Embryology lecture 3

From the blastocyst to the neural tube

Last time, we left the embryo looking like this:

The inner cell mass makes the body itself, plus some extra-embryonic membranes

This layer, the trophoblast, will make placenta and some other extra-embryonic material

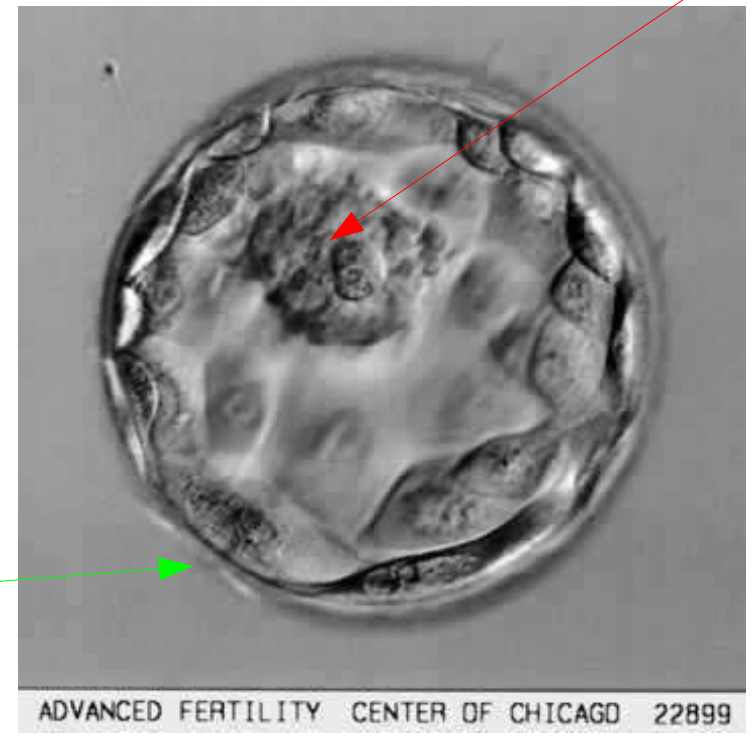


Image Credit: AFC Chicago (Creative Commons)

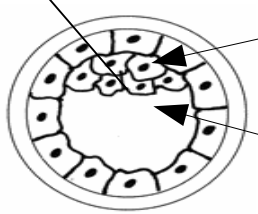
All of the cells that make your body now came from your Inner Cell Mass.

In the picture, the Inner Cell Mass is all of one type of cell.

It therefore needs to make its own internal differences.

Yet again, it uses simple geometry.

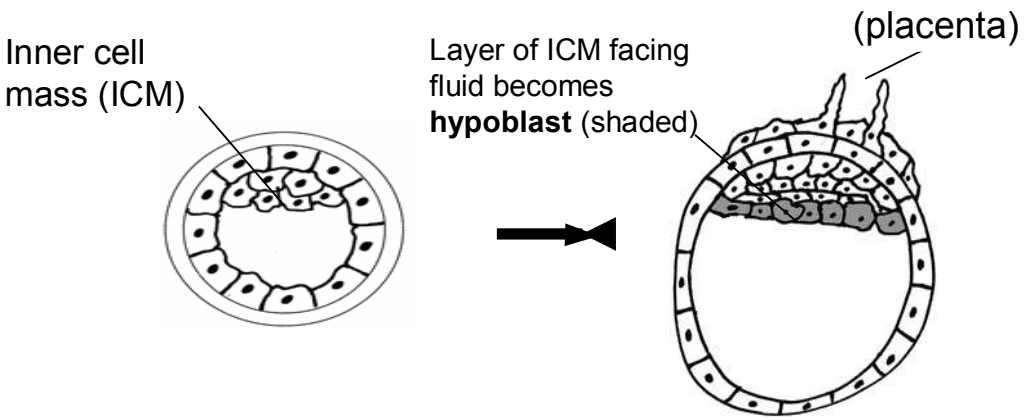
Inner cell mass (ICM)



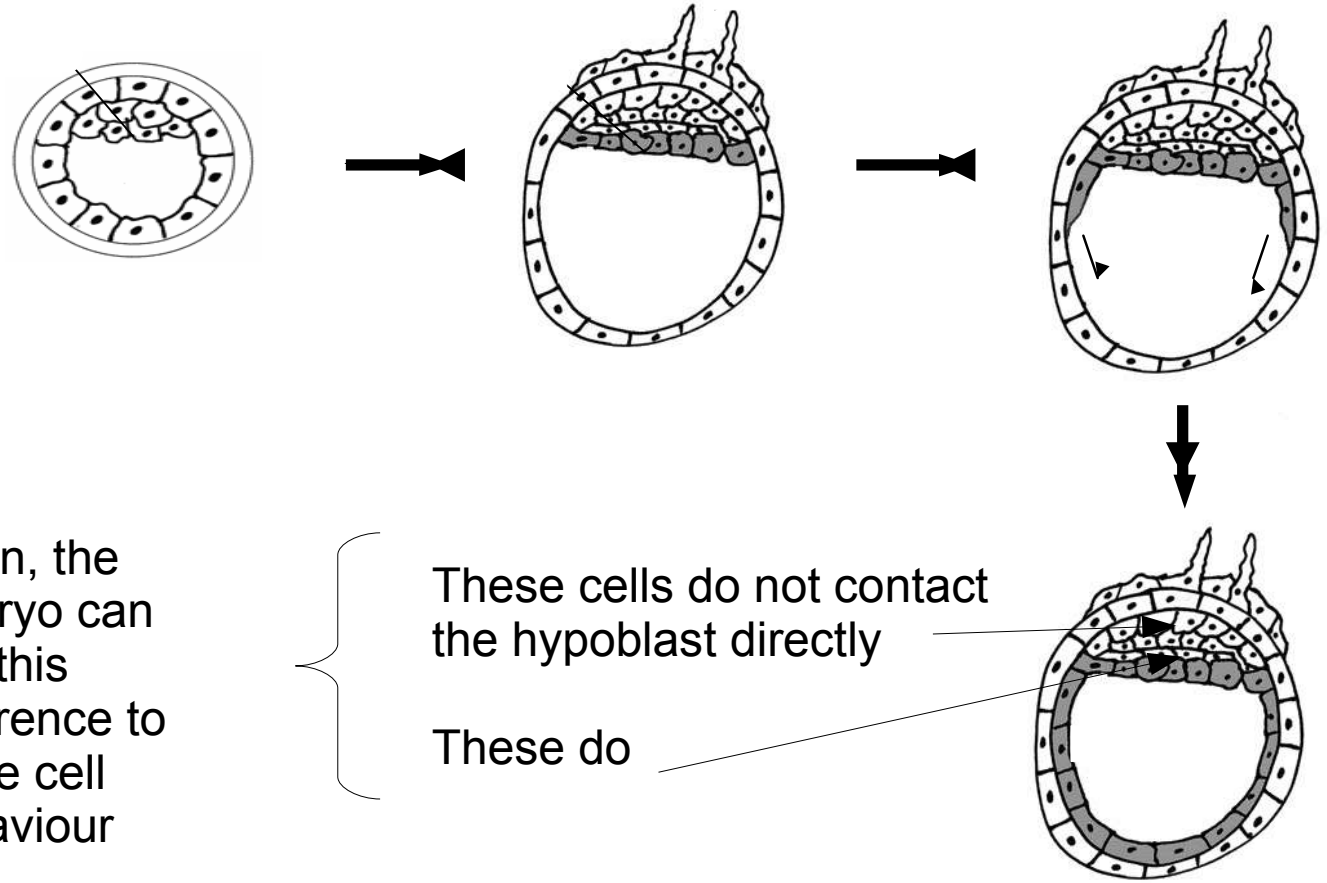
These cells do not face a free surface

These do

The ICM can use that to make a difference in cell behaviour.


Inner cell
mass (ICM)
Layer of ICM facing
fluid becomes
hypoblast (shaded)
(placenta)

cells invade uterus

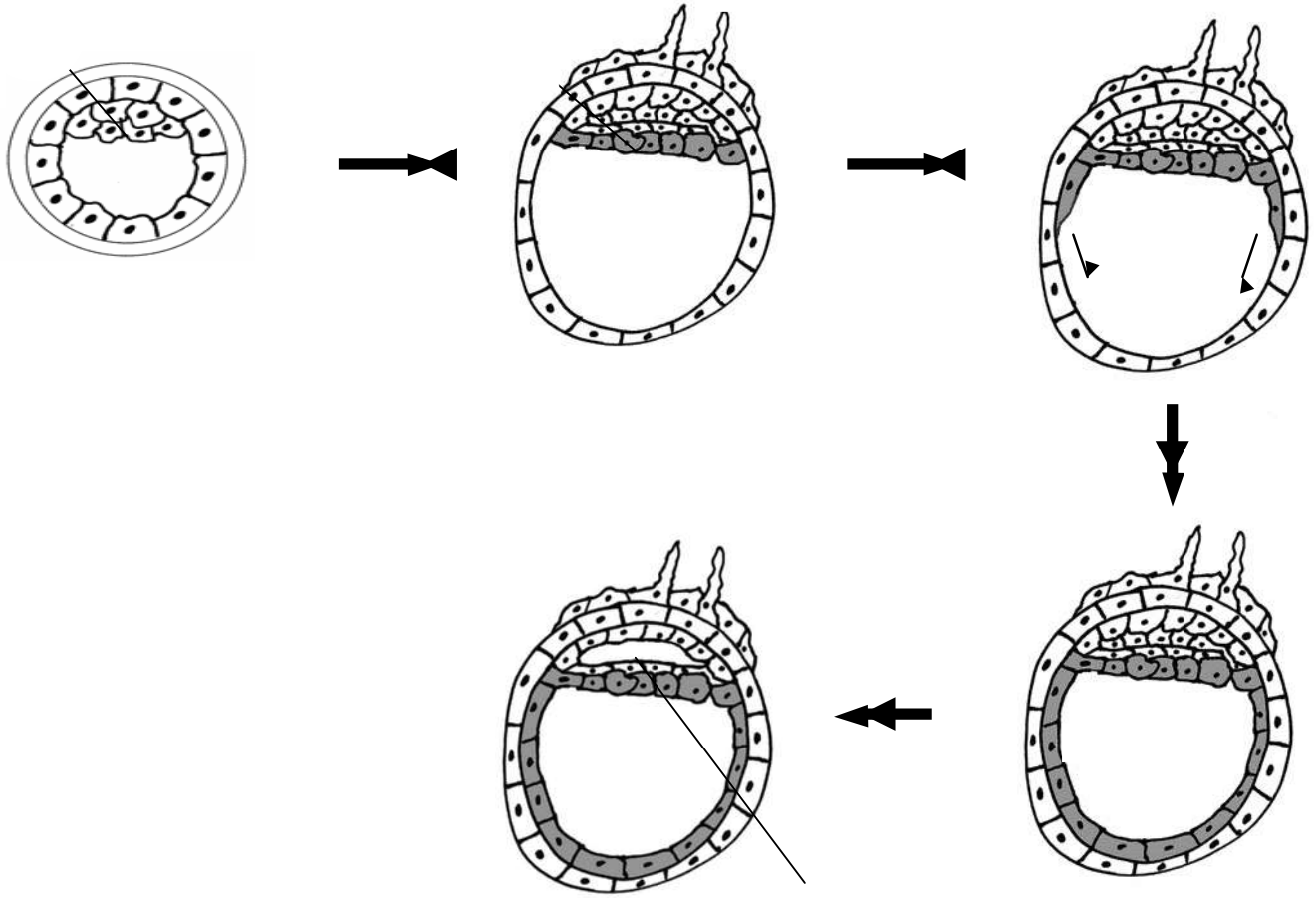


Again, the embryo can use this difference to guide cell behaviour

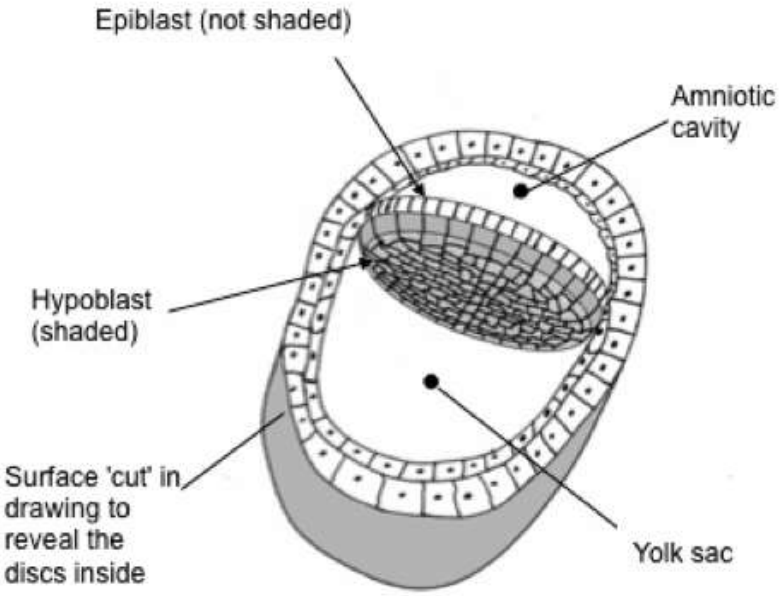
These cells do not contact the hypoblast directly

These do

r cells invade uterus



epiblast



This is not yet much like a baby, but the embryo has already achieved remarkable things. It has;

* Become multicellular

* Created differences where there were none

* Used these differences to construct the beginnings of a placenta, two cavities (yolk sac and amniotic), and a disc of cells that will go onto make the body proper.

Most 'errors' at this stage are lethal, but some subtle and rare 'errors' are tolerable by the embryo, and result in identical (monozygotic) twins;

Photo credit: Linda & Terri Jamison, Wikimedia Commons

Monozygotic Twinning (1) – cells separate inside Z.P.

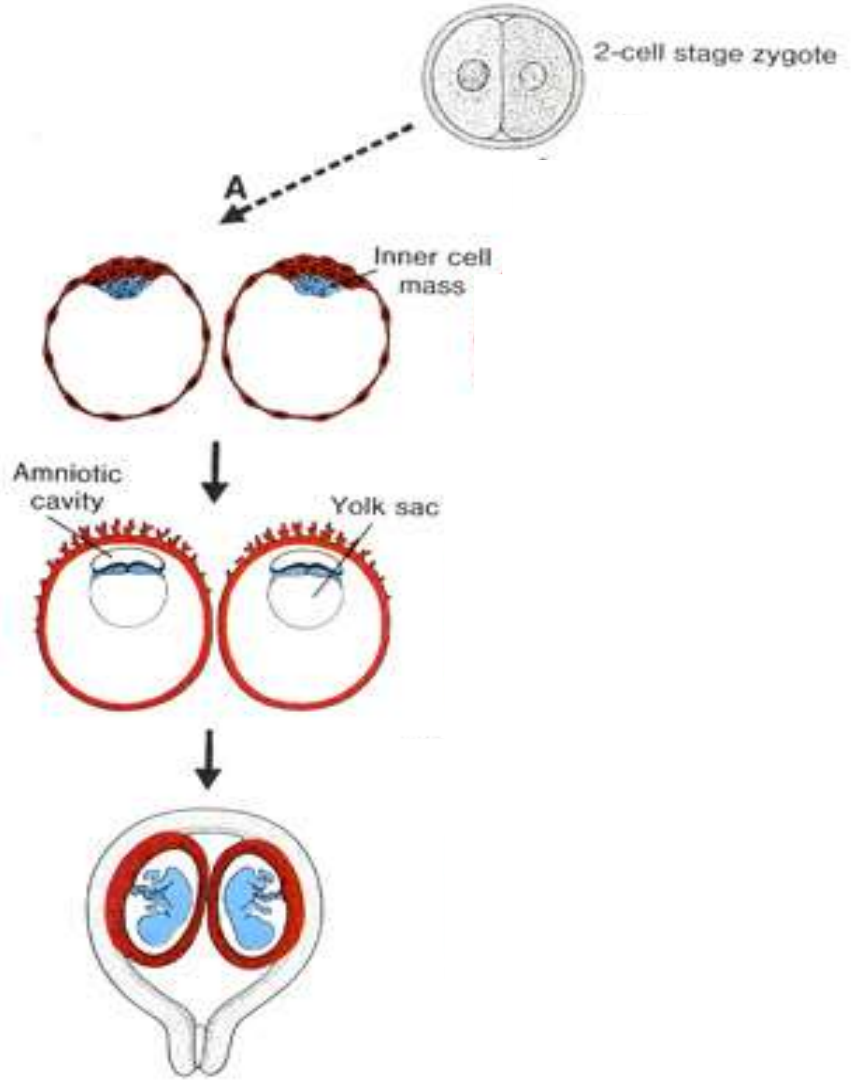


Image Credit: Harvey Kliman, Yale

Monozygotic Twinning (2) – Two Inner Cell Masses form

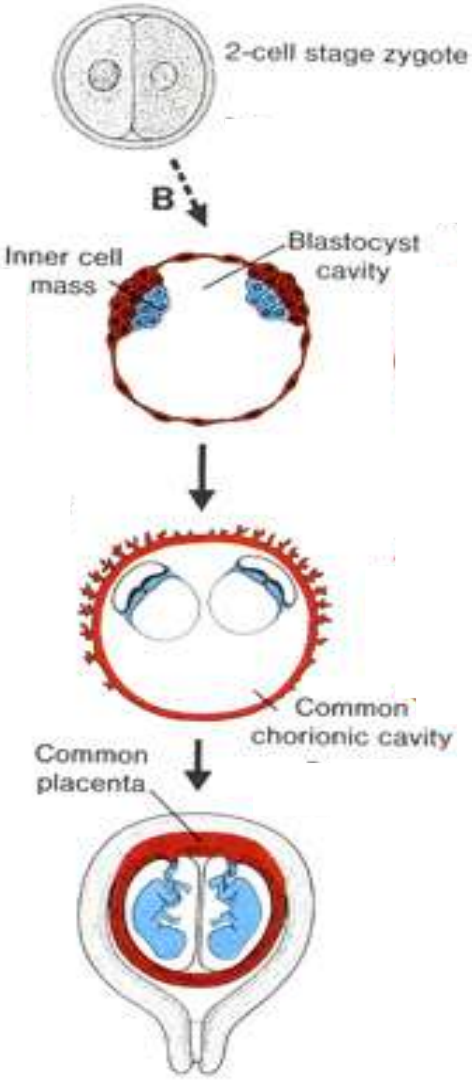
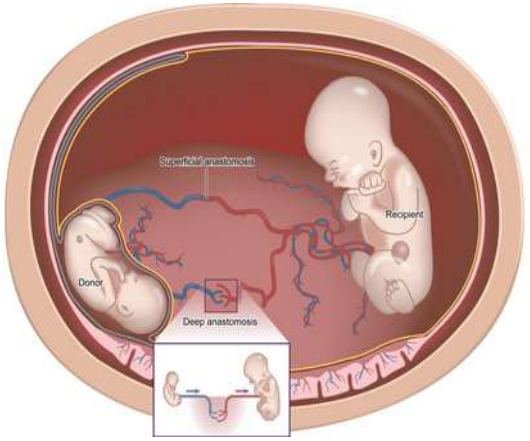


Image Credit: Harvey Kliman, Yale

Monozygotic Twinning (2) – Two Inner Cell Masses form

Danger of foetal transfusion syndrome ('twin-to-twin transfusion syndrome)



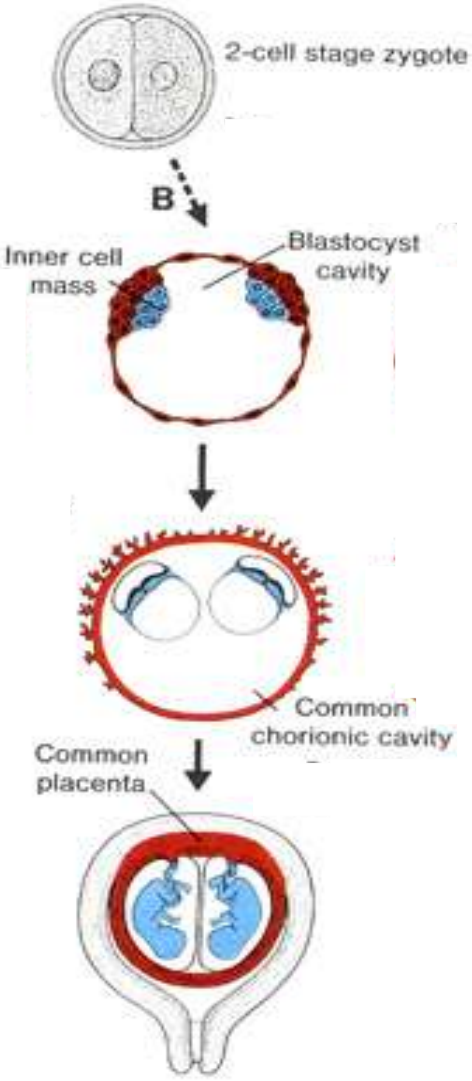


Image Credit: Harvey Kliman, Yale

The two types of twinning compared:

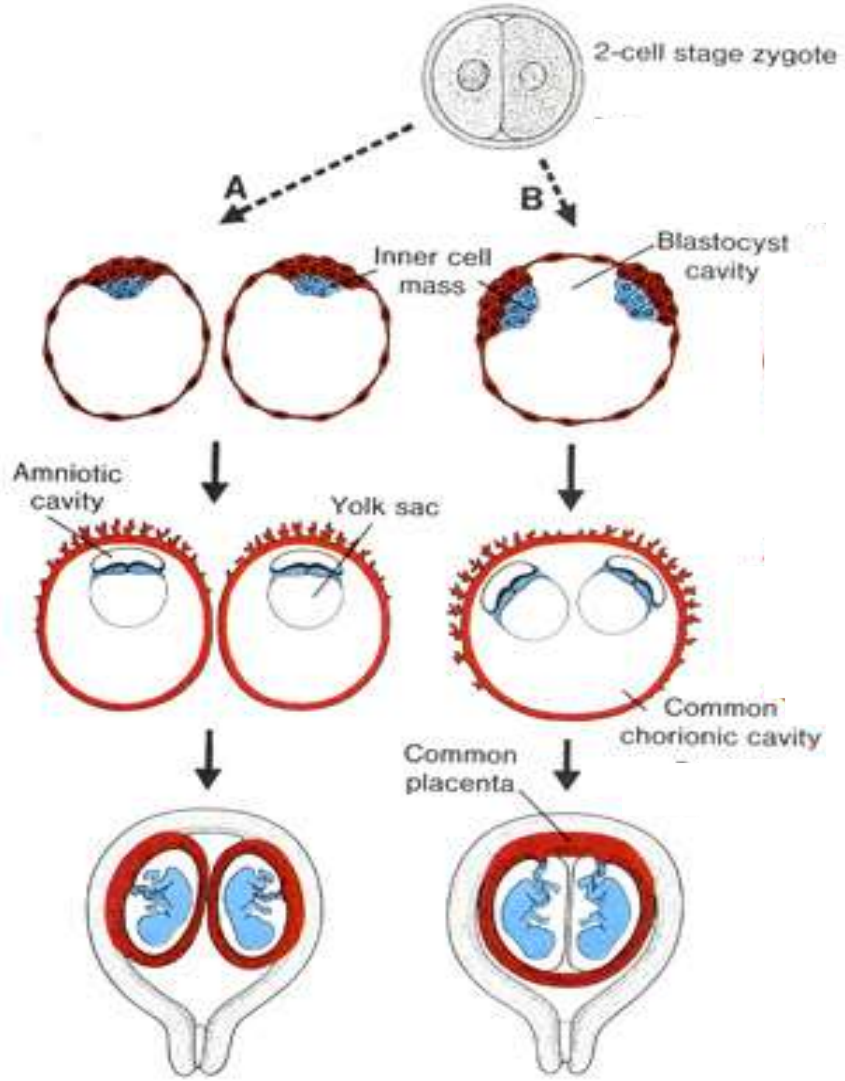
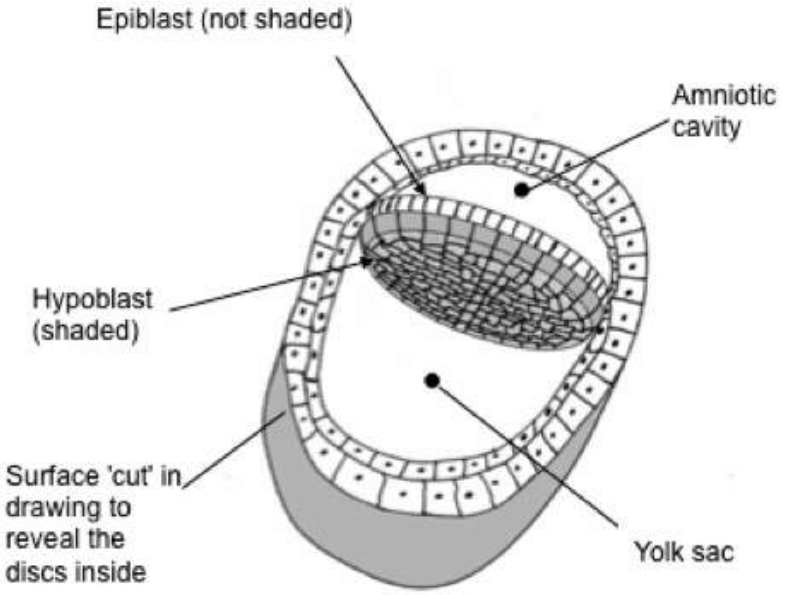


Image Credit: Harvey Kliman, Yale

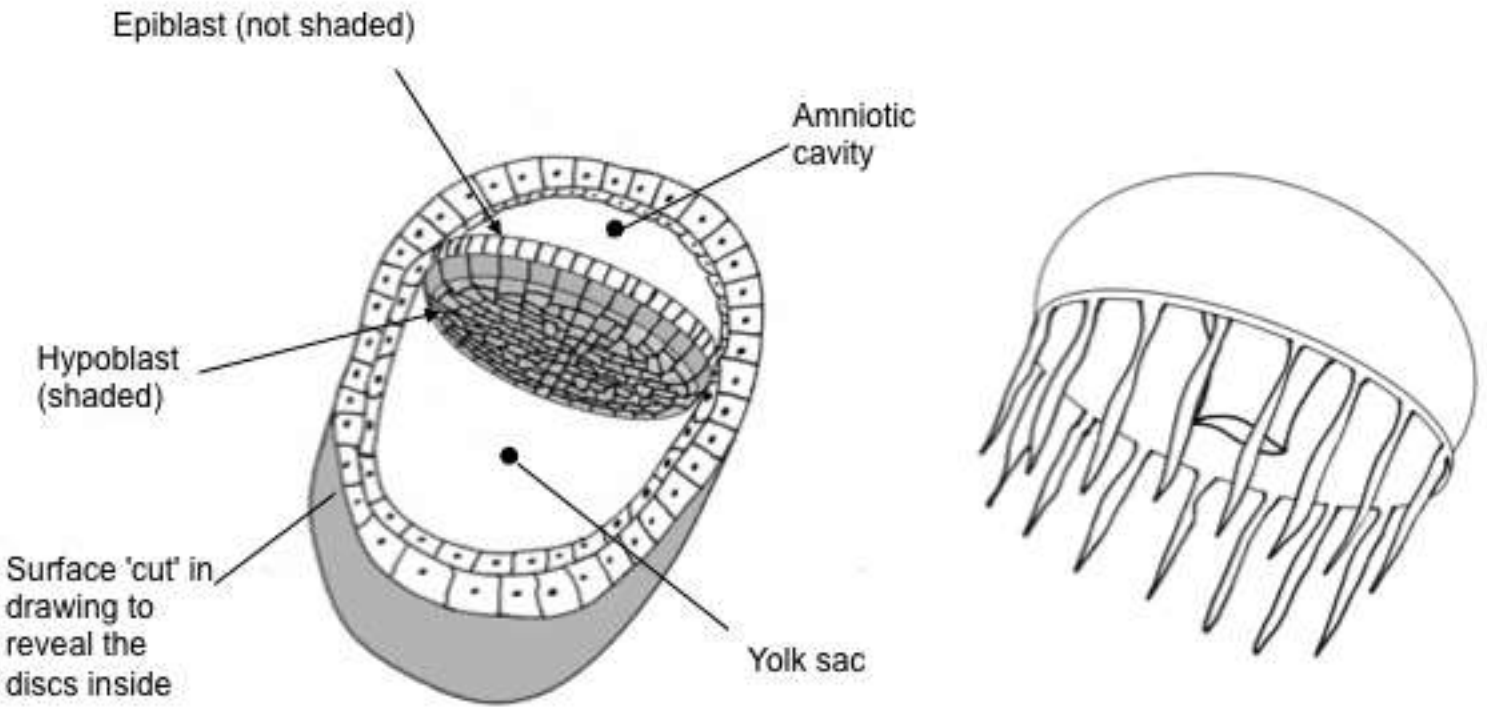
Axis formation

OK... back from the tangent... How does this

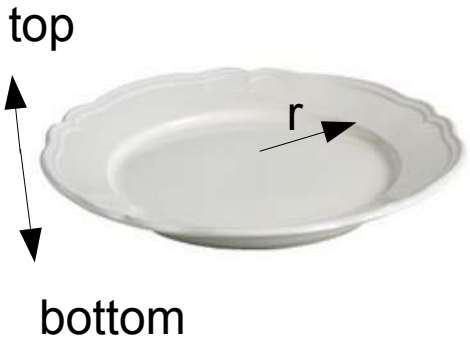


….turn into something more recognizably like a body?

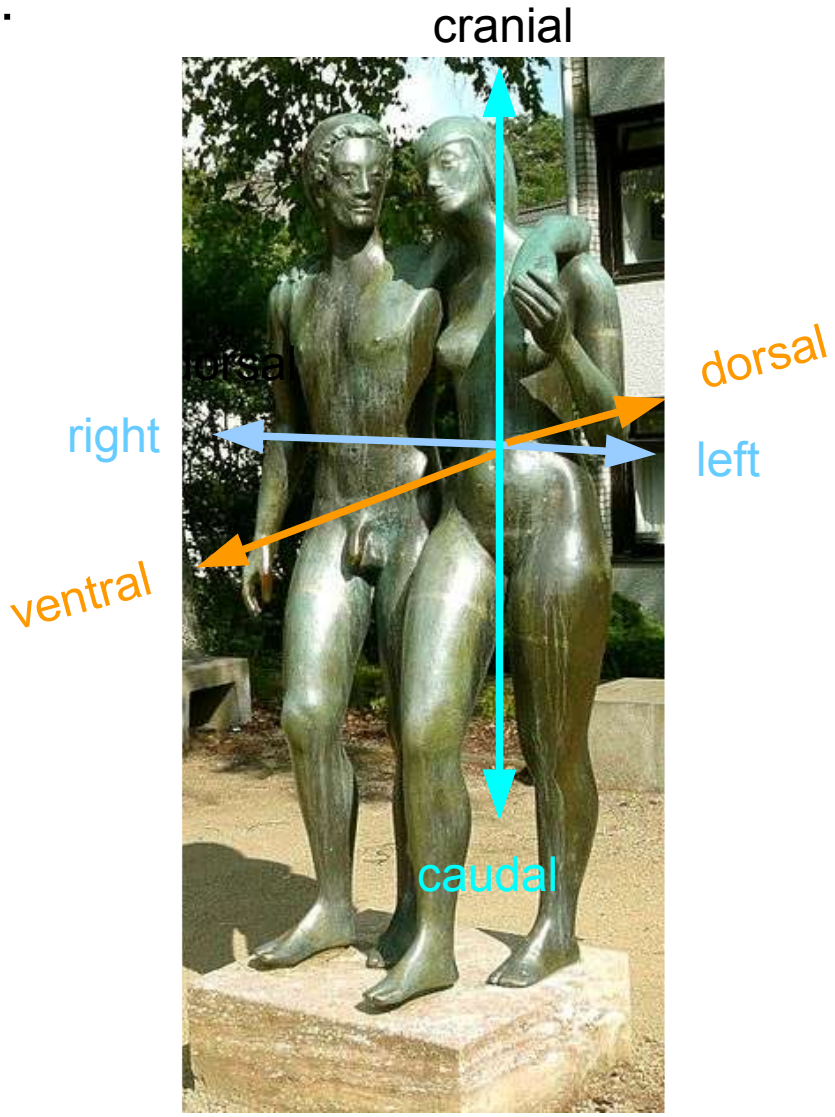
The symmetry properties of this early embryo are radial, rather like a jellyfish



This gives the embryo a mathematical problem:



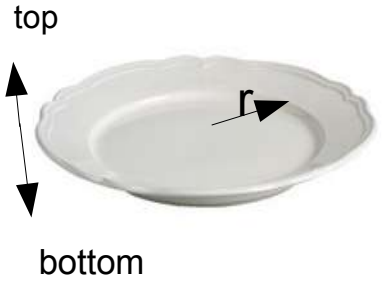
Disc: 2 axes



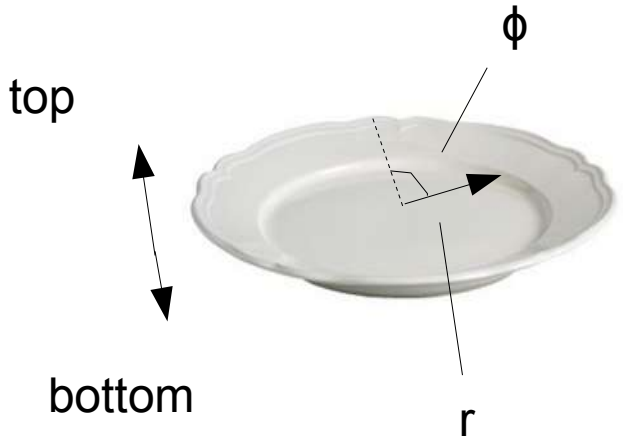
Human: 3 orthogonal axes

Sculpture: Wolfgang Kreutter (1924-1989) *The young couple/. Photo by Bad Laasphe*

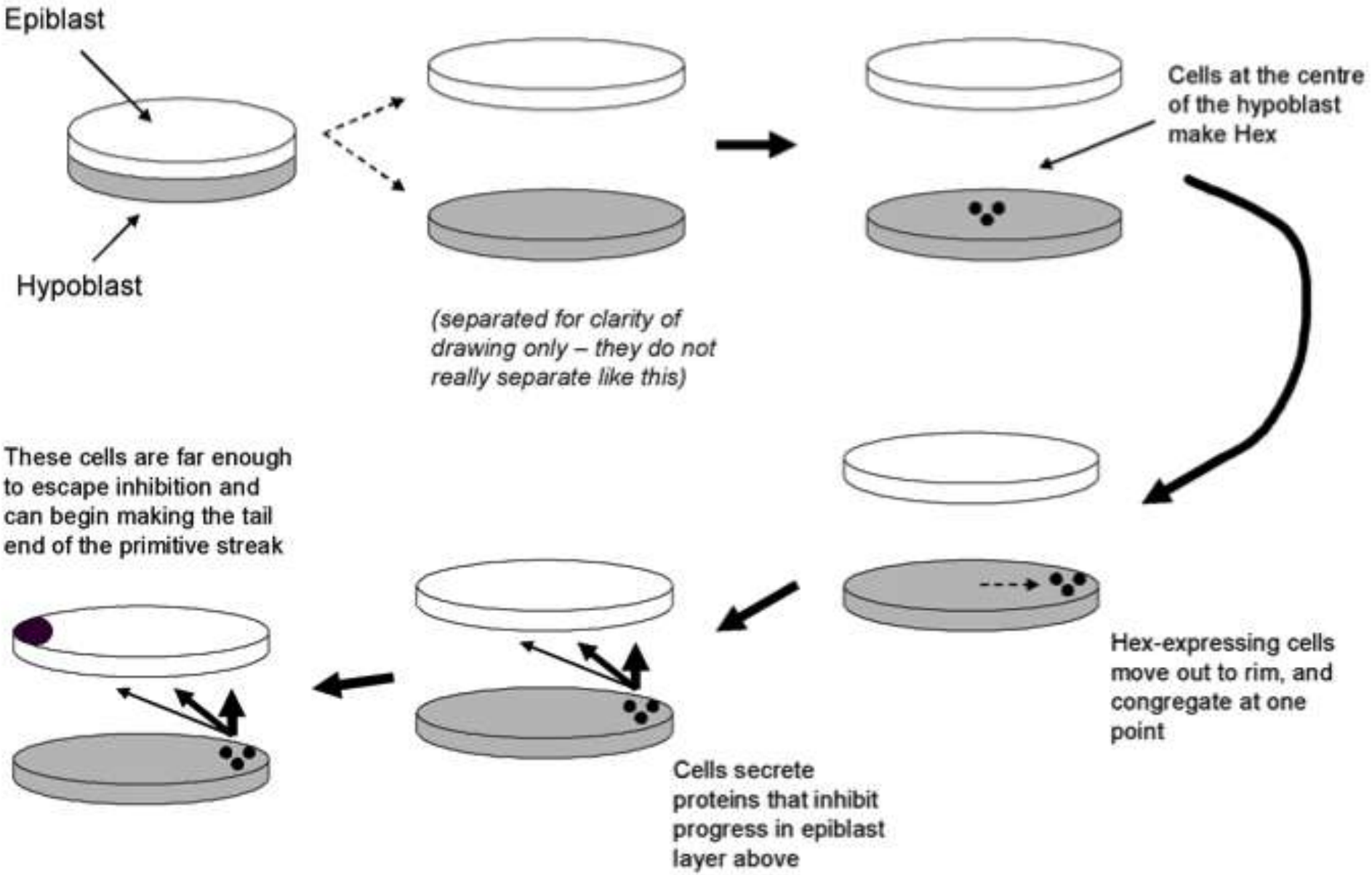
There is no way to transform the 2-coordinate system of a disc to a 3-coordinate system of a 3-D object.

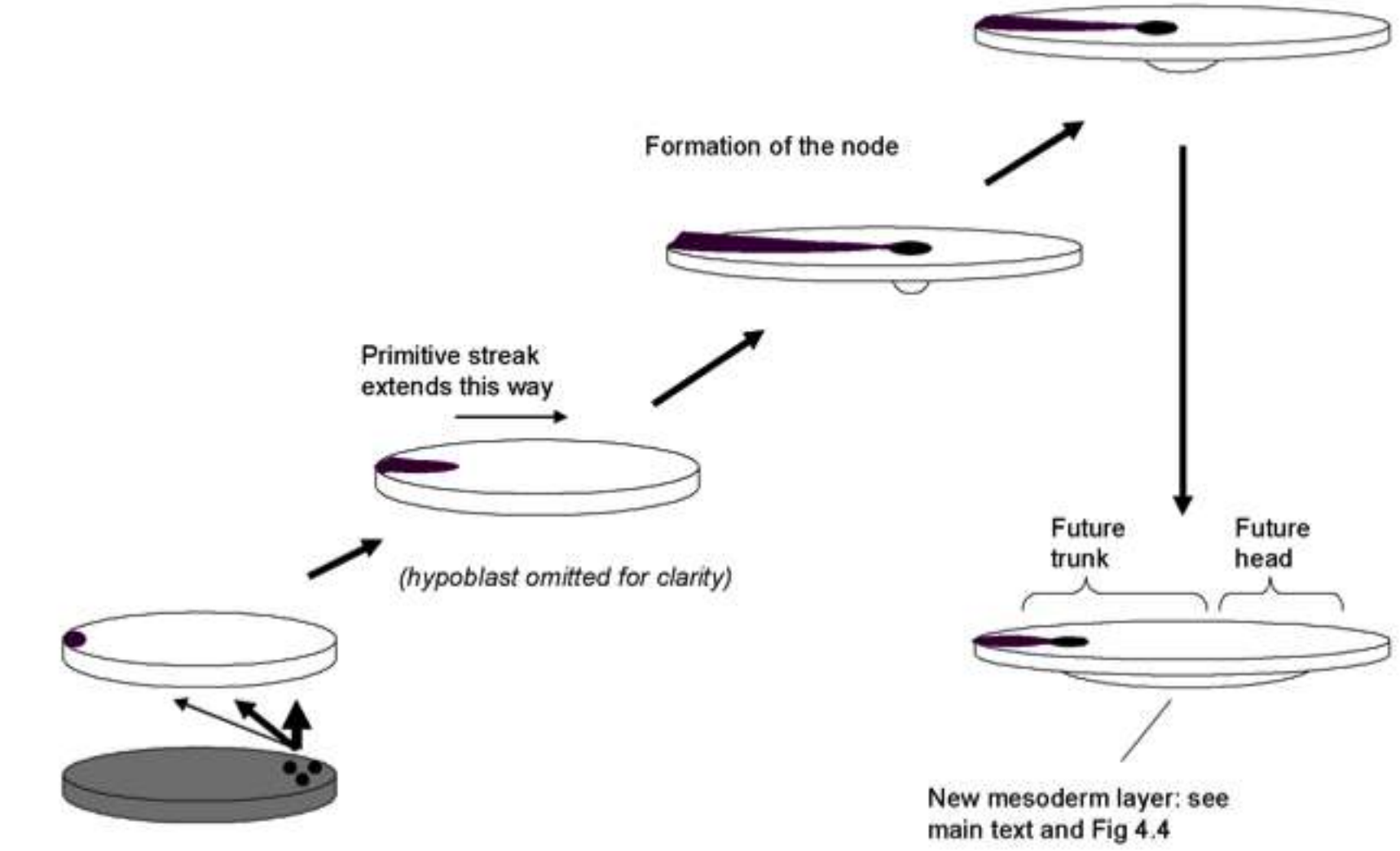


BUT, if the embryo can somehow make one part of the edge of the disc different, to mark '12-o-clock', then it can have 3 coordinates;



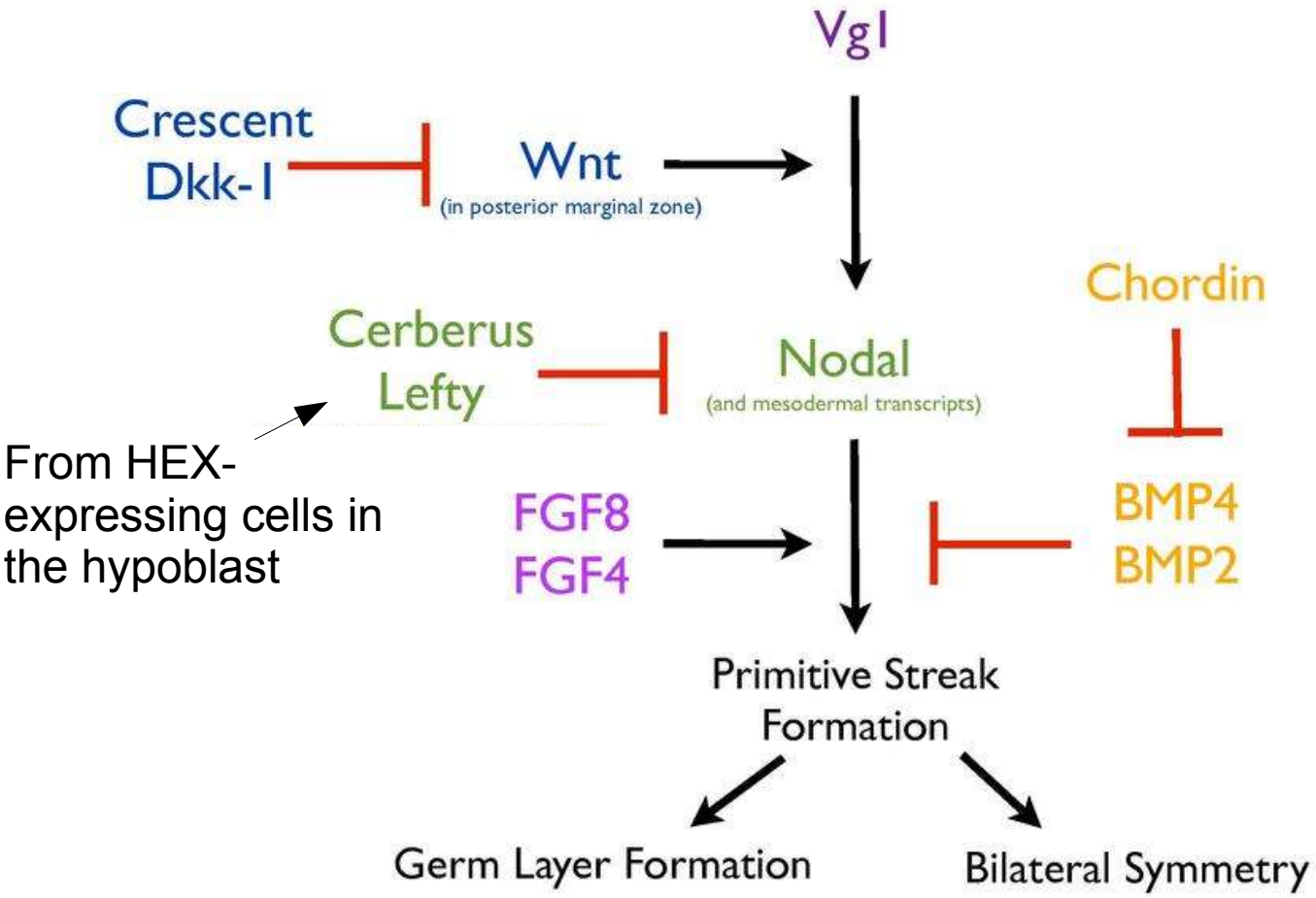
… and these can be transformed, with some cleverness, into the body axes.


Epiblast
Hypoblast
(separated for clarity of drawing only – they do not really separate like this)
Cells at the centre of the hypoblast make Hex
Hex-expressing cells move out to rim, and congregate at one point
Cells secrete proteins that inhibit progress in epiblast layer above
These cells are far enough to escape inhibition and can begin making the tail end of the primitive streak



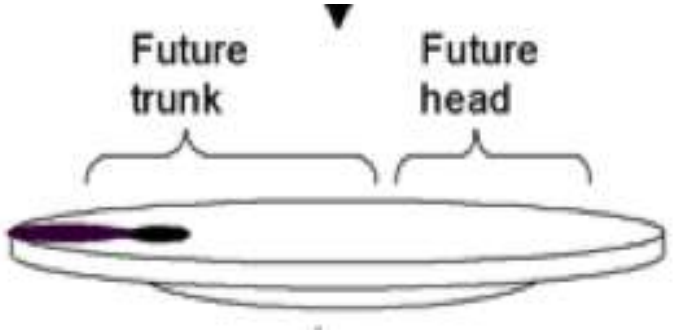
This is the end-point of Fig 4.2

What I have told you is an outline only – beyond it is a complex web of signals creating and stabilizing the position of the streak:



Most of this was worked out in mouse – human may not be the same.

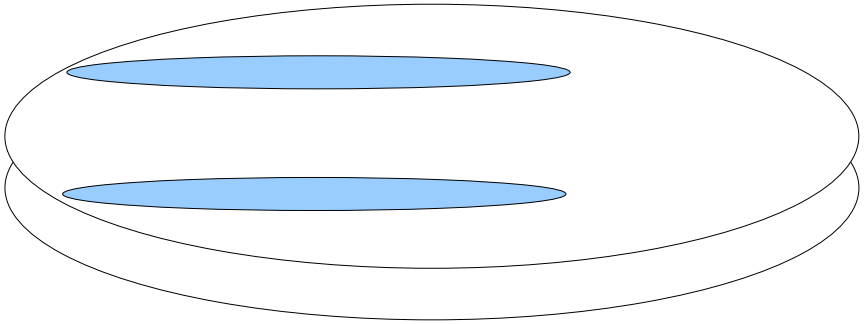
Do not try to learn this!! I have shown you in case you come across this stuff and think there is a clash with what I have told you. There isn't, and this image links the embryonic anatomy I have told you to the molecular signalling details.



Eventually, these coordinate systems will correspond to the body thus:

The formation of one body axis depends on the Hex-expressing cells being in one point on the rim of the hypoblast:

If there are two distinct sites, then two heads will form and maybe two primitive streaks:



This gets us to the third, very rare, form of monozygotic twinning.

Monozygotic Twinning (3) – Two Primitive Streaks form

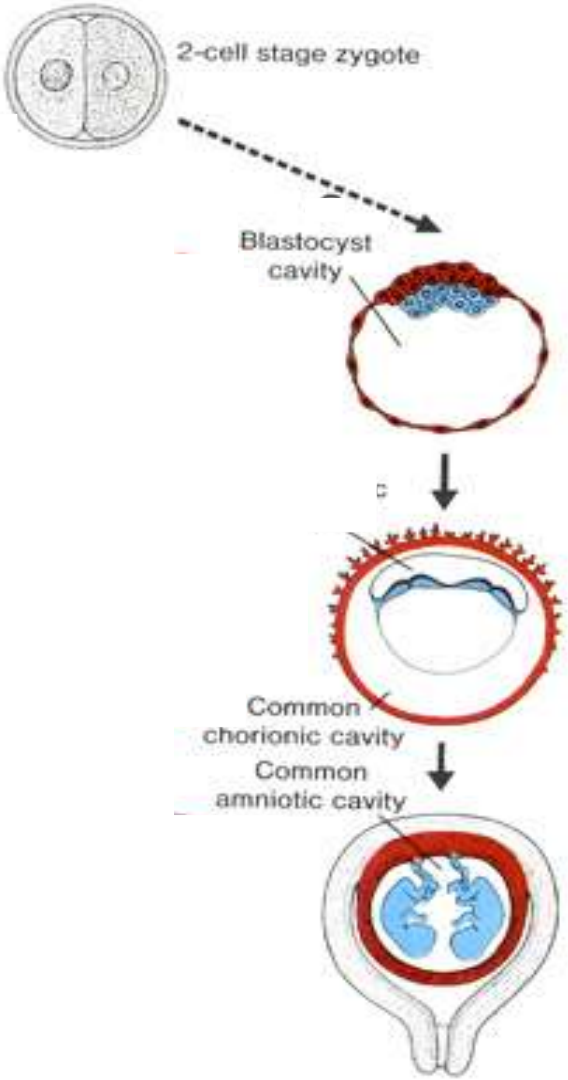
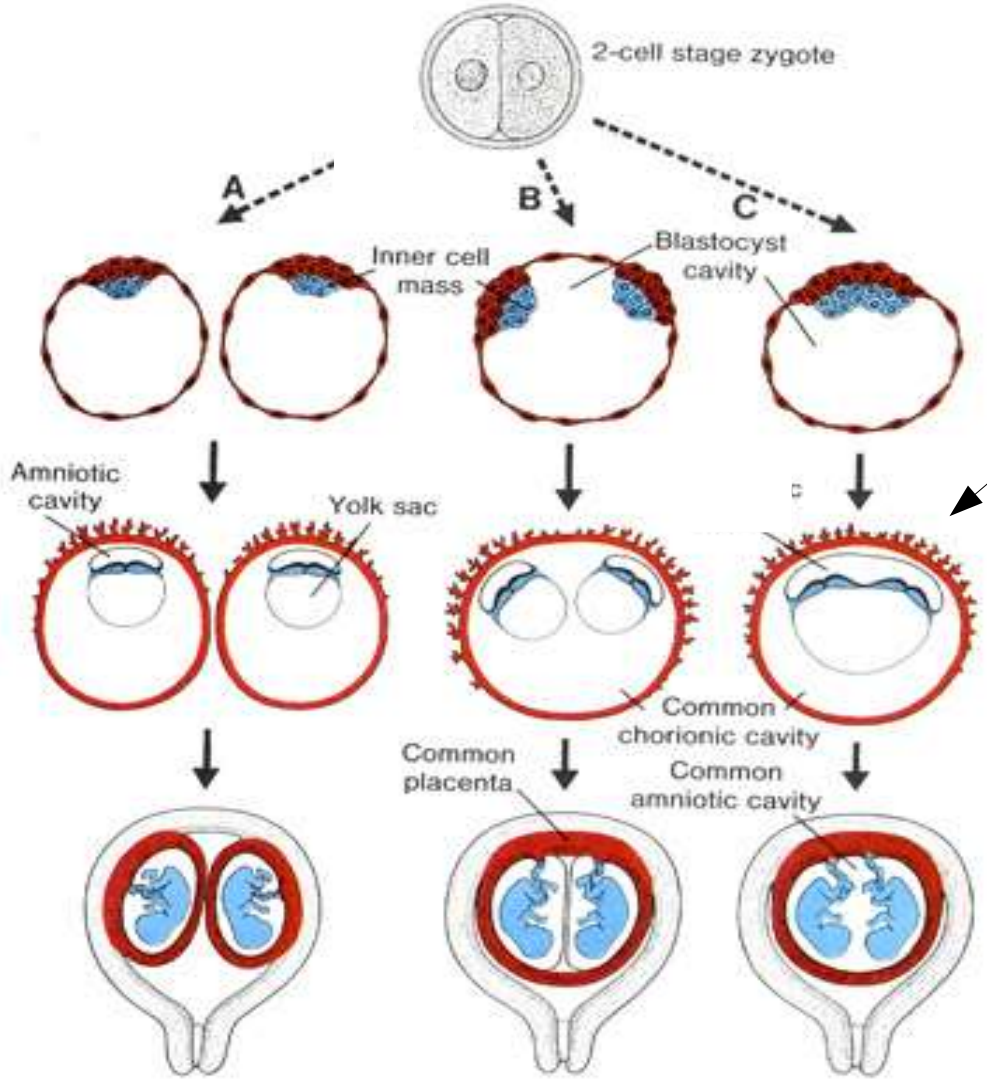


Image Credit: Harvey Kliman, Yale

All of the twinning types compared.



This is rather dangerous, because there is nothing definite (such as a membrane) to separate the two embryos.

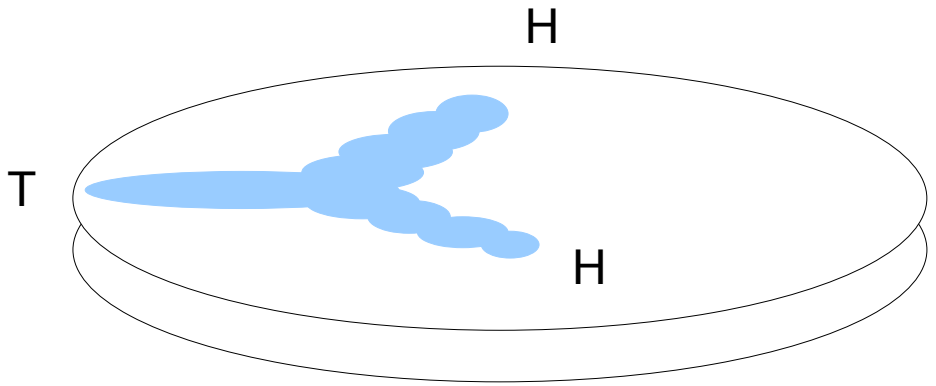
Image Credit: Harvey Kliman, Yale

Conjoined twins:

Chang & Eng Bunker, the Original “Siamese Twins” (as they called themselves for their stage act in PT Barnum's circus)

Partial axis duplications:

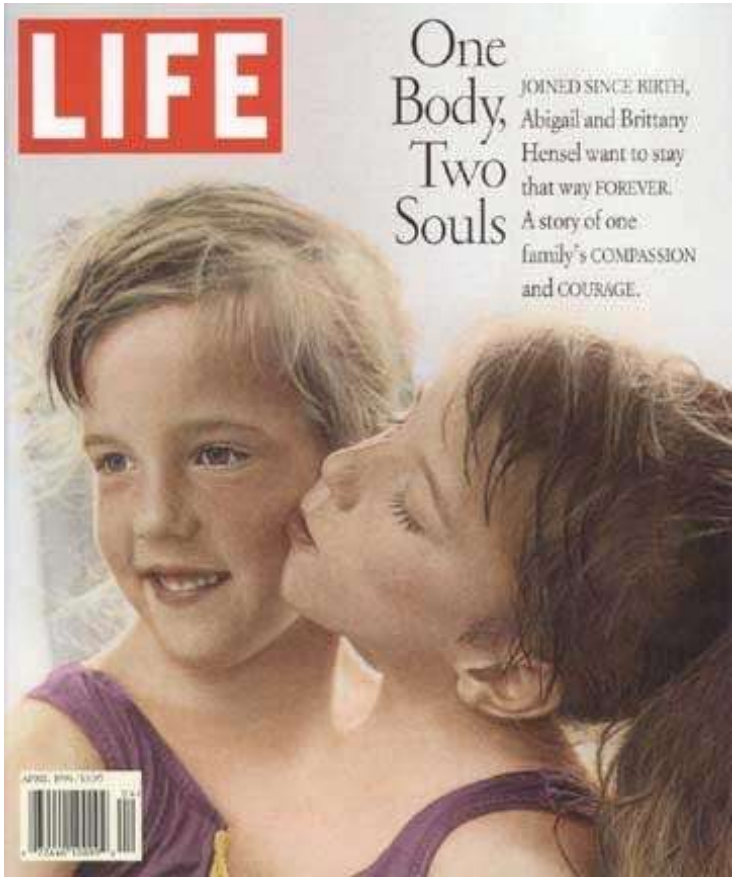
Things can get even more complicated if the two head organizing areas still agree on one site for the tail:

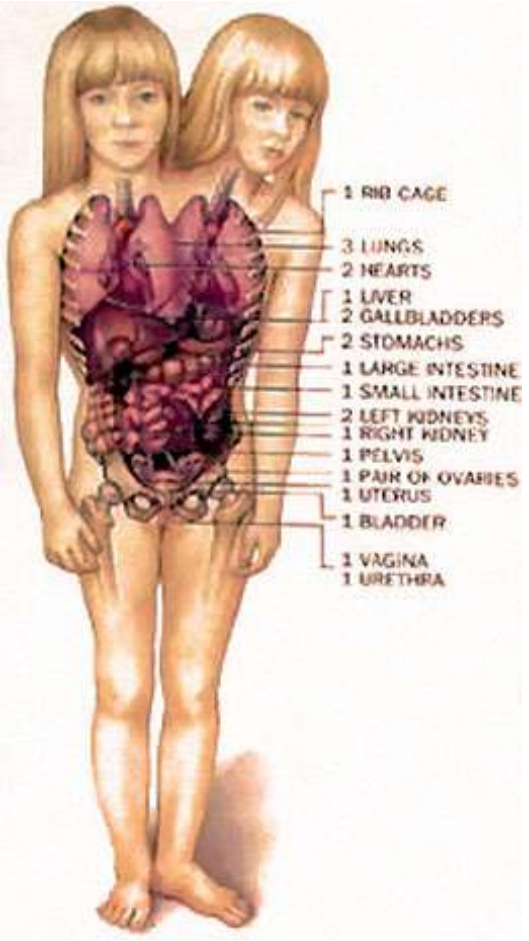


This gets us to the third, very rare, form of monozygotic twinning.

This has been seen many times in reptiles

Abigail and Brittany Hensel





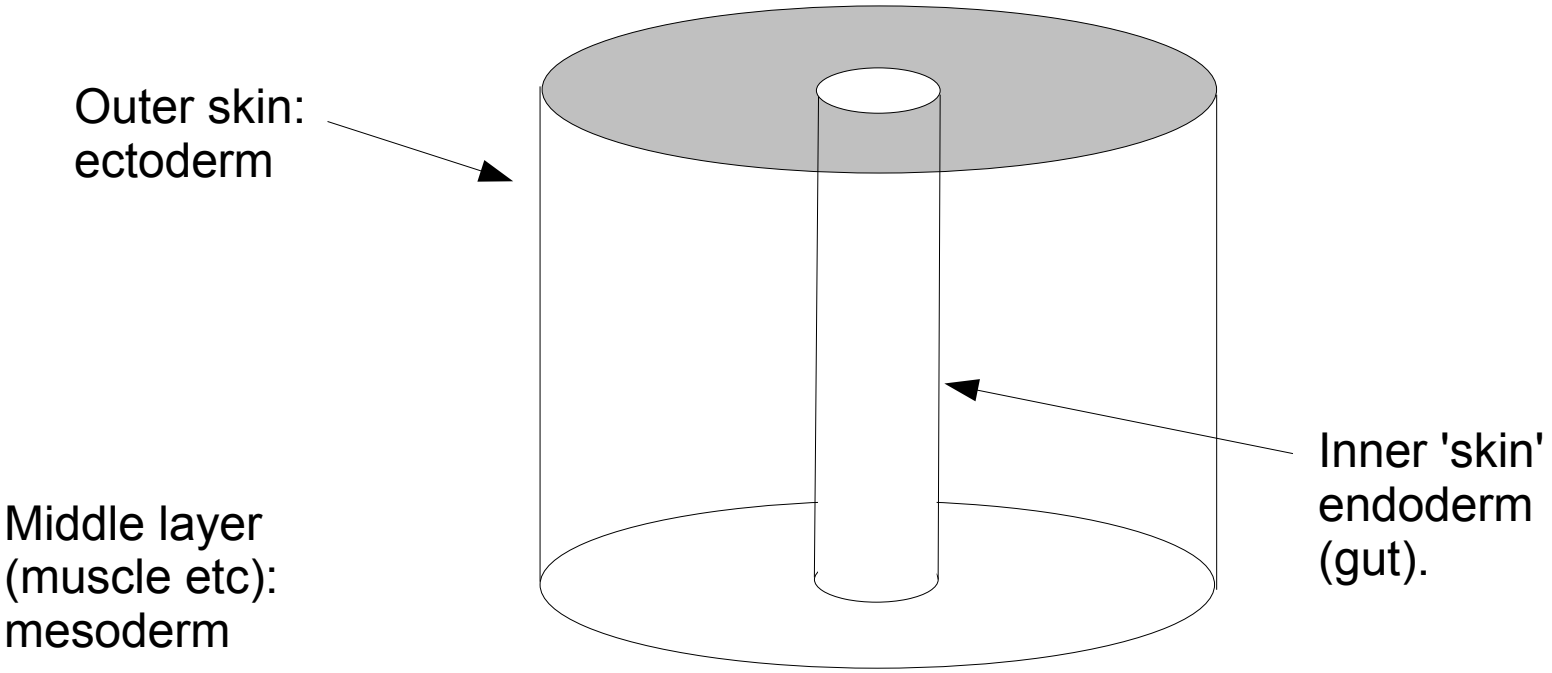
(a 3rd, rudimentary arm, was amputated in infancy)

Gastrulation

Back to normal development...

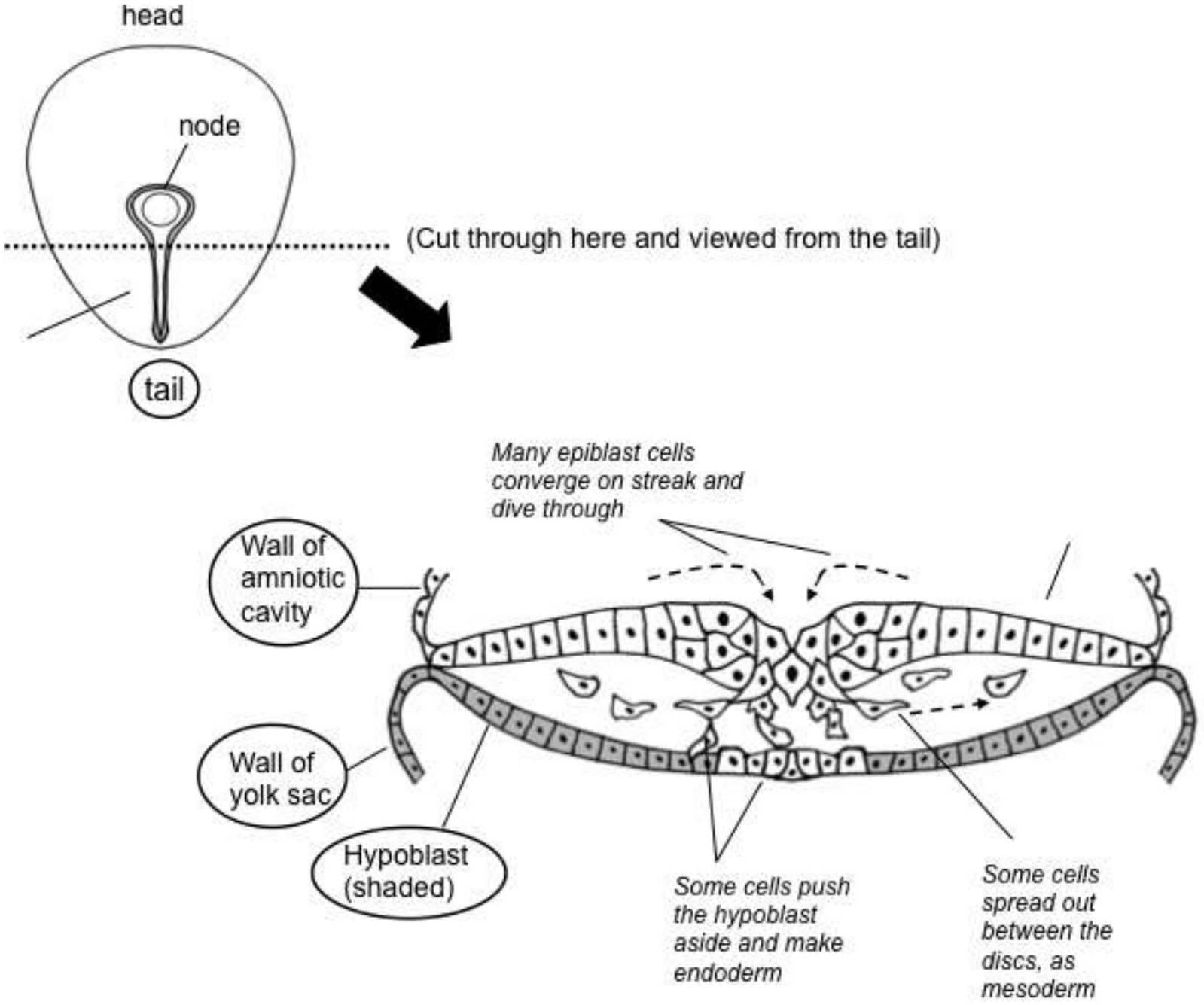
We are not just a flat disc.

Most crudely, we are a three-layered cylinder:

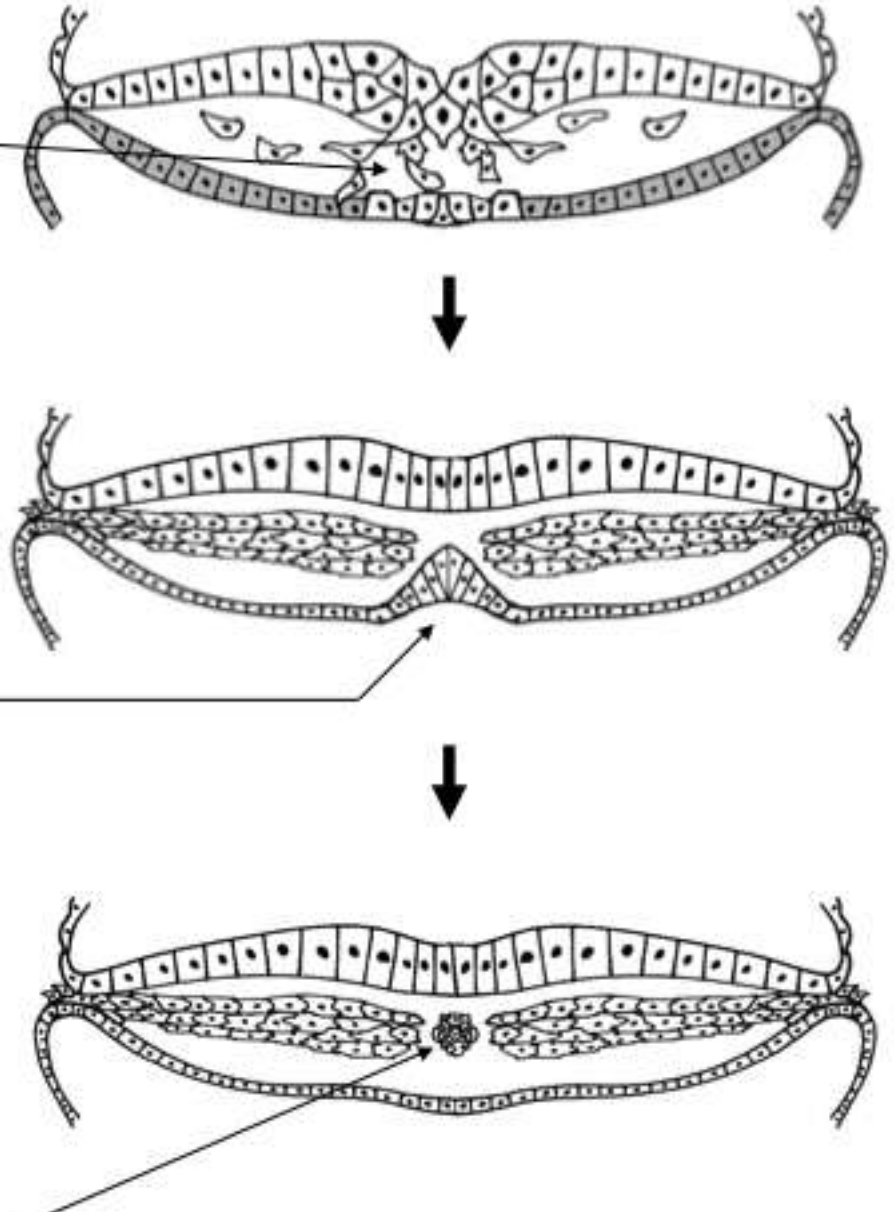


So how does the flat disc of the epiblast turn into a 3-layered structure?

Gastrulation


head
node
(Cut through here and viewed from the tail)
tail
Many epiblast cells converge on streak and dive through
Wall of amniotic cavity
Wall of yolk sac
Hypoblast (shaded)
Some cells push the hypoblast aside and make endoderm
Some cells spread out between the discs, as mesoderm

The embryo's endoderm forms from cells diving through streak (this is the same image as in the last figure, shown again here for continuity)

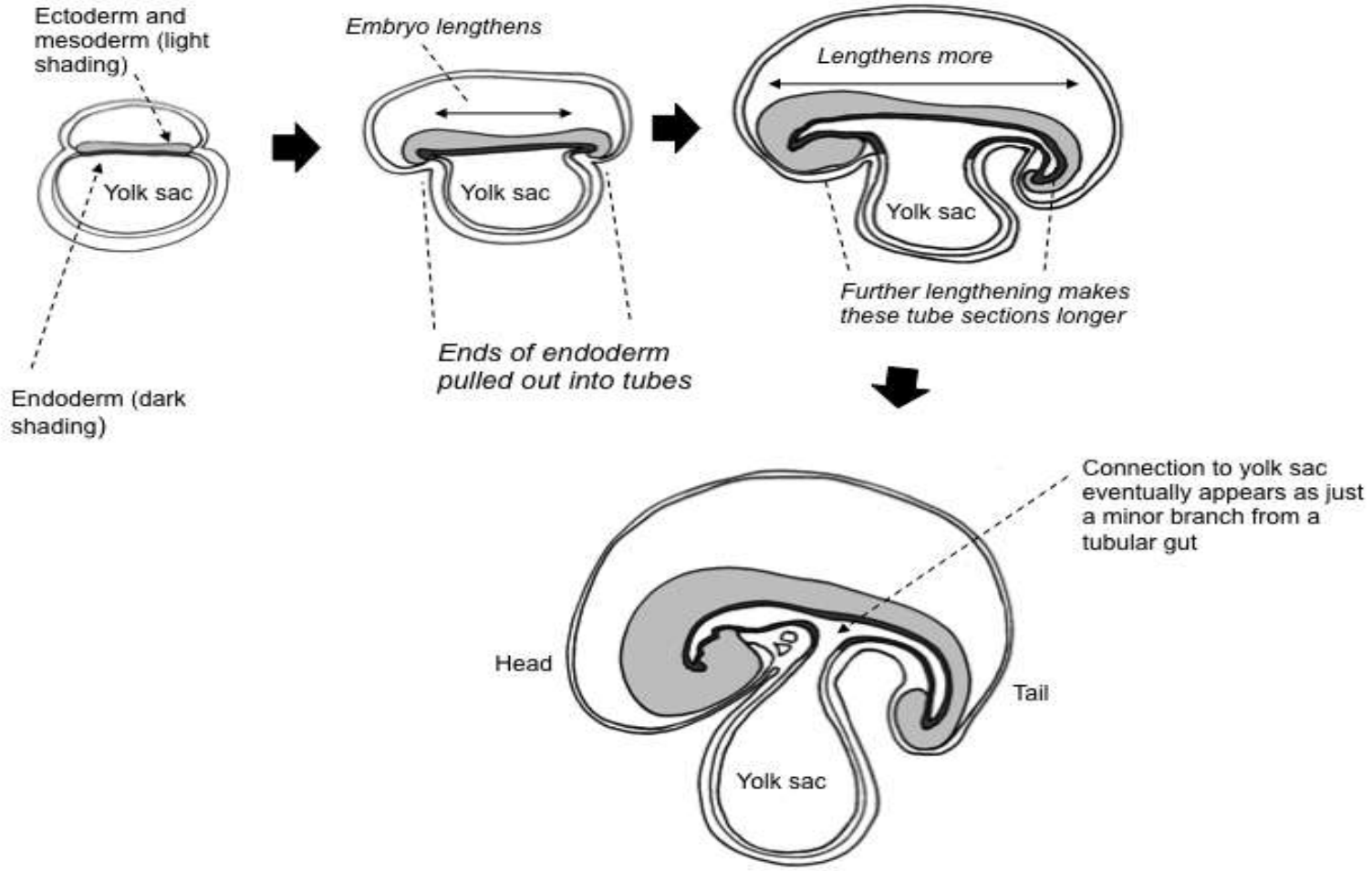


Middle part of new endoderm rises to make notochord plate…

…and detaches to become the notochord

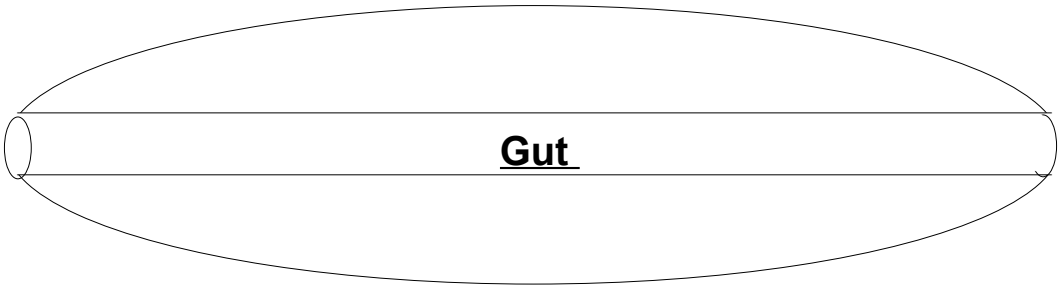
The endoderm thus starts off as a flat plate. LATER it will become a tube this way;

(seen from the side:)

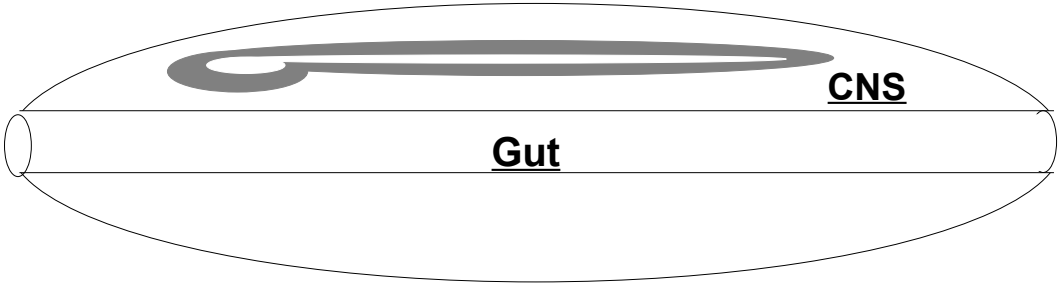


Neurulation

Earlier, I presented the vertebrate body as a tube within a tube.



This was an oversimplification: there are actually two tubes inside, one open (the gut) and one closed (the central nervous system);



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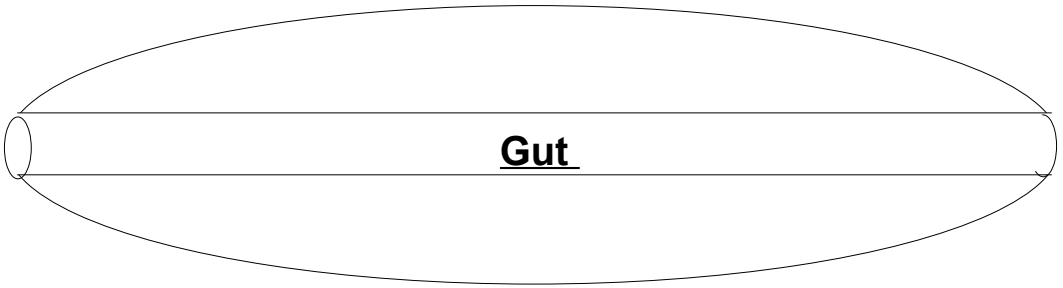

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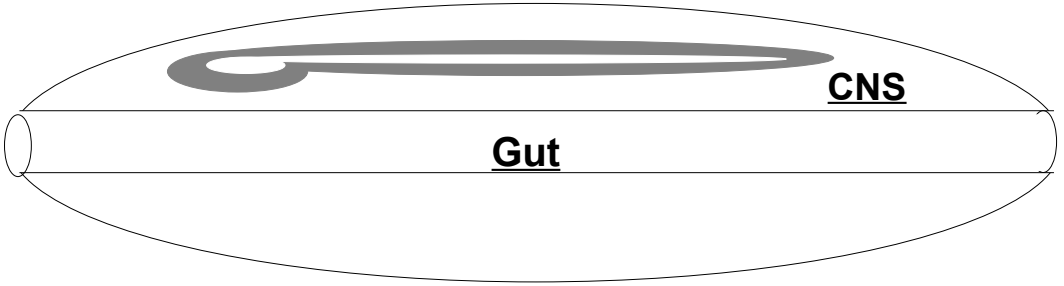
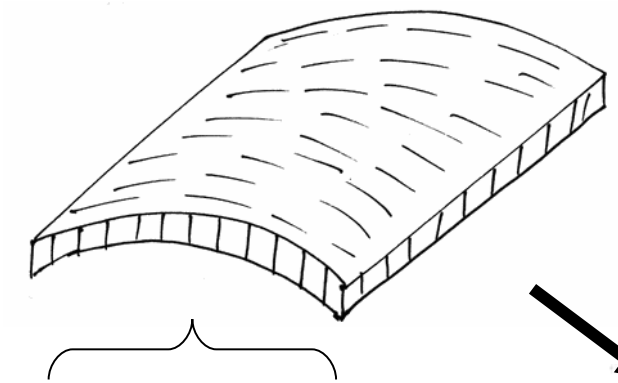
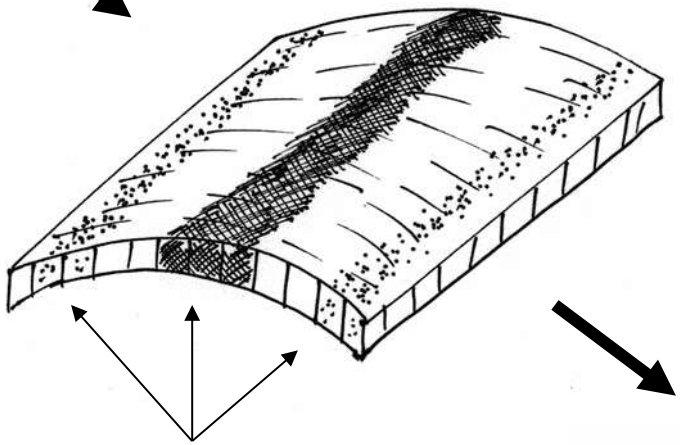


The CNS tube derives from the Ectoderm.

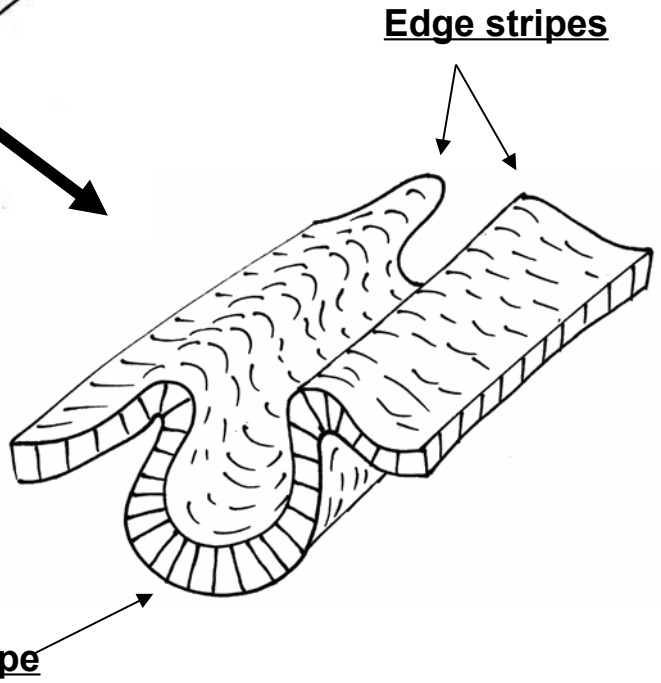
CNS formation begins when the ectoderm along the dorsal surface folds inwards, driven by local cell shape changes along three stripes;

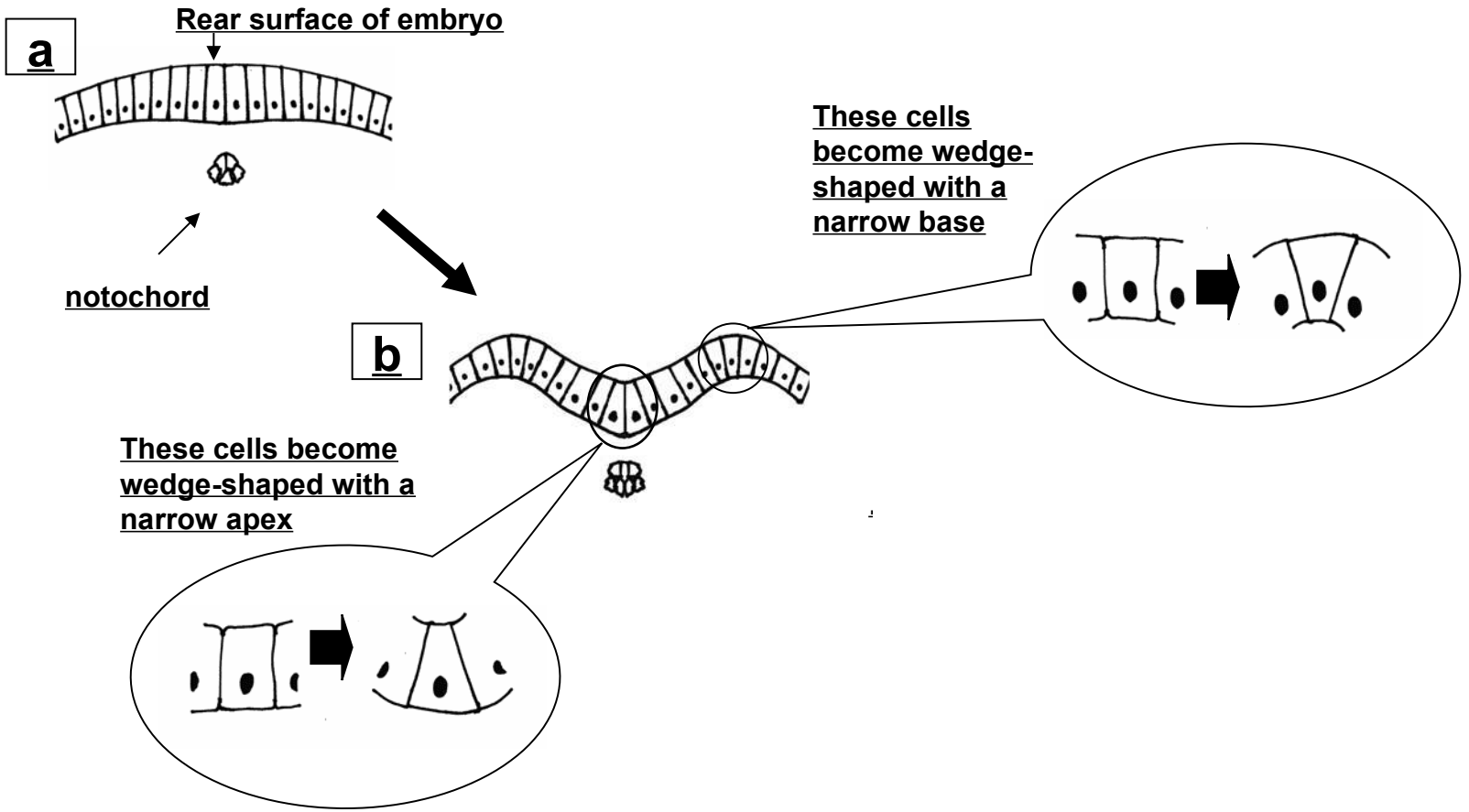


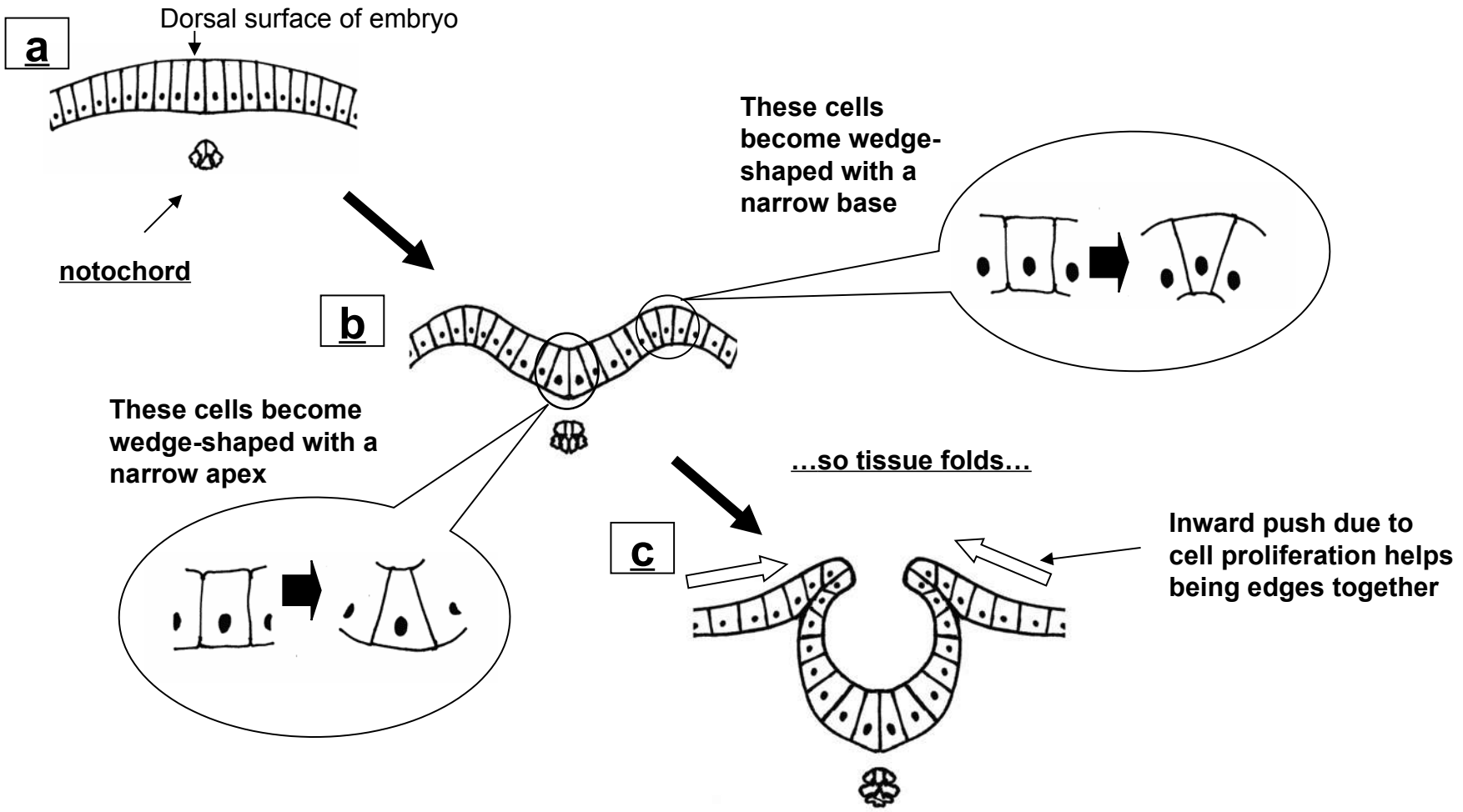
Ectoderm over the back

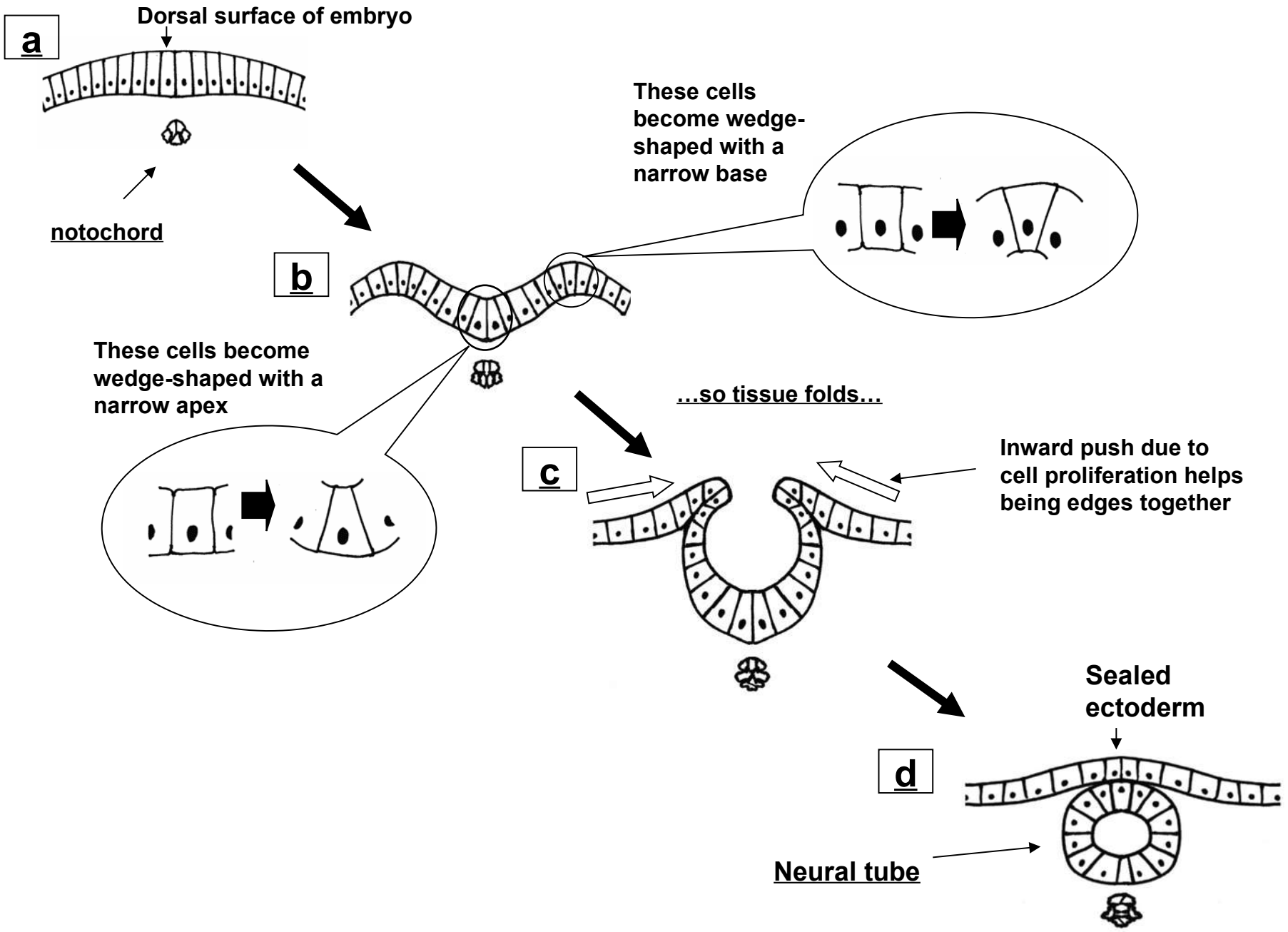


Two edge stripes and one centre stripe

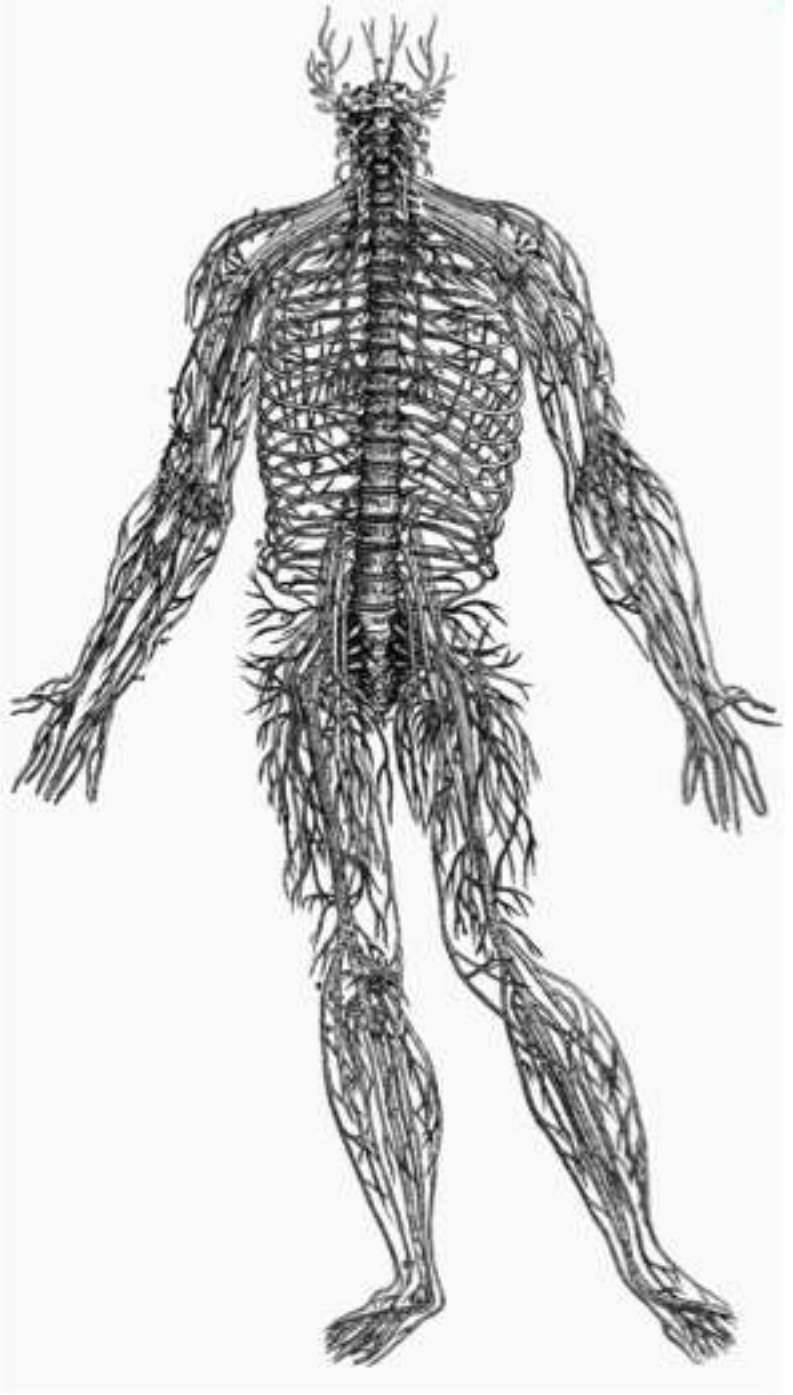



a
Rear surface of embryo
notochord
b
These cells become wedge-shaped with a narrow base
These cells become wedge-shaped with a narrow apex


a
Dorsal surface of embryo
notochord
b
These cells become wedge-shaped with a narrow base
These cells become wedge-shaped with a narrow apex
…so tissue folds…
c
Inward push due to cell proliferation helps being edges together

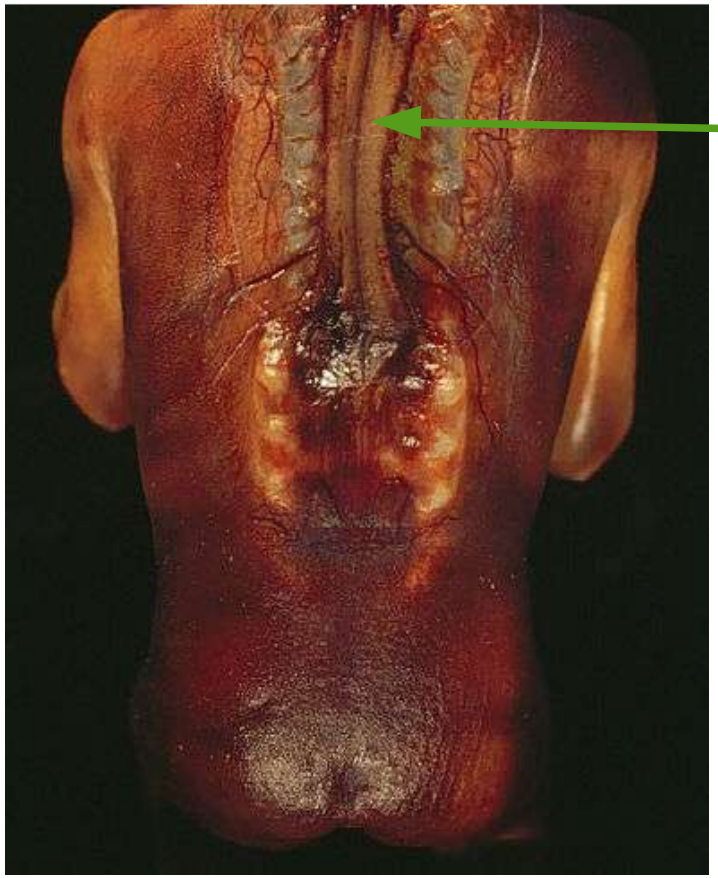

a
Dorsal surface of embryo
notochord
b
These cells become wedge-shaped with a narrow base
These cells become wedge-shaped with a narrow apex
…so tissue folds…
c
Inward push due to cell proliferation helps being edges together
d
Sealed ectoderm
Neural tube

Much later, cells in the neural tube send out processes to each other and to other structures in the body. Bundles of such processes are nerves, and together the processes and the cells make the nervous system (more about this in Year 2).



Image; Versalius *de Fabrici Humani*

The sealing up of the edges of the tube, and its separation from the ectoderm, sometimes fails:



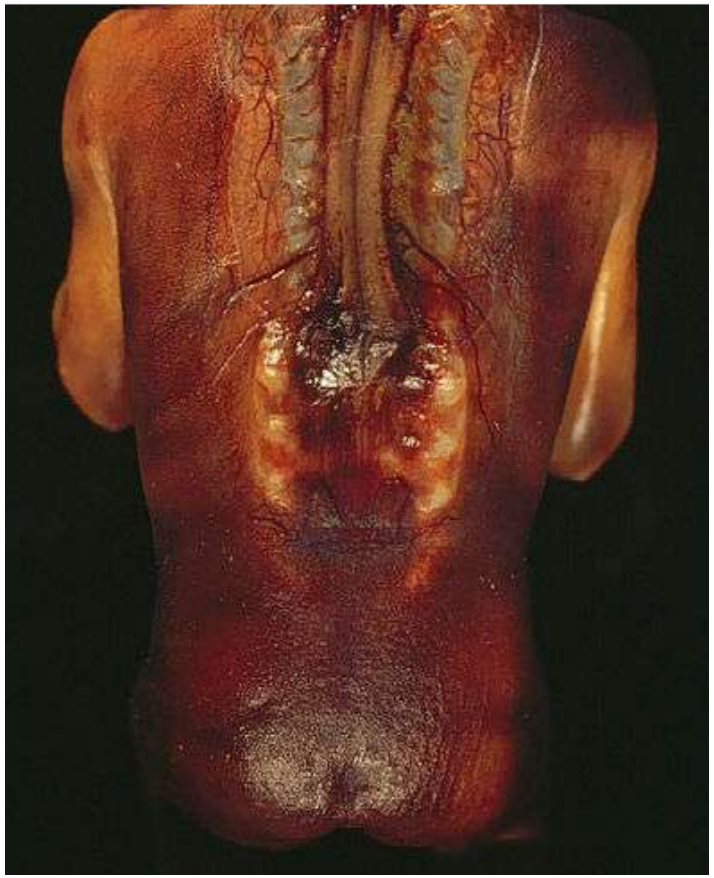
This is the exposed inside of the spinal cord: not a dissection but 'as it comes'.

Spina bifida (a very serious case)

Image: Ed Uthman, Wikimedia Commons

The sealing up of the edges of the tube, and its separation from the ectoderm, sometimes fails:

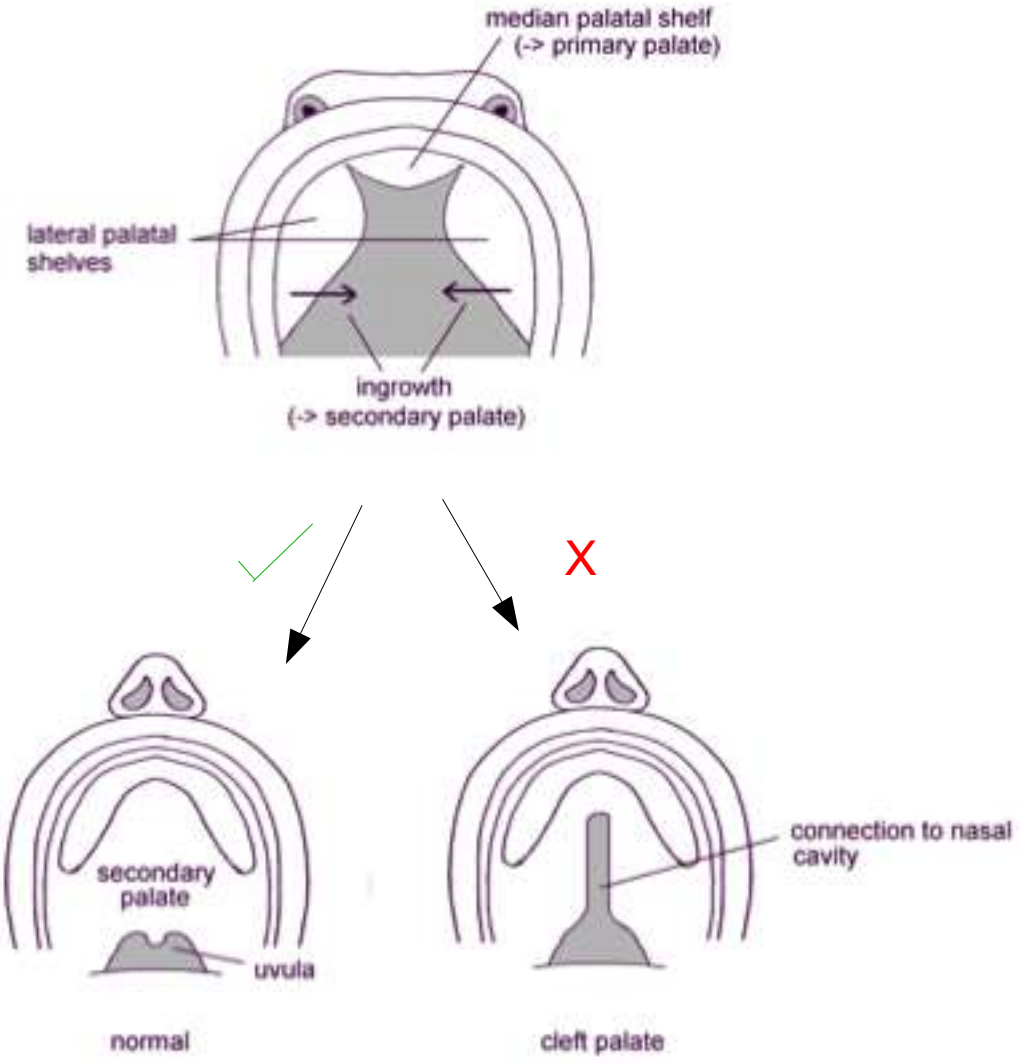
Anencephaly (the inside of the brain is open to the back of the head: this stops brain growth so the upper-back head is effectively missing. Incompatible with post-natal life).



Spina bifida (a very serious case)

Image: Ed Uthman, Wikimedia Commons

Another place that needs to be 'sealed up' is the secondary palate: this often fails.



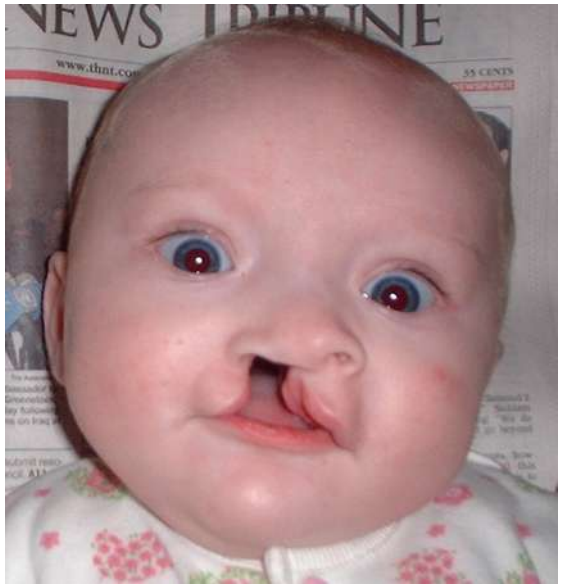
Orofacial cleft: also called ‘cleft lip and ‘cleft palate’

(the term ‘hare lip’ is deprecated and causes offence to some)

Danger of drowning when suckling milk

1/1500 births.

It is treatable surgically



6 months, untreated

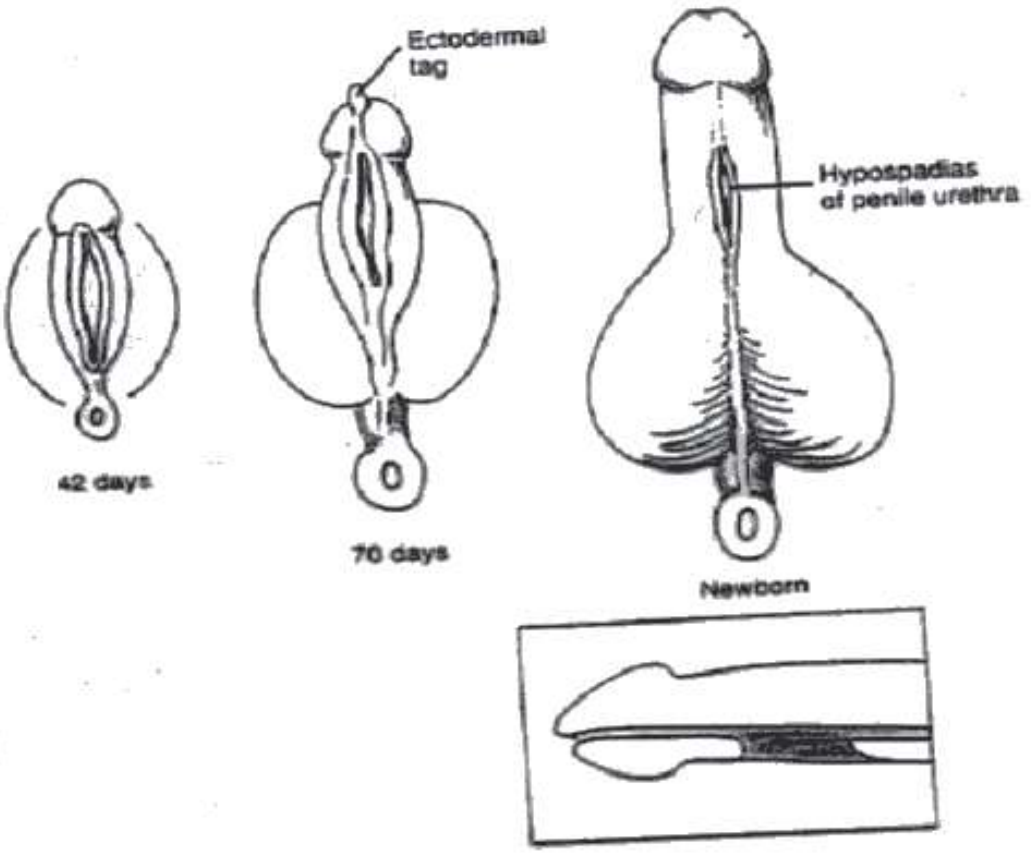
1 month later

7.5 years later

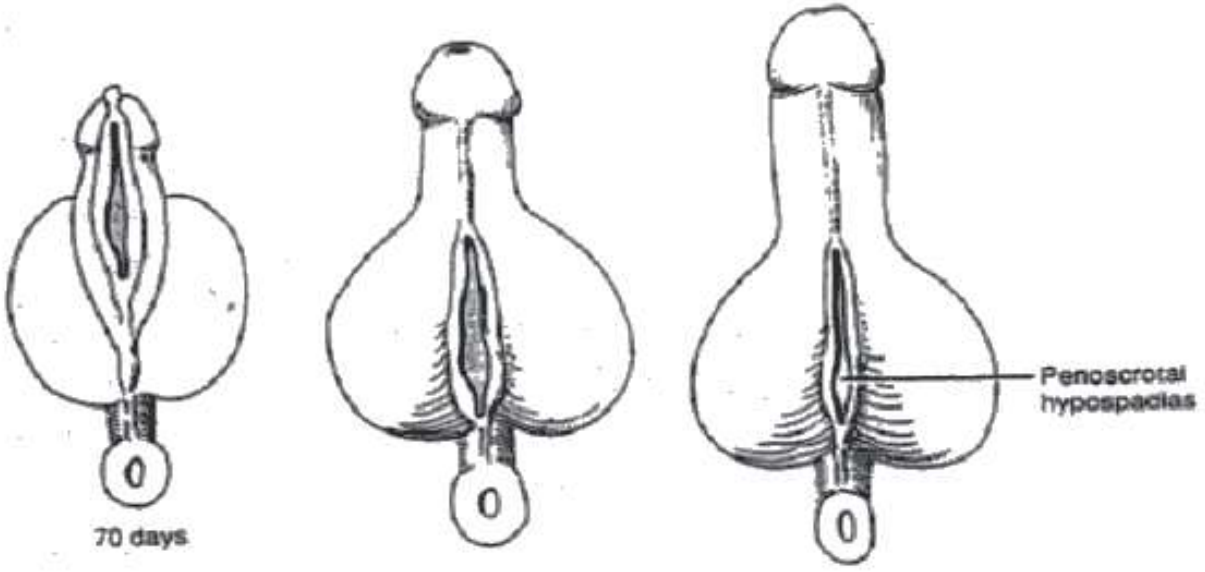
Image credit: King97tut, public domain, via Wikimedia Commons

Hypospadias

1/250 male births
(most are mild forms)



Don’t worry if you do not ‘get’ this: we will meet it again in more detail in Yr2 Renal & Urology.



There are very many other congenital abnormalities in humans (OMIM lists about 8,500).

I have introduced you to a few common ones to indicate why understanding embryology is important to your learning as medical students.