Embryogenesis 2
EP 5

Hey, hey, hey—It's Nikaela, and this is Cellfie Life, where we talk about complex science principles by relating them to I love Lucy episodes and bunnies.

If you have no idea what i'm talking about listen to the Early Embryogenesis episode, it was the episode right before this one.

Also, For those of you questioning my 3 heys. I heard someone say it in the library when I was writing this episode and thought I would try it on. I'm not sure how I feel about it.

Hi, Im Nikaela welcome to the Cellfie Life. This subject is a two-parter because it was getting a little longer than I wanted. I want to keep these episodes around 30 minutes-ish. So, I decided to chop the Embryogenesis review in half.

But first housekeeping!
I have set up a Patreon page, If you are enjoying the show and want to share the love, you can head over to pateron.com With Patreon you can pay a small amount of money each month to help me cover production costs. It will help me pay for hosting and pay my amazing editors that help me get these episodes out every week. You can support the podcast for as little as .25 cents an episode, a dollar a month. Or if you are just such a broke student and you need that dollar for ramen, I get it share the love by telling your friends about this podcast, and rating and reviewing.

You can follow me on Instagram, where I post review questions on my stories just about every day. You can also check out the website at cellfielife.com, where you can find the scriptnotes, gifs, memes, and YouTube links I talk about in the show.

Now, lets jump right in-

Okay, so last episode we talked about fertilization and implantation, and cleavage and morulas, and blastocysts and the trophoblasts and the inner cell mass. And how the inner cell mass gives rise to the bilaminar disk which ultimately gives rise to the germ layers. I know, we covered a lot.

And this is where we are going to pick up on this episode.

We are going to pick up right after implantation. The embryo is just heading into gastrulation at this point, which we have already talked about a little, in the previous episode, but were gonna talk about it more in detail here. Gastrulation is the formation of the 3 germ layers. It also happens about the 3rd week of development, so it happens pretty early.

We haven't gone over these germ layers but do you remember them from school…?

Q: r what are the 3 layers of the trilaminar disk called?
A: Ectoderm, Mesoderm, Endoderm.

If you got that one give yourslf a high five-

Follow up:

Where do these 3 layers develop from?
A: the inner cell mass that forms the bilaminar disk which is made up of the epiblast and hypoblast. The epiblast layer will become the trilaminar disk which is made up of ectoderm, mesoderm and endoderm.

Let's talk about how these 3 layers form.

We will start by taking another look at the bilaminar disk just to remind us where we're at. The bilaminar disk has formed and is the 2 pancakes, remember? the top layer is the epiblast and the bottom layer is the hypoblast.

Cells of the epiblast migrate inward, downward and then differentiate.

Picture the migration of the epiblast cells like 2 waterfalls facing each other. These waterfalls are long and on the epiblast layer. These waterfalls are happening where the primitive streak formed. Remember the primitive streak is a grooved structure along the caudal midline of the bilaminar disk. In the last episode, we talked about it being that one line of syrup on our pancakes.

From either side this continuous passage begins down the center of the top pancake, like symmetrical waterfalls facing each other. So if you were standing in the middle of a canyon and water was coming in from both sides creating these symmetrical waterfalls this is what the epiblast layer does. The spot where you are standing would be on top of the hypoblast layers. So these moving cells of the epiblast are what macroscopically create the primitive streak.

So the epiblast cell that just went down the waterfall, that is the primitive groove, the cells that fall down the waterfall go down and start mixing with the layer that is the hypoblast. The hypoblast layer starts deteriorating and the new differentiated epiblast layer have now completely replaced the hypoblasts. So now we have a new bottom layer of cells. Called the endoderm.

The endoderm is derived from the epiblast

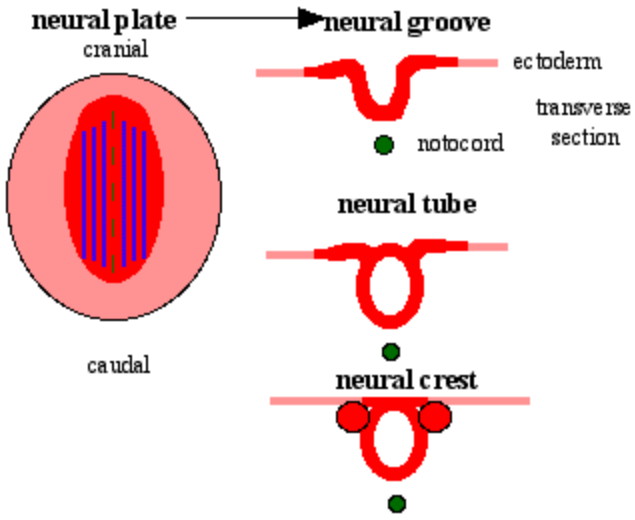
The epiblast cells don't stop there they continue down the waterfall and stat making a middle layer of cells in between the newly formed endoderm layer, and that top epiblast layer. THis middle layer of cells which has been derived from the epiblast but positions itself below the epiblast and above the endoderm is now called the mesoderm.

So now we know that the endoderm and mesoderm are both derived from the epiblast.

So now the remaining part of the epiblast is like, no I've changed I need a new name too! The remaining portion is now called the ectoderm.

So the epiblast layer is actually super talented. It has now created the endoderm, mesoderm, and epiderm along with the notochord.

In the last episode, we mentioned that the notochord starts in the middle of the middle so the notochord is a knot of cells that forms in the middle of the mesoderm.



Neural tube patterning

https://embryology.med.unsw.edu.au/embryology/index.php/Notochord

But these 3 layers the endo, meso and ecto derms are also known as the germ layers.

Neurulation - this is the process where the neural tube forms. Later it will form the brain spinal cord, and miniges. We enter the neurulation phase with the 3 primary germ layers and this is where they start differentiating further to become different types of tissues.

Another flashback to school days question. Do you remember what the germ layers, gives rise to in developed bodies?

Let's review that really quick

Q: what does the ectoderm give rise to?
A: remember the ectoderm is the “attract o derm” so it gives rise to things we might think of as attractive about a person. Their (big doctor) brain, skin, hair, the lens of the eye. The tricky one to remember is the adrenal medulla,

Q: how about the mesoderm? What does the mesoderm develop into?
A: The mesoderm is the means-o-derm, which is the means of how you get around. Think skeletal muscles, circulatory system, and most of the excretory systems; the gonads are also from the mesoderm germ layer, cause you’re getting around ;) as well as the adrenal cortex.

So because the adrenals are composed of 2 different germ layers make sure you pay attention to that. The adrenal medulla is from the ectoderm, and the adrenal cortex is from the mesoderm. I actually think this makes a lot of sense if you think about it. So, the adrenal glands are these small glands that basically are just sitting on top of your kidneys. But they produce hormones.

When I think who the big player in hormone production is, I'm thinking the brain. Which we know is from the ectoderm layer. The adrenal medulla is the inside of the adrenal glands and the adrenal cortex is the the outside. Remember we talked about cortex meaning bark, or shell in Latin. So the cortex is the outside of the adrenal gland. The hormones get made inside, in the medulla, the adreanal medualla is from the ectoderm. The outside of these galnds is from the mesoderm layer. Mesoderm like the layer that makes the kidneys that these things are hanging out on top of. Does that help a little? I find if I get a better picture I don't have to memorize everything because I understand it.

The last gem layer, is the endoderm.
A:the endoderm forms the pancreas, thyroid, bladder, parts of the liver, and the epithelial lining of the digestive and respiratory tracts.

Humans are basically complicated origami

So the short version of neurulation is that folding of the three germ layers, specifically the ectoderm results in the formation of the neural tube. Different parts break off of the ectoderm, these are called neural crest cells and these travel throughout the forming body, to make things like the adrenal medulla, and autonomic ganglia, and those other parts of your nervous system that aren't housed in the brain or spinal cord.

Obviously, it's more complicated than origami, and in med school, you'll need to know all the details but honestly, of all the things as long as you understand that neurulation is the folding of the germ layers that starts the diffreneting and results in the formation of the neural tube which ultimately forms the brain and spinal cord, I think we will be okay. Nurulatioin = human origami

Also, I don't think this will be on the test, but remember how folic acid deficiency can result in spina bifida that's one reason why a lot of female multivitamins contain folic acid and if you are trying to get pregnant you should definitely be taking this vitamin.

While we are speaking about things that can harm the fetus, let's chat about teratogens.

Teratogens are things that interfere with development and cause defects or death. However, not every teratogen has the same effect. Teratogens range from alcohol to environmental chemicals, bacteria, viruses, drugs, so really anything that can hurt development can be called a teratogen.

I just looked up Teratogen in my little root word book. Which I really love and use al the time its called dictionary of rootwards and combining forms by Donald J Borror . It was recommended to me the first time i took anatomy, and now it has a perma place in my heart. Also that's not an add, I just talk about root words a lot, and this is where im looking most of them up. I'll like it in the script notes.

https://www.amazon.com/Dictionary-Word-Roots-Combining-Forms/dp/0874840538/ref=sr_1_fkmr0_1?keywords=dictionary+of+rootwards+and+combining+forms+by+Donald+J+Borror&qid=1578785683&sr=8-1-fkmr0

Any way, Terato means monster in Greek, and gen means to bare or produce. Which is really kind of terrible, but now you should never ever forget what a teratogen is or does. Who came up with that word?? I think that it is really kind of terrible. (Torrible is a combination of terrible and horrible.) Teratogens are torrible.

While we are talking about the few things that can be harmful to a growing embryo and fetus, let's talk about TORCHES. T-O-R-C-H-E-S is an acronym for things that can cross the placenta and harm the baby.

TORCHES stands for

TO - toxolasma gondii
R - rubella
C-cytomegalovirus
HE-herpes and HIV
S-syphilis.

Toxoplasma gondii is actually a parasite that you can get from cats. So like changing the kitty litter, if the cat is infected, you can also get it from eating undercooked meat or from mother to child, like what we're talking about.

Rubella - which is a virus and preventable because there is a vaccine

Cytomegalovirus is a virus, as the name says, and most people who are infected are asymptomatic. This virus usually only causes problems in pregnancy or those with weakened immune systems.

Herpes- is a super common sexully transmitted infection The greatest risk of transmission to the fetus and the newborn occurs in case of an initial maternal infection contracted in the second half of pregnancy. But doctors can treat with antivirals and in some cases c sections are recommended.

HIV - human immunodeficiency virus (HIV) and i googled HIV and passing it on to baby and read an article that said if you work with your doctors and follow guidelines, 99% of HIV-infected women will not pass HIV to their babies. I had no idea it was that is was 99% preventable of passing it on to your child if you worked with your doctor and of course have access to the drugs.

Syphilis - is caused by a spirochete bacteria called *Treponema pallidum* which is a spirochete. Which means it is corkscrewy. Syphilis is treatable with the right drugs but left untreated can cause problems. Like neurosyphilis.

Now let's talk a little bit about stem cells. I know awkward segway but we were going over neurulation and then we took a sidetrack into bad things for fetus, let's circle back around and finish up the neurulation talk with some details about stem cells. Which are really frekin cool. Like how!? How!? How do they know they are supposed to do that and not do that other thing.

There are chemical messengers and only certain genes are turned on, but still, science is pure magic and I freakin love it. SO let's talk about stem cells.

When talking about stem cells you might hear terms such as specification and determination and in the past I have heard these explained in a slightly confusing manner but it's really not confusing at all.

Specification is reversible

Determination is not reversible.

This is not the best metaphor but what popped it to my head immediately is dating and marriage. We're just gonna pretend like divorce isn't thing for this metaphor.

A lot of people like to date around before they get married and once they find someone they like they might be like, 'okay, you don't completely terrible are now my significant other, boyfriend, girlfriend, whatever have you.

Now this is still a reversible action, so in terms of stem cells this would be considered specification. The cell is reversibly designated as a specific cell type. Now if things are working out really well you might move on to marriage. Marriage is a more serious commitment, some might even say irreversible. This is determination in stem cell talk. Before determination the cell can become any cell type, after determination the cell is in it for life.

Now how a cell knows to become a certain type of cell is what I think is a really cool area of research. Determination is, forgive me, determined by a lot of different things like, how much

cytoplasm is in the cell, RNA distribution, one of my favorites is when the neighbor tells it what to do.

“On wednesdays we wear pink”

So the neighbor cell that tells the cell what to become secretes morphogens. Like its the queen bee telling everyone else what to do, by messenger. These messages are telling the person what to morph into.

Basically, the perfect human morphogen example is Regina George.

“On Wednesdays we wear pink”

Quite frequently morphogens work by gradient so the closer the cell is to the morphogen point of release, the higher exposure it will be subjected to. Some of the prepbooks name some common morphogens, but I’m not gonna lie here. The only one I really remember is Sonic Hedgehog (Shh), which is the best nerdy name for anything in science.

Question for you. If you do research and discover a little protein, like a morphogen. What would you name it? I would definitely name it after some small creature. What would you call it? What would I call it.? I co9uld just call it creature… or doby? I asked my brother and he suggested karl Malone, the mailman. He’s been a lifelong jazz fan. Or navi from zelda. I might call one avo toast. Cause i could.

If anyone has some really great names, I want to hear them. Send them to me on insta: @thiscellfielife.

Really i want to see them. Show me your nerdy creativity

Okay, back on track. So we have specification, determination and then we have differentiation. If we are sticking with the marriage analogy this is like maturing in the relationship. Stem cell differentiation may include changing the structure and biochemistry. Like when you get into medical school and now your person will move across the country with you.

specification -

Determination-

Differentiation -

So Stem cells are essentially cells that can differentiate into lots of different types of cells. There are 2 main types of cells that are talked about: embryonic stem cells and adult stem cells (aka somatic stem cell)

Embryonic stem cells are pluripotent stem cells that are taken from the inner cell mass.

Q: what stage of embryology are there inner cell mass cells?

A: Remember the inner cell mass was that group of cells that huddled together in the blastocyst that later differentiated into the germ layers.

Refresher that pluripotent basically means that these cells can form any cell in the body. And there are different levels of potency.

O - that's potent. What do you mean?

So lets go down the line from greatest level of potency to least amount of potency.

Totipotent means that the cells can differentiate into any cell type. So the morula's cells would be totipotent because these cells can differentiate into any cell type, either the placenta structure or the fetus.

The next is pluripotent

Pluripotent stem cells are master stem cells that can potentially create any cell within the human body. So the inner cell mass cells, are pluripotent.

The next level of potency is multipotent

Multipotent stem cells can differentiate into multiple types of cells within the particular group. This is what most somatic stem cells are. A common example of a multipotent cell is the Hematopoietic stem cell which are capable of making red blood cells and platelets and all the different types of white blood cells.

A lot of differentiation depends on the cell's neighbors, just like determination was influenced by morphogens. Differentiation can be determined or influenced by inducers. It's like when someone wants you to do something so they induce you with pizza. So if someone is trying to get you to do something (with pizza, or pancakes. I'm in a mood for pancakes) they would be the inducer. The person responding to the bribe is the responder and the responder is considered competent if they are able to respond to the inducing signal.

https://media.giphy.com/media/7Wst0EswP4C665l8sA/giphy.gif

This stuff is important and can be confusing, so lets review that one more time. Here we go.

Specification determination then differentiation.

Determination can be influenced by morphogens. After determination cells can differentiate. Cells that have not yet differentiated or can give rise to other cell are stem cells and these are grouped by their potency. Cell potency refers to the varying ability of stem cells to differentiate into different specialized cell ypes. The hierarchy of potency is TPM. totipotent, pluripotent, multipotent. I've never heard a great way to remember this TPM -idk toilet paper man.. Lol i don't know, but there levelof potency is also contained in their name. Totally, plural and multiple

Determination and Differentiation can be determined or influenced by inducers. If a cell is open to inducing it is called competent.

I have a khan academy video link in my notes if you need an extra visual.

https://www.youtube.com/watch?v=uUH5YI5dTOg

So inducers help cells to differentiate. This can happen through autocrine, paracrine, juxtacrine signals.

Do you remember what these crine words mean?

Autocrine: is when the signal acts on the same cell. So the cell sends a signal to itself. Like when you leave yourself a post it on the door so you won't forget to grab your lunch out of the fridge as you're rushing to the lab.

Paracrine: the signal is for the general area. So you send out a message to the people in the general area you are in.

Juxtacrine: This is for the person sitting right next to you. Please pass a note to that person.

One thing that I think is really cool is that induction is not always a one-way path. Cells can induce each other to become certain cell types. When this happens, it is called **reciprocal development.** Kaplan had a cool example in their book, the lens of the eye and the optic cup induce each other which is called... reciprocal development.

O my gosh, we're getting so close

We are getting close, I promise, really close. I know that embryogenesis is very dense but the last item I want to cover is fetal circulation.

We need to know the fetal circulation specifically because fetal circulation works quite a bit differently than adult circulation because the fetus isn't using its lungs to take in oxygen. It's getting its oxygen from mom through the placenta. Remember that mom and baby's blood is not mixing. In the last episode, we talked about the formation of the placenta at the beginning. If you need a quick review. But in the meantime, let's do a little pop quiz on the topic...

Q: Can you remember what extraembryonic structure will form the baby's portion of the placenta?

A: the chorion.

Follow up

Q: what cells give rise to the chorion?

A: trophoblasts.

Another question from the last podcast.

Q: what extraembryonic membrane surrounds the fetus?

A: the amniotic sac, which is full of amniotic fluid.

When people say their water broke its this amniotic sac and the fluid that they are talking about. So the fetus is surrounded by this fluid that acts as an extra protective layer surrounding the

fetus. THis also means that the fetus isn't using its lungs to get oxygen. So how is the fetus getting oxygen? From the placenta, from the mom. BUt how does this work as far as circulation?

So you probably remember that your arteries carry oxygenated blood away from your heart and lungs, and veins carry deoxygenated blood back to your heart and lungs.

In the fetus the arteries still carry blood away from the heart but the blood is not oxygenated because the baby is getting its oxygen from the placenta. So the fetus is getting its oxygen from the fetal vien.

okay

Oxygenation happens through diffusion. The little oxygen molecules that are on moms red blood cells jump ship and hitch a ride on the baby's red blood cells. THis switching from mom's rbc's to fetus rbc's is done with the help of fetal hemoglobin. Fetal hemoglobin has a higher affinity for oxygen. The waste products from baby, such as c02 are diffused the opposite way from fetus to mom. Just to be clear mom and fetus's blood does not mix. Diffusion is happening across the placenta.

Lets follow the oxygenated blood from the placenta, and lets do it magic school bus style. So we are a little redblood cell and we just picked up some oxygen in the placenta and we are now catching the umbilical vein and traveling through the umbilical cord.

Pop quiz.
Q: what 2 extraembryonic structures form the umbilical cord?
A: the yolk sac and allantois

From the umbilical cord we are heading towards the liver where some of the oxygenated blood is going to go to liver to feed it oxyen but we go through a shut called the **ductus venosus** into a very large vessel called the inferior vena cava, when we enter the Vena Cava we bump into some deoxygenated blood returning from delivering blood to the kidney and the legs and get all mixed together. We enter into the right atrium of the heart.

Remember that blood doesn't need to go to the lungs for oxygen so the blood doesn't need to go to the right ventricle to be pumped into the lungs. To get around this our red blood cell goes through a shunt called the **foramen ovale.**

The foramen ovale is a short cut from the right atrium to the left atrium. It's like a secret door that only the people in the know get to use. And by people in the know, I mean the fetuses. This forman ovale works because of pressure differentials. In fetus the right side of the heart has higher pressure, this will change after birth. And the pressure causes a healthy heart to slam that trap door shut, and make it impossible to pull open against the pressure.

From the left atrium, we enter the left ventricle, where we are pumped out through the aorta and dispersed throughout the body.

but some of the blood that was in the right atrium went down into the right ventricle and when the heart pumps we know that it will send that blood to the lungs. But it doesn't need to go there to get oxygenated. so the blood that was in the pulmonary arteries can get back on track b going through the **ductus arteriosus** into the aorta, where it et back on track. It's like when yiu take a wrong turn and then take a side road to get bak on track.

There is also a lot of pressure in the lungs right now which helps keep blood from flowing there. They are basically squeezed shut.

Now we dropped our oxygen off our oxygen and need to make our way back to pick up some more oxygen and get rid of the CO2 we picked up; we make our way to the internal iliac arteries and take a right at the ulta and hop on the umbilical artery expressway headed right towards the placenta. Another thing to note here is that the placenta isn't resistant at all. The placenta wants the blood to come there and get more oxygen.

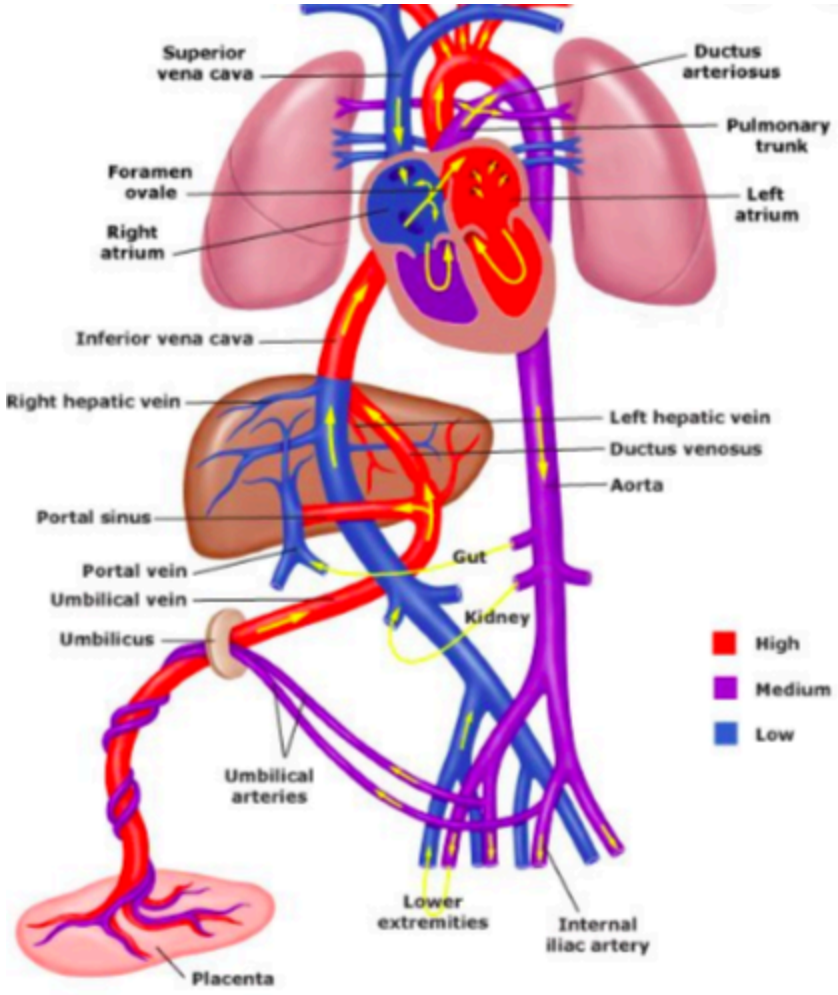
Overall important things to remember about fetal circulation:

Fetal circulation is not as clean-cut as our circulation, oxygenated and deoxygenated blood is getting mixed together.

Fetal circulation works because of the different pressures.

- -right atrium high pressure
- -lungs high pressure
- -placenta low pressure

For pressures, you can substitute in the word resistant. So the lugs are highly resistant to blood flow and the placenta isnt resistant to blood flow.



The other reason fetal circulation works is because of adaptations

Adaptations

Umbilical vein - blood from the placenta to liver and ductus venosus.

Ductus venosus. - allows blood to go from the vein to the inferior vena cava.

Foramen ovale. - blood from the right atrium to the left atrium.

Ductus arteriosus. Allows blood to go from the pulmonary artery to the aorta

Internal iliac artery - umbilical artery - low resistance.

Khan academy has a great video on fetal circulation that is linked in the notes.

https://www.youtube.com/watch?v=-IRkisEtzsk

Last thing

humans are pregnant for 38.5 weeks!!!

And then, events are further separated out into trimesters, which are approx 13 weeks.

Vaginal birth is also called parturition and happens because of the hormone **oxytocin,** which creates uterine smooth muscle contractions.

OMG, we're done!!!!!

I feel like the last 3 episodes, female reproduction, and embryogenesis episodes are some of the heaviest in the biology section of the mcat review.

Pat yourself on the back.

We MADE it!!

Study hard, friends!