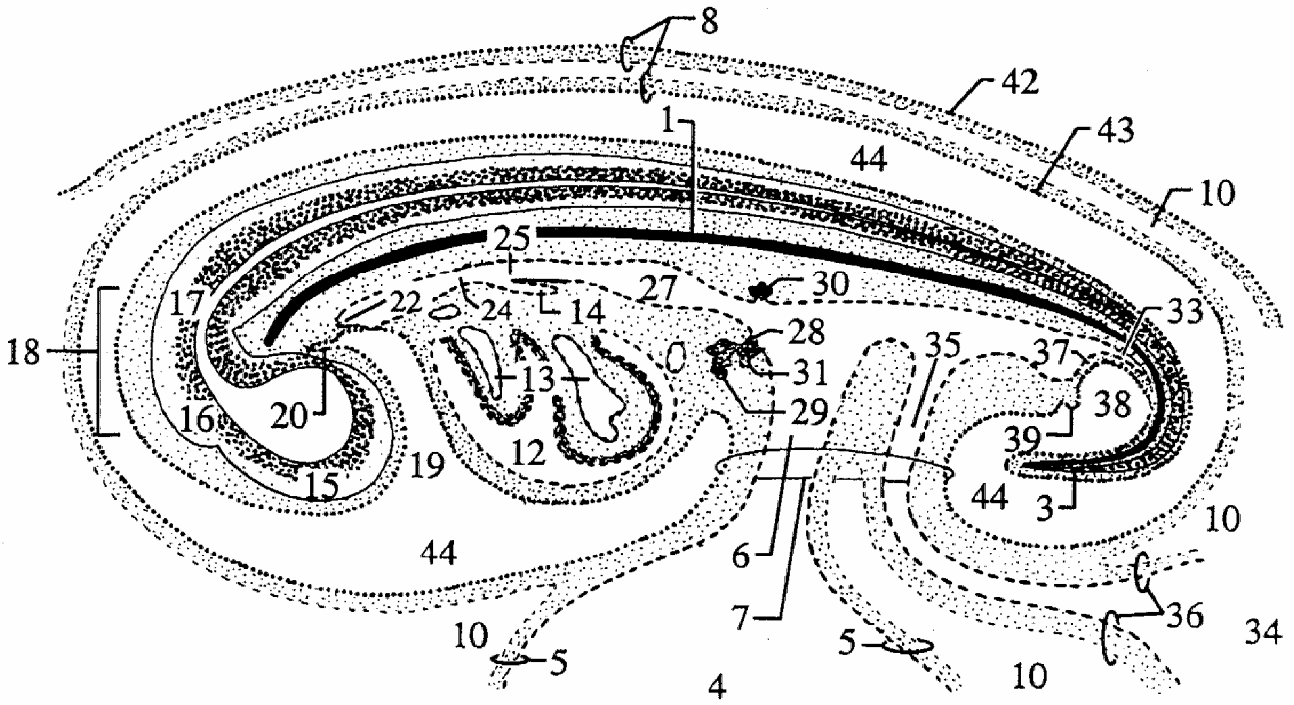
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity



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25. Esophagus
26. Mesenteron
27. Stomach
28. Liver primordium
29. Gall bladder
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31. Ventral pancreas
32. Metenteron
33. Tail gut
34. Allantois
35. Allantoic duct
36. Allantoic splanchnopleure
37. Cloacal membrane
38. Proctodeum
39. Phallus
40. Cranial chorioamniotic fold
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity

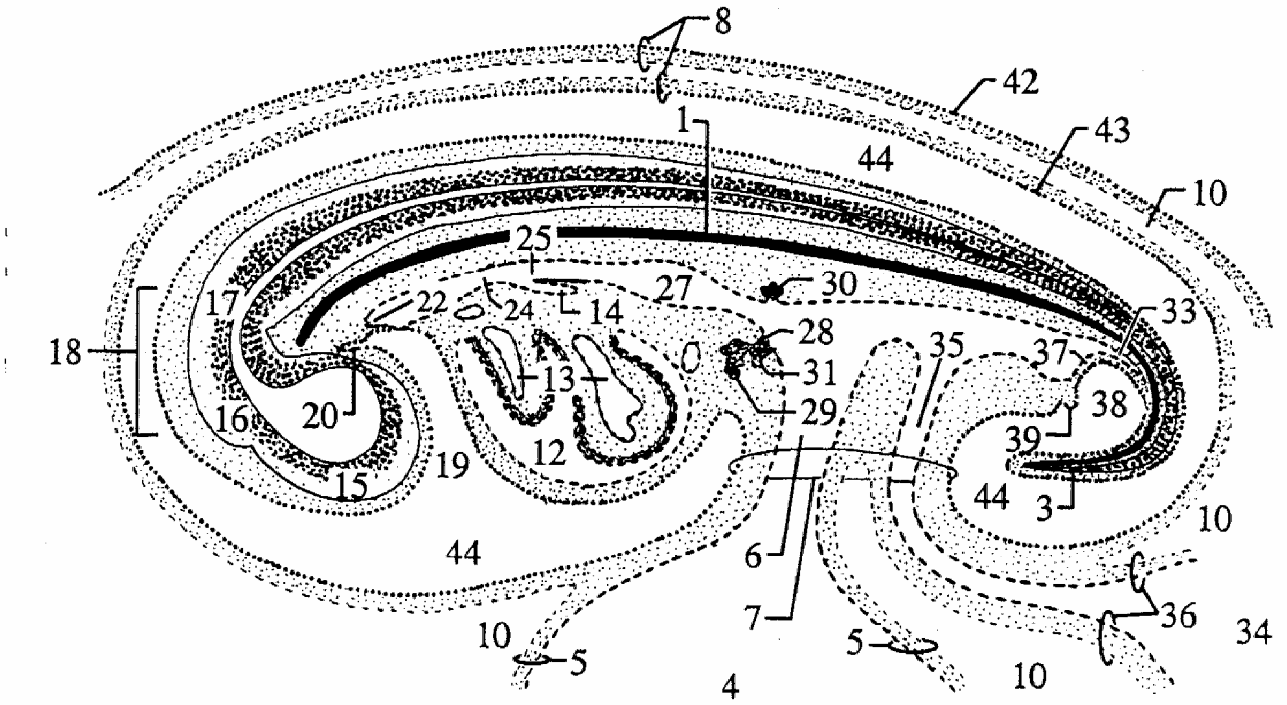
Initial development of the Urogenital System

Labio-scrotal swellings

Genital tubercule (phallus)

Allantois (Proximal segment forms bladder)

Umbilicus



1. Notochord
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3. Tail
4. Yolk sac
5. Yolk sac splanchnopleure
6. Vitelline duct
7. Umbilical cord
8. Somatopleure
9. Splanchnopleure
10. Exocoelom
11. *Septum transversum*
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14. Lung primordium
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17. Rhombencephalon
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33. Tail gut
34. Allantois
35. Allantoic duct
36. Allantoic splanchnopleure
37. Cloacal membrane
38. Proctodeum
39. Phallus
40. Cranial chorioamniotic fold
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity

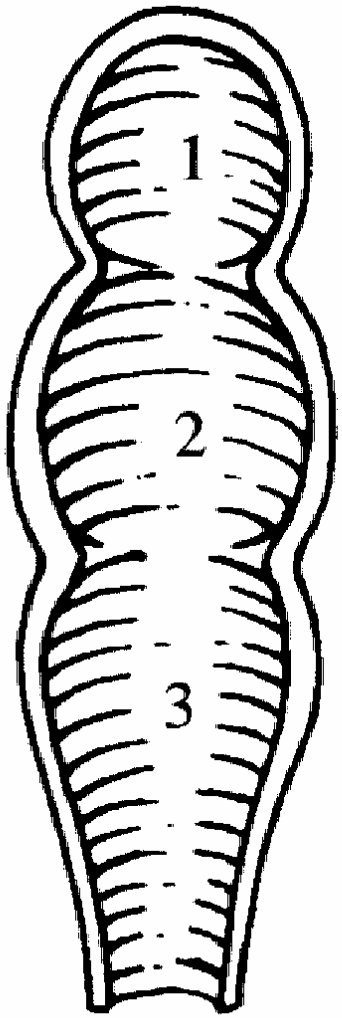
Development of the head and face

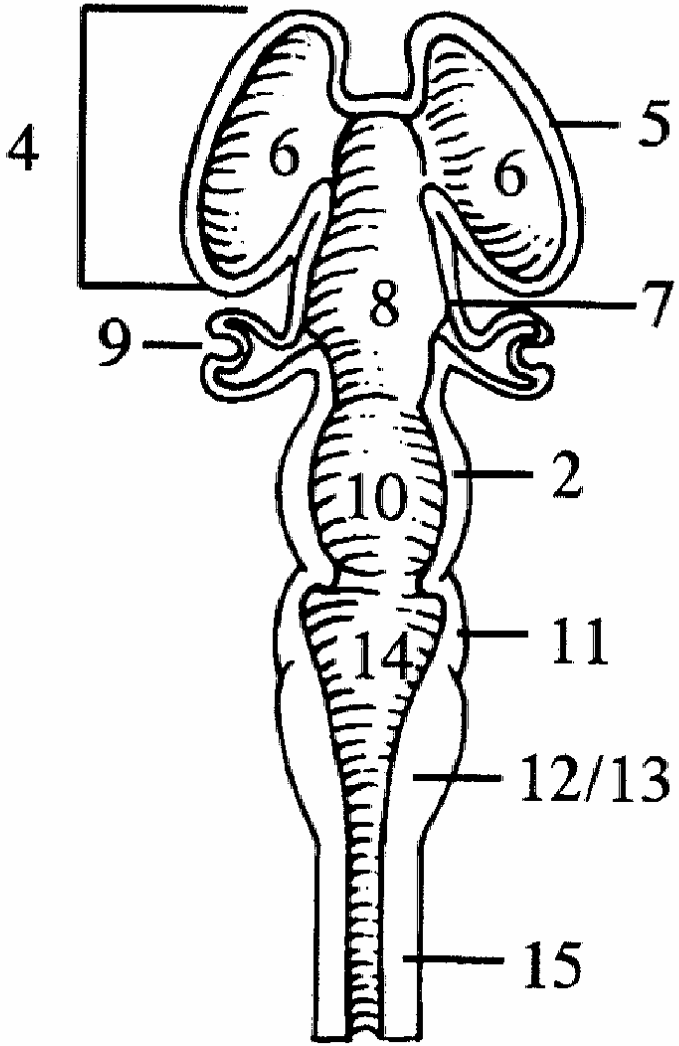
Formation of the eyes

Rathke's pouch, Seessel's pouch

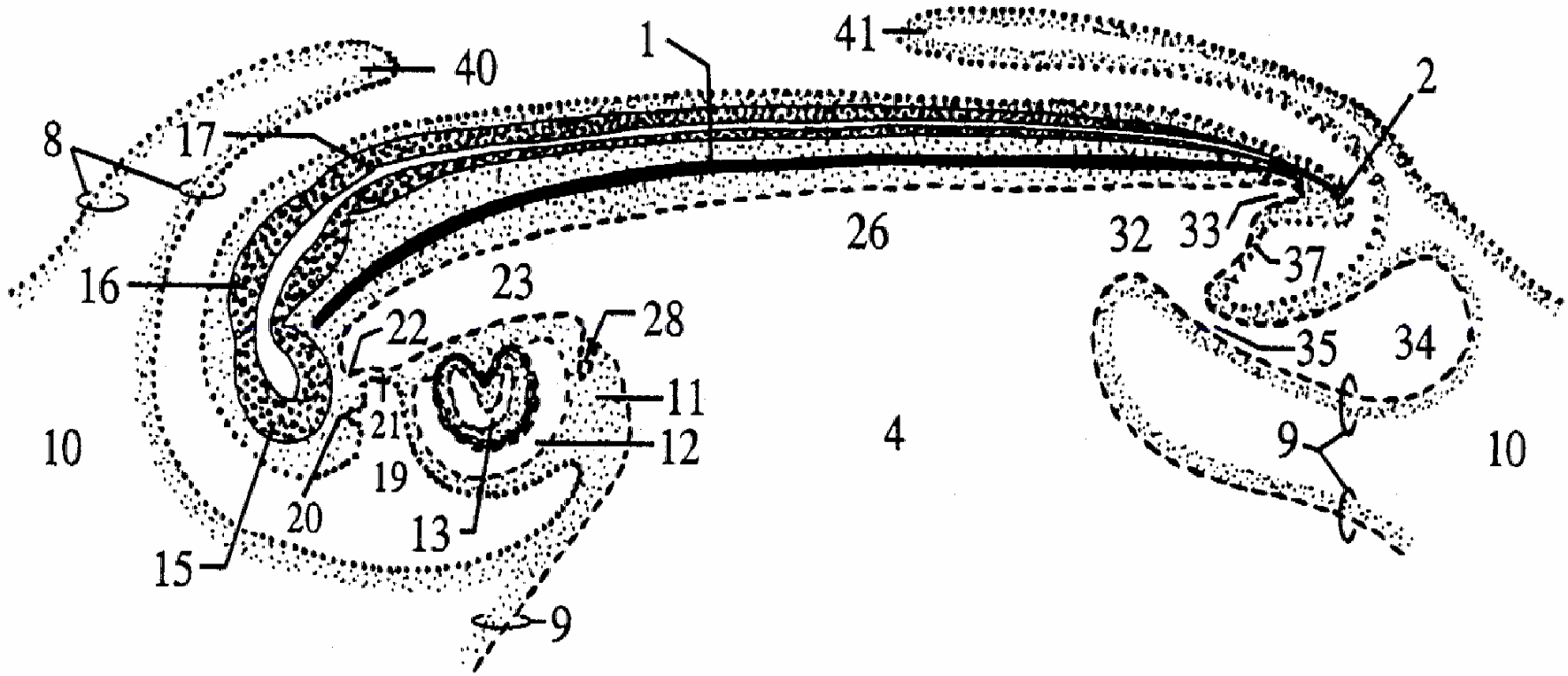
Pharyngeal pouches, arches, grooves and membranes → **Face formation**

Formation of the ear





1. *Prosencephalon*
2. *Mesencephalon*
3. *Rhombencephalon*
4. *Telencephalon*
5. Cerebral hemisphere
6. Lateral ventricle
7. *Diencephalon*
8. Third ventricle
9. Optic cup
10. Mesencephalic aqueduct
11. *Metencephalon*
12. *Myelencephalon*
13. *Medulla oblongata*
14. Fourth ventricle
15. Spinal cord



1. Notochord
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5. Yolk sac splanchnopleure
6. Vitelline duct
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9. Splanchnopleure
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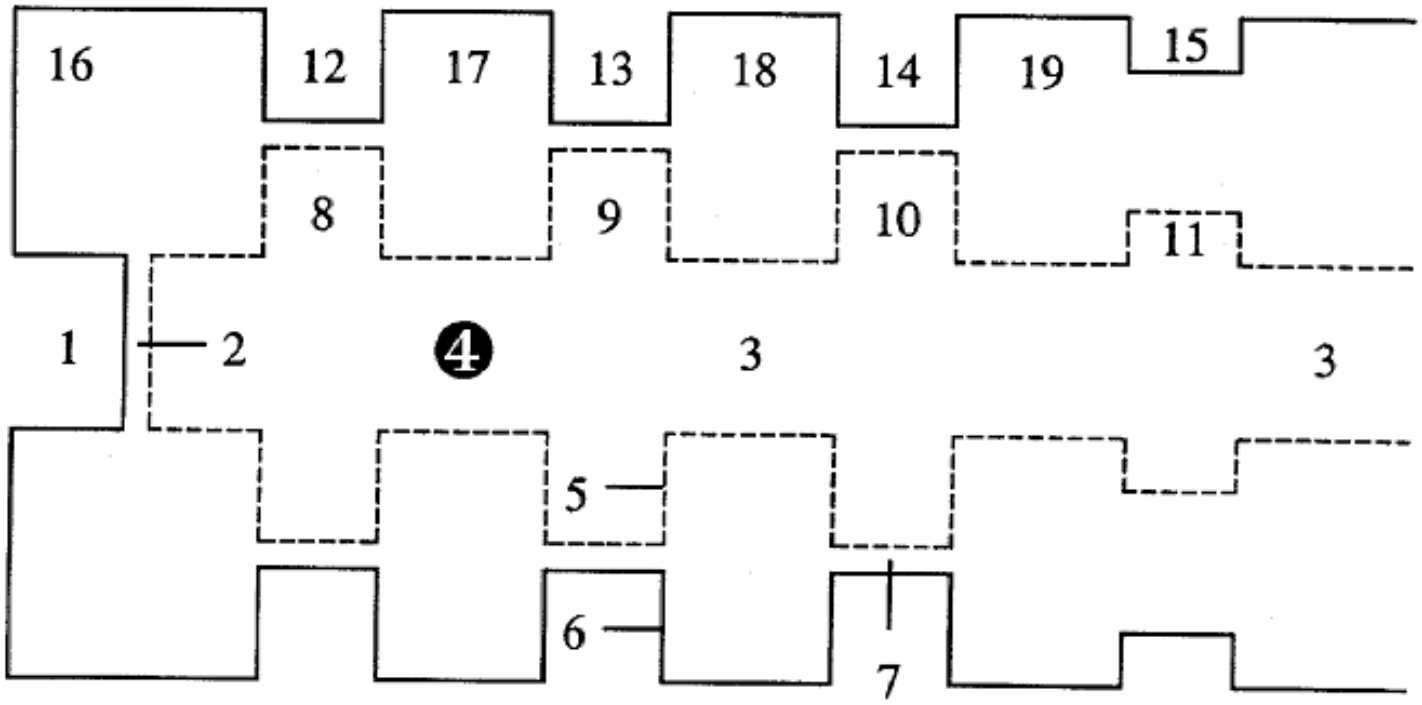
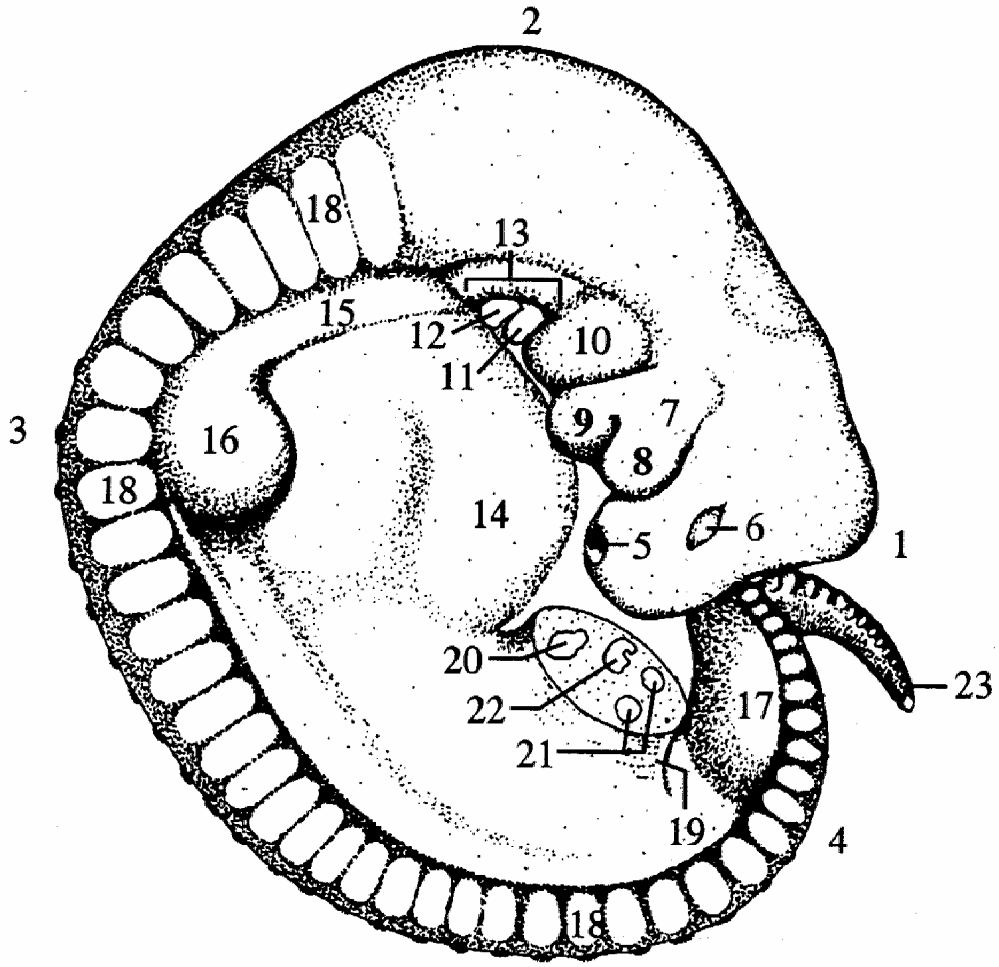
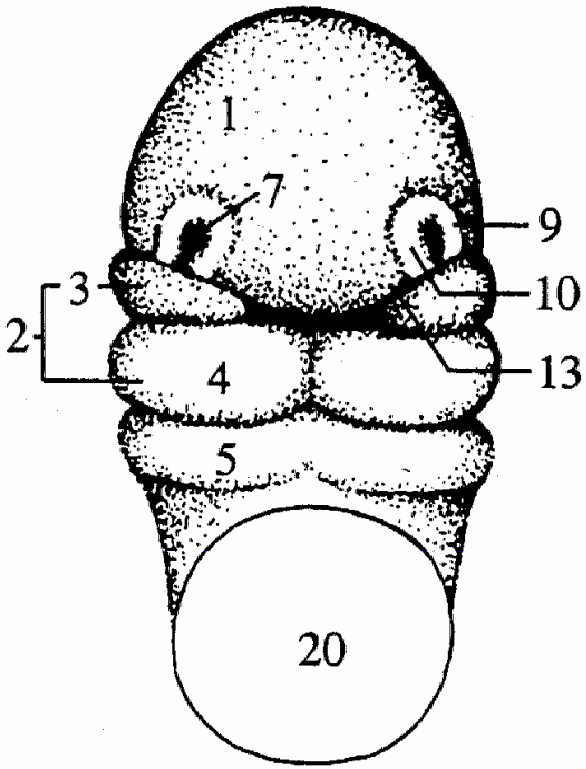
19. Stomodeum
20. Rathke's pouch
21. Oropharyngeal membrane
22. Seessel's pouch
23. Pre-enteron
24. Pharynx
25. Esophagus
26. Mesenteron
27. Stomach
28. Liver primordium
29. Gall bladder
30. Dorsal pancreas
31. Ventral pancreas
32. Metenteron
33. Tail gut
34. Allantois
35. Allantoic duct
36. Allantoic splanchnopleure
37. Cloacal membrane
38. Proctodeum
39. Phallus
40. Cranial chorioamniotic fold
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity



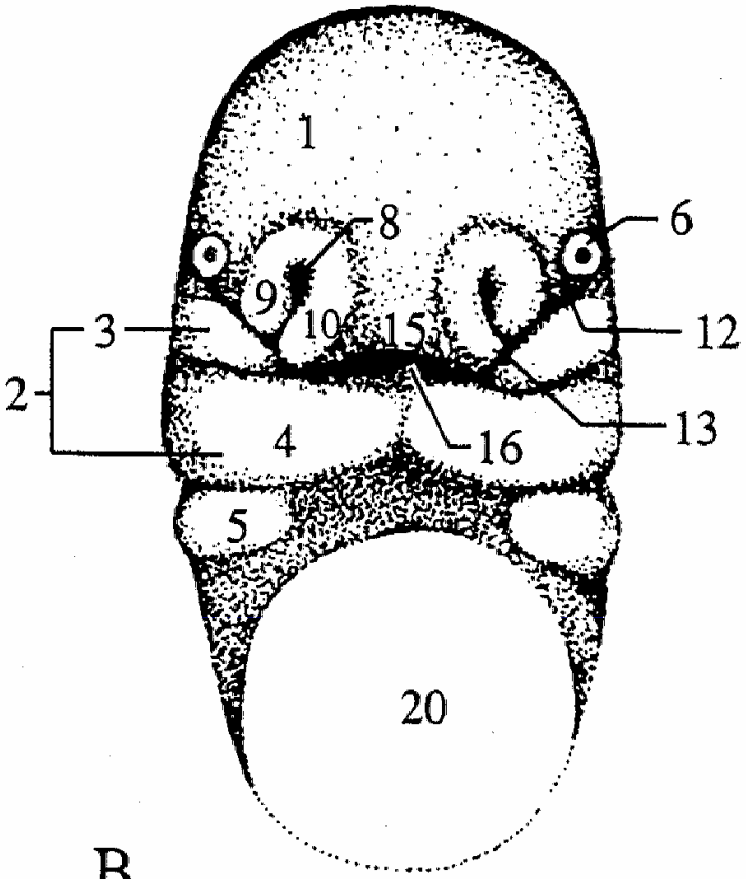
1. Stomodeum
2. Oropharyngeal membrane
3. Pre-enteron
4. Tuberculum impar
5. Endoderm
6. Ectoderm
7. Pharyngeal membrane
8. Pharyngeal pouch I
9. Pharyngeal pouch II
10. Pharyngeal pouch III
11. Pharyngeal pouch IV
12. Pharyngeal groove I
13. Pharyngeal groove II
14. Pharyngeal groove III
15. Pharyngeal groove IV
16. Pharyngeal arch I
17. Pharyngeal arch II
18. Pharyngeal arch III
19. Pharyngeal arch IV



1. Cephalic flexure
2. Cervical flexure
3. Dorsal flexure
4. Sacral flexure
5. Nostril
6. Eye
7. Pharyngeal arch I
8. Maxillary prominence
9. Mandibular prominence
10. Pharyngeal arch II
11. Pharyngeal arch III
12. Pharyngeal arch IV
13. *Sinus cervicalis*
14. Heart & liver bulge
15. Wolffian ridge
16. Thoracic limb bud
17. Pelvic limb bud
18. Somites
19. Umbilical cord (transected)
20. Allantoic duct
21. Umbilical arteries
22. Umbilical vein (left)
23. Tail

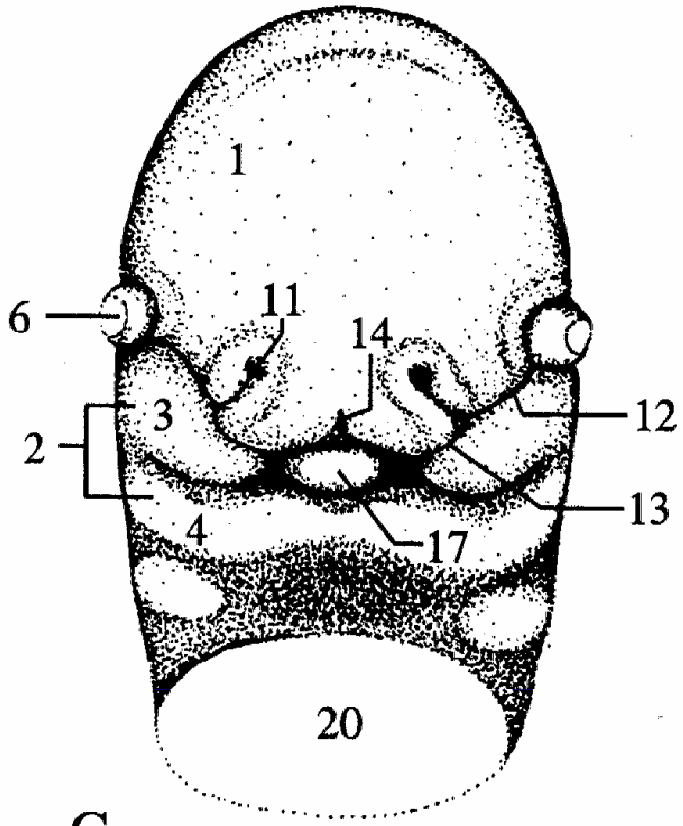


A

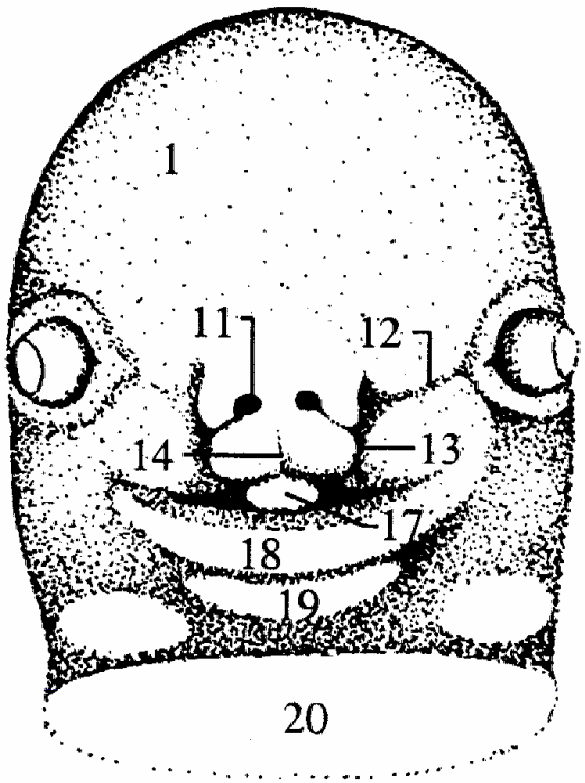


B

1. Frontonasal prominence
2. Pharyngeal arch I
3. Maxillary prominence
4. Mandibular prominence
5. Pharyngeal arch II
6. Eye
7. Nasal placode
8. Nasal pit
9. Lateral nasal prominence
10. Medial nasal prominence
11. Nostril
12. Nasolacrimal groove
13. Nasomaxillary groove
14. Philtrum
15. Upper lip
16. Oral groove
17. Tongue
18. Mandible
19. Chin
20. Neck (transected)



C

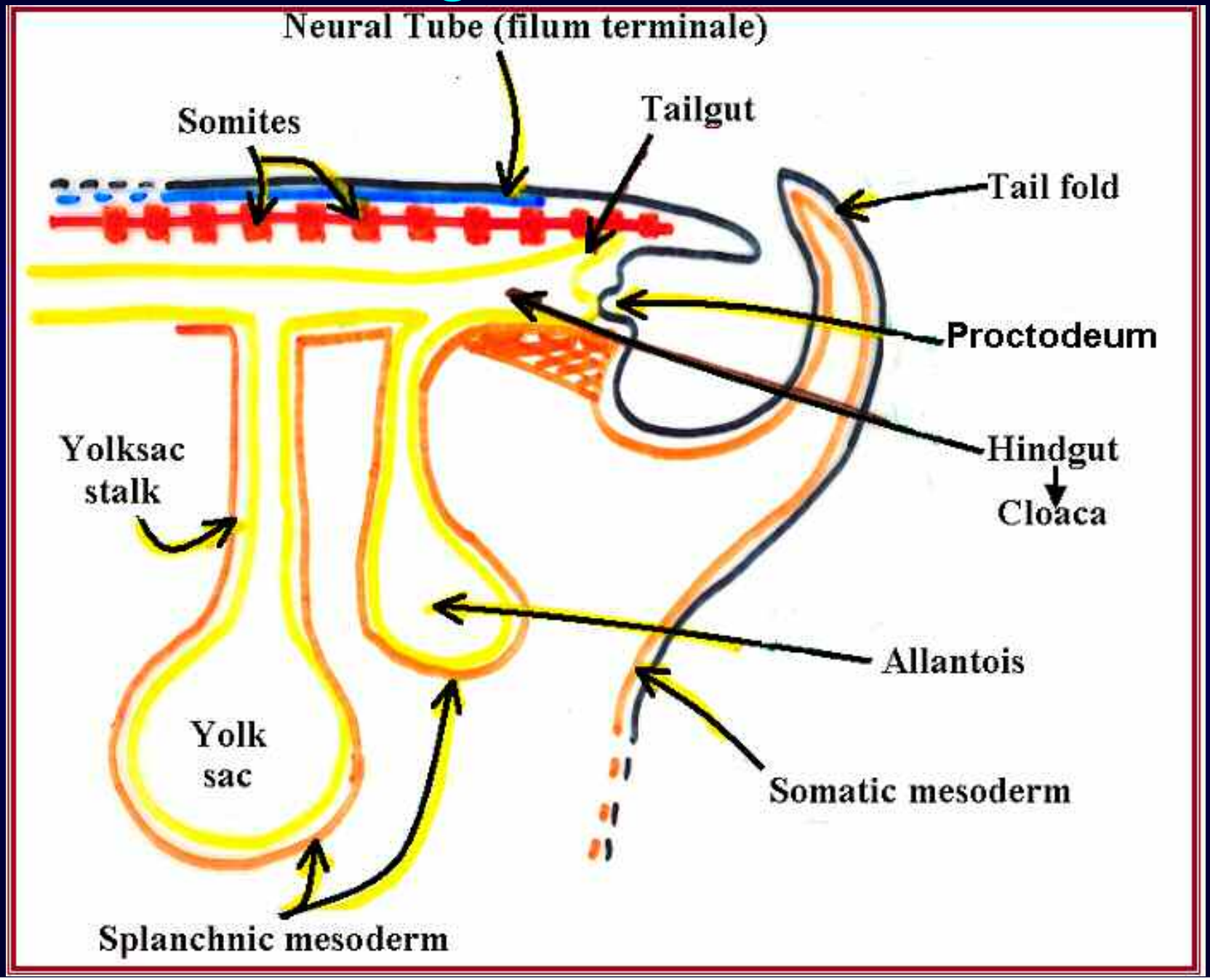


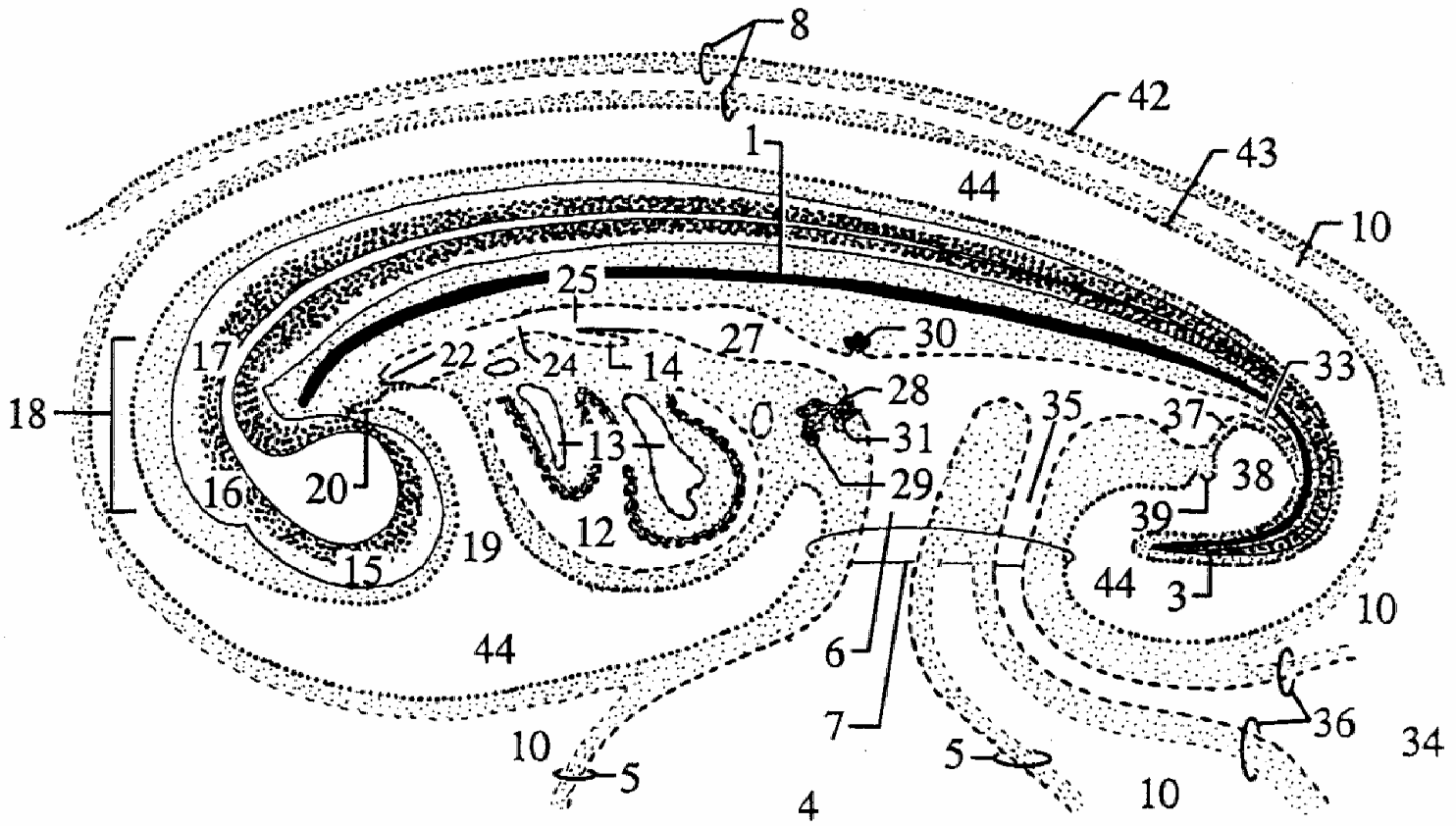
D

1. Frontonasal prominence
2. Pharyngeal arch I
3. Maxillary prominence
4. Mandibular prominence
5. Pharyngeal arch II
6. Eye
7. Nasal placode
8. Nasal pit
9. Lateral nasal prominence
10. Medial nasal prominence
11. Nostril
12. Nasolacrimal groove
13. Nasomaxillary groove
14. Philtrum
15. Upper lip
16. Oral groove
17. Tongue
18. Mandible
19. Chin
20. Neck (transected)

Formation of the tail

Longitudinal Section





1. Notochord
2. Tail bud
3. Tail
4. Yolk sac
5. Yolk sac splanchnopleure
6. Vitelline duct
7. Umbilical cord
8. Somatopleure
9. Splanchnopleure
10. Exocoelom
11. *Septum transversum*
12. Pericardial cavity
13. Heart
14. Lung primordium
15. Prosencephalon
16. Mesencephalon
17. Rhombencephalon
18. Cephalic flexure
19. Stomodeum
20. Rathke's pouch
21. Oropharyngeal membrane
22. Seessel's pouch
23. Pre-enteron
24. Pharynx
25. Esophagus
26. Mesenteron
27. Stomach
28. Liver primordium
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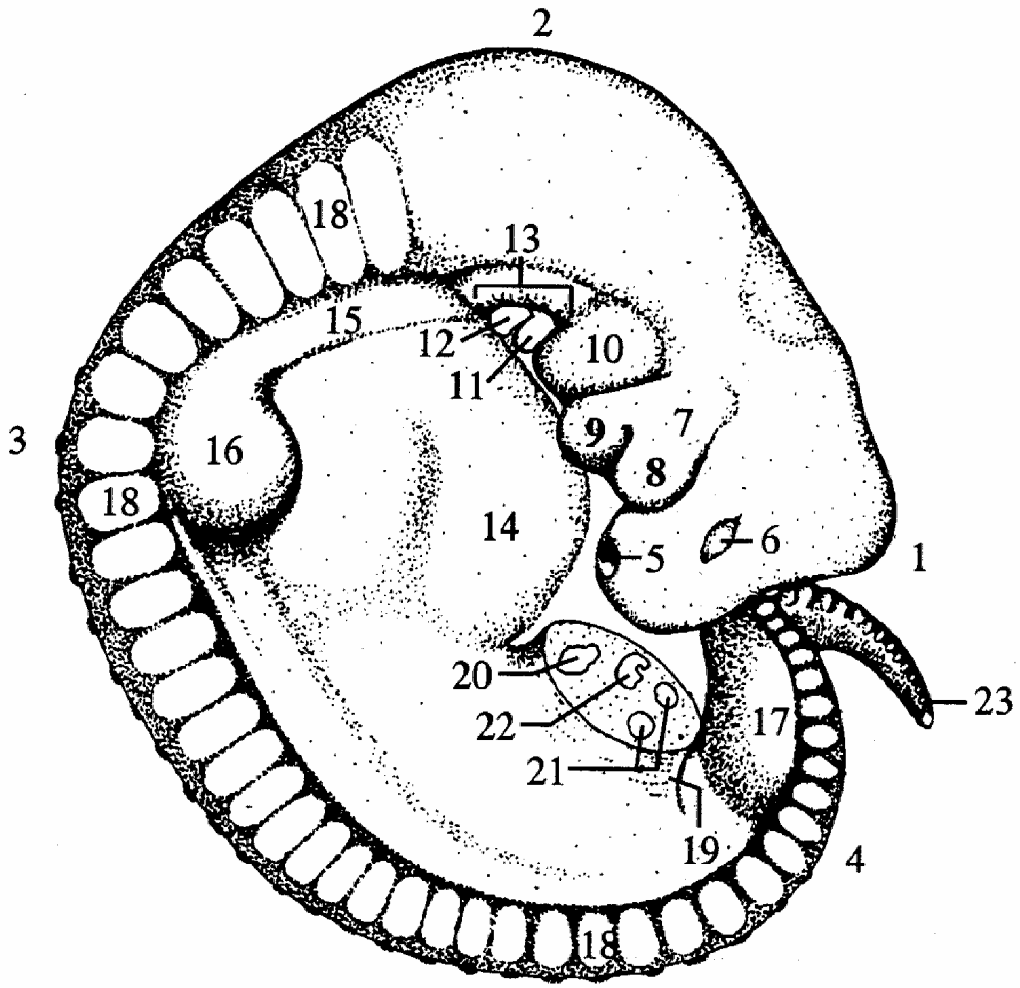
37. Cloacal membrane
38. Proctodeum
39. Phallus
40. Cranial chorioamniotic fold
41. Caudal chorioamniotic fold
42. Chorion
43. Amnion
44. Amniotic cavity

Formation of the limbs



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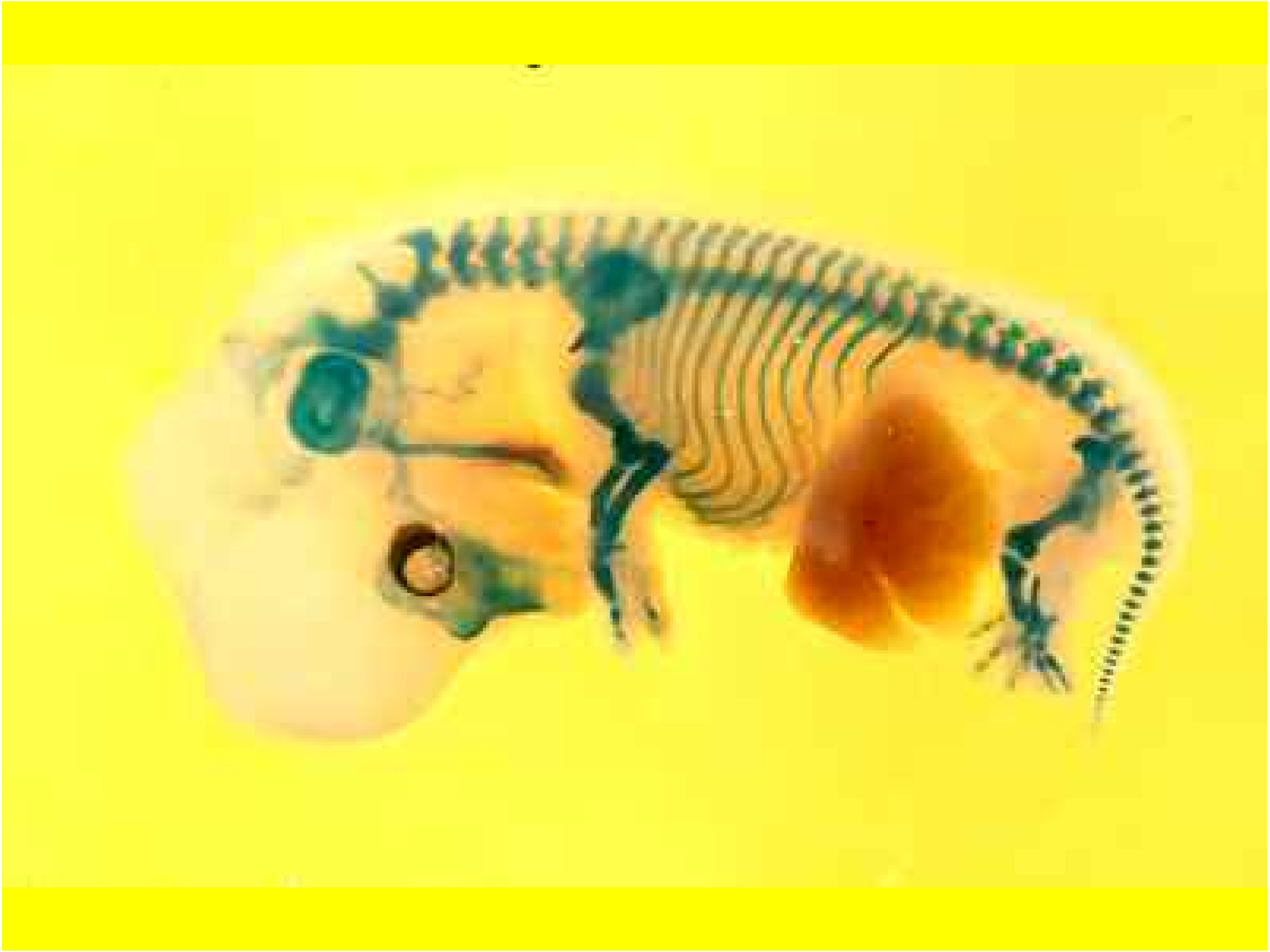
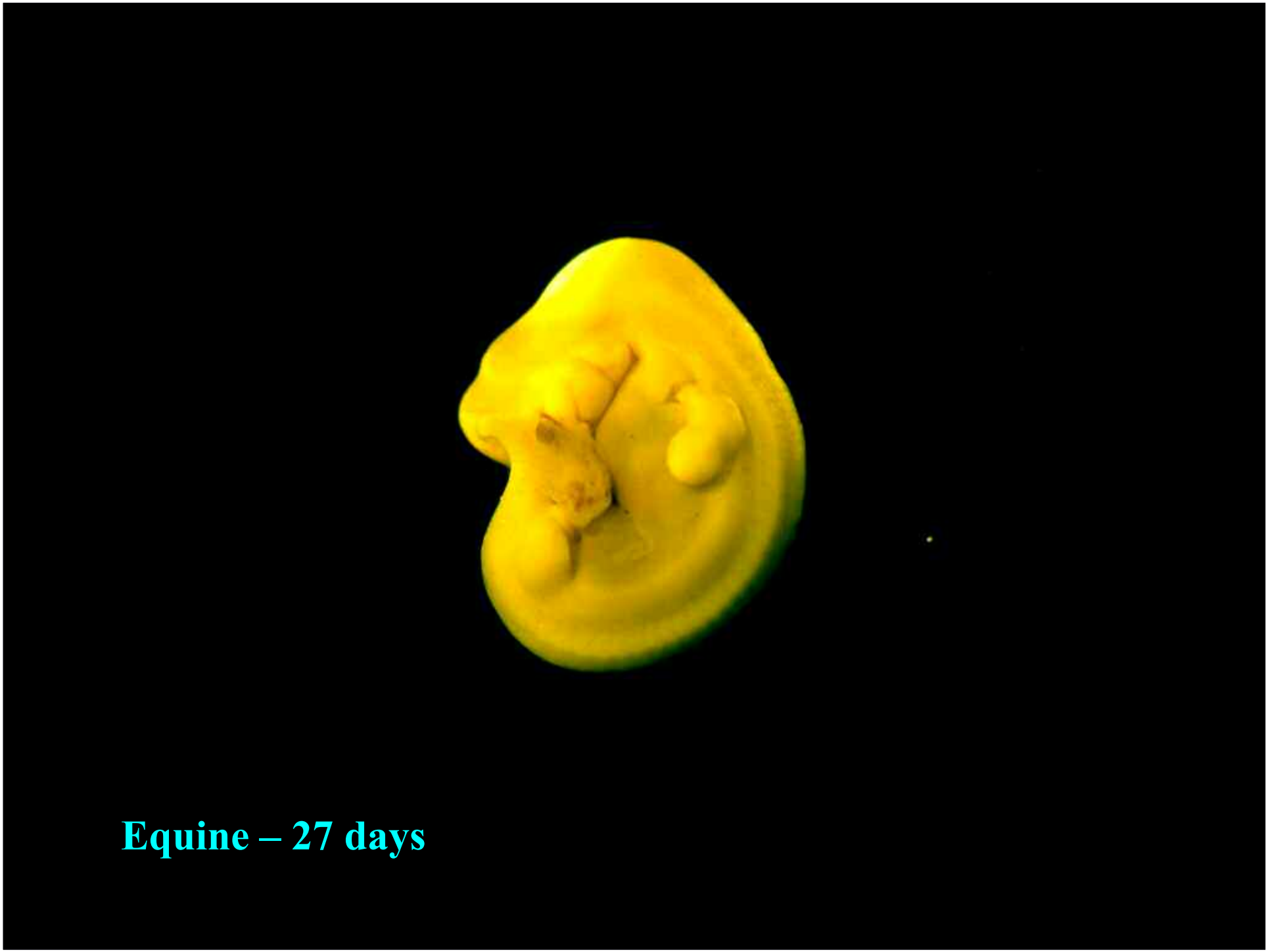
22. Umbilical vein (left)
23. Tail



Equine - 25 days



Equine – 27 days


Equine – 31.5 days

Equine – 34 days


Equine – 38 days


Equine – 40 days

Fetal Phase

Development of organ primordia

Organogenesis

Teratology