

Human Embryology in Court

A case study using a courtroom setting to reinforce the principles of human embryology
In this activity students will be asked to serve as an expert witness on two different lawsuits involving an understanding of human embryology.

CONCEPT MAP OF UNIT

Human Embryology in Court is designed to reinforce the principles of embryology. Embryology is a valuable concept that revisits and integrates the principles of animal reproduction, cell communication, cell regulation, cellular metabolism, differentiation, gene regulation, growth, meiosis, and mitosis. The case study is applicable to general biology, environmental science, and human biology courses.

APPLICABLE LEVELS:

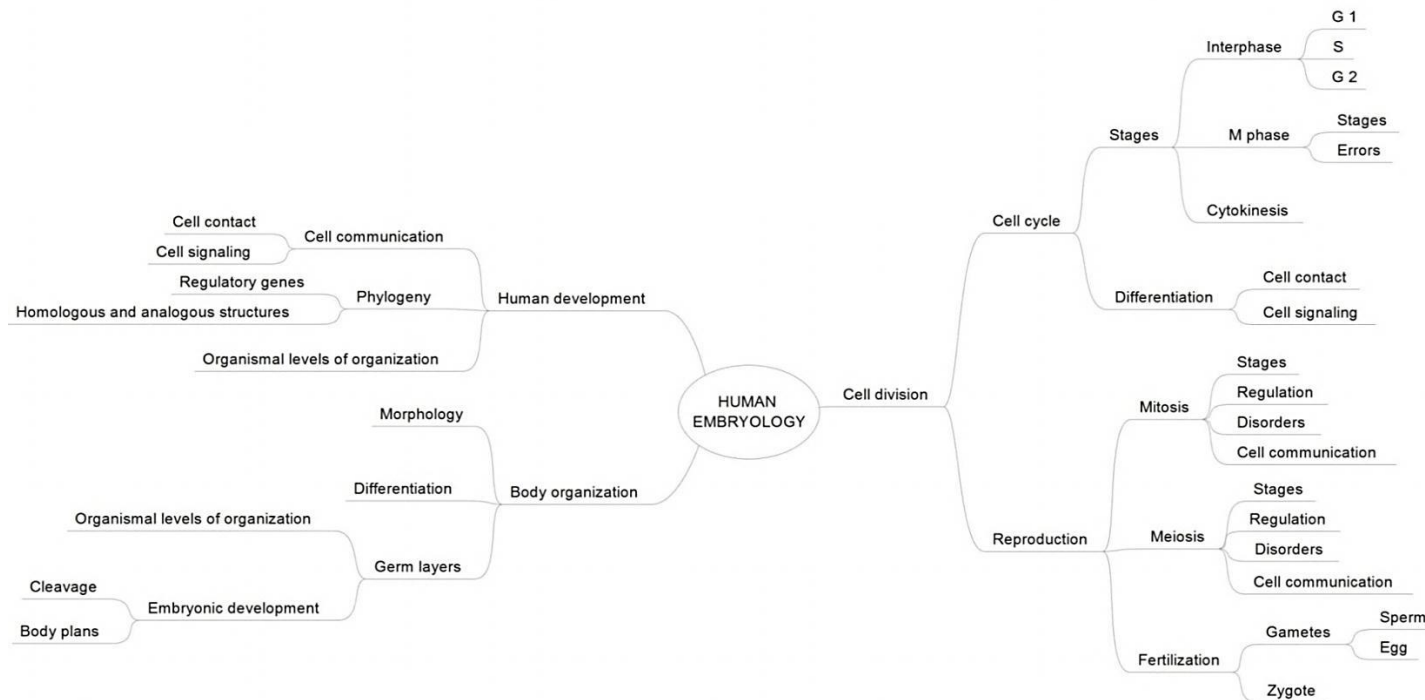
High School
Undergraduate

APPLICABLE COURSES

Biology
Environmental courses

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KEY TERMS	UNIT ESSENTIAL OUTCOMES	INSTRUCTIONAL NOTES
Asexual reproduction, cell division, cell cycle, development, differentiation, embryology, fertilization, gene regulation, growth, meiosis, mitosis, sexual reproduction.	<p>Students define and correctly use scientific terminology in describing organisms and biological processes.</p> <p>Students will apply specific facts about the major concepts of biology to answer scientific queries.</p> <p>Students will extrapolate information by studying models of biological principles.</p> <p>Students will synthesize information to solve critical thinking problems using clear and well organized essays.</p> <p>Students will apply principles of scientific inquiry to make hypotheses and conclusions.</p> <p>Students will engage in argument by obtaining, evaluating, and communicating evidence from data sources.</p>	<p>Time 1 ½ Hours</p> <p>Materials LCD projector for PowerPoint presentation Internet access</p>

MAJOR CONCEPT	MAJOR CONCEPT	MAJOR CONCEPT	MAJOR CONCEPT
Cell replication	Cellular metabolism	Genetics	Homeostasis
LESSON ESSENTIAL QUESTION	LESSON ESSENTIAL QUESTIONS	LESSON ESSENTIAL QUESTION	LESSON ESSENTIAL QUESTION
How does cell division contribute to the embryological development of organisms?	What is the role of metabolic processes such as cell transport, cellular respiration, and cell signaling on cell division and development of an organism?	What are the roles of genes and gene regulation in the growth and development of an organism?	Explain how various environmental factors can affect the growth and development of an organism?

ADDITIONAL INFORMATION

This activity is aligned with the instructional philosophies and student learning outcomes of the Common Core State Standards Initiative (CCSS), Next Generation Science Standards (NGSS), and Vision and Change in Undergraduate Biology Education initiative.

Human Embryology in Court

A case study using a courtroom setting to reinforce the principles of human embryology

In this activity students will be asked to serve as an expert witness on two different lawsuits involving an understanding of human embryology.

Instructor's Content

Introduction

Human Embryology in Court is designed to use embryology information as a conceptual model for reinforcing and integrating the principles of animal reproduction, cell communication, cell regulation, cellular metabolism, differentiation, gene regulation, growth, meiosis, and mitosis.

Case studies are stories are used as teaching tools for apply a theory or concept to real situations. The problems presented in case studies require students to define what assumptions are needed, what information is relevant, and what steps or procedures are required in order to solve them.

Case studies incorporate the content objectives of the course into problems, connecting previous knowledge to new concepts, and connecting new knowledge to concepts in other courses and disciplines. Aside from teaching content, case studies in biology courses achieve the following objectives:

- Teaches students to be active learners
- Makes information relevant and pertinent to students
- Presents information in a user-friendly way
- Embeds the facts of the course in a problem-solving real-world scenario
- Instills workforce skills
- Links disparate information to provide a holistic systems approach to learning course content

Human Embryology in Court is a case study designed to use embryology principles as a conceptual model for reinforcing and integrating the principles of animal reproduction, cell communication, cell regulation, cellular metabolism, differentiation, gene regulation, growth, meiosis, and mitosis. Embryological development is an incredible orchestration of cell division, cell communication, and cell differentiation with the goal of producing an organism from a single fertilized egg. In humans, the progression of early embryological development is typically divided into Carnegie stages and account for the first 50 days of development. According to Stedman's Medical Dictionary, the Carnegie stages (kar-nā'gē) are 23 numbered stages of human embryonic development defined by conspicuous anatomic features such as the appearance of limb buds. Each stage represents a period of cell differentiation that leads to the development and formation of organ systems.

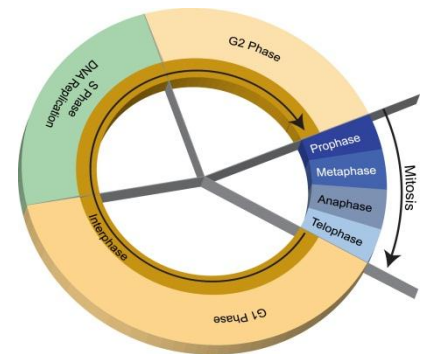


Image courtesy of National Human Genome Research Institute

Case Study Background

In this case study, the students are given the following websites to research the developmental events going on during the different stages of human embryological development:

- **The Visible Embryo Project**
<http://www.visembryo.com/baby/>
- **MedLine Plus –Fetal Development**
<http://www.nlm.nih.gov/medlineplus/ency/article/002398.htm>
- **The Multi-Dimensional Human Embryo website**
<http://embryo.soad.umich.edu/index.html>
- **PBS Odyssey of Life – Morphing Embryo**
<http://www.pbs.org/wgbh/nova/odyssey/clips/>
- **LSUHSC. –The Virtual Human Embryo**
http://virtualhumanembryo.lsuhs.edu/HEIRLOOM/Stages/Stages_intro.html

It is recommended to bookmark these websites on a centralized presentation computer to demonstrate the use of these embryology resources. Instructional computers in a learning lab can also have the websites bookmarked to streamline the project for the students. A useful image showing fetal critical stages of development is available on the NIH NIAAA: Understanding the impact of alcohol on human health and well-being website at <http://pubs.niaaa.nih.gov/publications/Social/Module10KFetaExposure/Module10K.html>.

After the students are familiarized with the embryology websites, they are then asked to read short statements about situations in which women at different stages of pregnancy are exposed to chemicals that affect cell division or cell differentiation. In the first case the students are introduced to an accidental chemical release from a petrochemical company located near a city. The chemical absorbs into lungs and interferes with mitosis by reducing the mitotic division rate. Because of the chemicals polarity, it leaves the body through the sweat and urine within three days after exposure. The second case involves exposure to an estrogen-like drug that persists in the body at biologically active levels for two months.

In each case, students use the information they gathered about the developmental events of the Carnegie stages to hypothesize the possible effects of teratogens on the fetus. The students are placed in the of expert witnesses responsible for hypothesizing the probable cause of birth defects in the children of women exposed to the chemicals. Students must use the evidence they collected from the embryology websites to evaluate the probable harm caused by the chemical depending on the time of exposure during the mother's pregnancy. Both of the case studies are based on litigations that occurred within the past few years.

Instructional Recommendation

For two case studies, student will be given the following challenge:

"In this activity you will be asked to serve as an expert witness on one or two different lawsuits involving an understanding of human embryology. Every year in North America dozens of courts carry out trials in which chemical manufacturers and drug companies are sued for purportedly harming children who were exposed as an embryo to harmful chemicals or drugs. Expert witnesses in these trials are expected to evaluate whether the injury to the child was caused by the exposure or was due to some other factor. Other factors causing injuries include naturally occurring birth defects or exposure to other conditions such as overconsumption of alcohol. As part

of the expert witness you will research the stages of human embryology and make hypothesizes about the types of birth defects that are likely to occur during different stages of embryological development.”

In case study 1, plaintiff lawyers defending the women confirmed that five women were exposed to release. Each was exposed to the chemical at a different stage of pregnancy:

- i) Woman 1- 5 days after fertilization
- ii) Woman 2- 12 days after fertilization
- iii) Woman 3- 20 days after fertilization
- iv) Woman 4- 2 months after fertilization
- v) Woman 5- 6 months after fertilization

In case study 2, a woman is suing an over-the-counter supplement manufacturer for harm to her child. She claims the company was negligent for not warning her that the dietary supplement she was taking contained phytoestrogens that could cause harm to the embryo. The women’s plaintiff attorney affirms that the baby boy was born with incompletely formed genitals, a condition called hypospadias.

It is recommended to break the students into two groups; one group will be assigned to Case 1 and the other to Case 2. Then have the students present their findings to the whole class. Each group could also be assigned into subgroups that each use only one embryology website as their source of information. The subgroups can then “fact check” each other’s answers and present a consensus of their findings to the whole class based on their investigations of the different websites. Student answers will vary based on the details of each Carnegie stage described in the different websites.

Student Queries

Let the students debate the accuracy of the assessments of the cases during the whole class presentation. Use the information from the human embryology websites and the Instructor’s Answer Key to help the students validate their conclusions. Students are provided with suggested websites for researching the biology content of the questions asked in each case study.

References

Ambrose, Susan A., Bridges, Michael, DiPietro, Michele, Lovett, Marsha C., and Norman, Marie, K. How Learning Works: Seven Research-Based Principles for Smart Teaching. San Francisco: Jossey-Bass, 2010.

Davis, James R., and Arend, Bridget D. Facilitating Seven Ways of Learning: A Resource for More Purposeful, Effective, and Enjoyable College Teaching. Sterling, VA: Stylus, 2012.

Gupta, Ramesh C. Reproductive and Developmental Toxicology. New York: Elsevier Science. 2011

Nilson, Linda B. Teaching at Its Best: A Research-Based Resource for College Instructors. San Francisco: Jossey-Bass, 2010.

Kassuba, Sherree L. Environmental Causes of Birth Defects. Yale-New Haven Teachers Institute. Accessed 13 September 2013. <http://www.yale.edu/ynhti/curriculum/units/1982/7/82.07.07.x.html>.

Instructor Answer Key

Case Study 1

1. How do teratogens affect mitosis and differentiation?

Teratogens can slow down or stop mitosis by interfering with cellular metabolism. They can also interfere with differentiation causing the production of abnormal cells. Cell communication can also be disruption. These factors in turn affect the overall organization of the body.

2. Which body parts are developing during the following embryonic period based on the Carnegie stage description?

- 5 days after fertilization

Carnegie stage 4 - The embryo is a free-floating blastocyst that enters the uterus. The cells of the embryo are not differentiated and the blastocyst is not yet attached to a placenta.

- 12 days after fertilization

Carnegie stage 5 - The three germ layers are forming and the embryo is now attached to the placenta. Blood vessels between the embryo and placenta are growing rapidly.

- 20 days after fertilization

Carnegie stage 9 - The cells making up the brain and spinal cord are forming the full length of the central nervous system. The heart tissue is starting to form and differentiate. The segmented body plan is beginning to differentiate.

- 2 months after fertilization

Carnegie stage 23 – The taste buds are forming on the surface of the tongue. The baby teeth are finishing their development. The fingers get longer and the toes lose their webbing. The skin begins to mature and the tail starts to disappear.

- 6 months after fertilization

No Carnegie Stage - The bone marrow begins to make blood cells. The lower airways of the baby's lungs develop but are still not mature. The baby begins to store fat. The brain is setting up neural pathways for vision and hearing.

3. Explain what type of defects you would expect in the child.

- 5 days after fertilization

There is usually no harm to embryo because it is not getting resources through the placenta. In some cases the toxin can prevent the embryo from forming a placenta during this period and thus causing a very early miscarriage.

- 12 days after fertilization

The embryo will likely be so malformed that a miscarriage will occur. Also, it is possible for the baby to be significantly deformed meaning it could be missing limbs or body segments.

- 20 days after fertilization

Major brain and heart defects would be noticeable. Also, it is possible for the baby to be slightly deformed meaning it could have abnormal limbs or body segments.

- 2 months after fertilization

The baby could not have sense of taste and it could have malformed teeth. The fingers could be shortened and the toes could still have webbing. A tail may be present also.

- 6 months after fertilization

The baby may have blood cell deficiencies causing problems with the immune system and transporting oxygen. The lungs are likely to be defective. Vision and sight could be impaired.

4. Develop a brief class presentation describing the type of defects you would expect in the child if the women were exposed at their stage of pregnancy. Also, explain what other information you would need to know about each woman to assert if the birth defect was caused by the exposure or by other factors. Your report could use images showing human embryological development or relevant birth defects.

The students should display the correct Carnegie and developmental stages for the time of chemical exposure. Plus, they should be correctly discussing how the body systems are affected based on the developmental processes that are affected.

Case Study 2

1. At which Carnegie stages does sexual development occur?
Sexual develop begins in Carnegie stage 17 and is differentiating internally into male and female by Carnegie Stage 23. The external genitals are finalizing and clearly visible as female and male by 15 weeks after fertilization.
2. At what stage is hypospadias likely to occur?
Hypospadias is likely to occur late in the sexual development stages such as Carnegie stage 23 or later.
3. What is the role of estrogen in sexual development?
Estrogen starts differentiating the gonad into an ovary or testicle at Carnegie stage 17 in the female. In the male, the SRY gene helps the gonad turn into testes because of testosterone production. Too much estrogen can make the testes nonfunctional. Later in development, too much estrogen will delay or stop development of the male external genitals.
4. How do sex hormones affect the cell differentiation involved in the development of the sexual organs?
Estrogen and testosterone are solely responsible for sexual development. The embryo starts with separate and shared components of both genders. Estrogen develops the female components and differentiates the shared components into female parts. Testosterone develops the male components and differentiates the shared components into male parts.
5. Develop a brief class presentation describing the human embryonic timeline related to sexual development. Explain how early or late exposure to the phytoestrogens could affect sexual development. Also, explain what other information you would need to know about other factors that could interfere with sexual development in an embryo. Your report could be in the form of a PowerPoint presentation showing human embryological development and possible sexual development birth defects such as hypospadias.
The students should display the correct Carnegie stages for the time of progression of sexual development. They should then show how too much estrogen can affect early and later exposure.

Student Handout Next Page

Human Embryology in Court



U.S. Supreme Court, Photo courtesy of Architect of the Capitol

Human Embryology in Court

In this activity you will be using information from embryology websites to determine the possible injury to an embryo caused by the mother's exposure to a harmful chemical. One case involves exposure to a hazardous pollutant and another case investigates the administration of a drug with potentially harmful effects.

Introduction

Human embryological development is an incredible orchestration of cells going through rounds of mitosis and differentiation with the goal of producing the human body plan. Cells are constantly communicating with other embryological cells and with chemical factors in the blood to coordinate the process. Much of the success of any embryo relies on the optimal environmental conditions and nutrients needed for cellular respiration and differentiation.

Early in its development, the human embryo is an undifferentiated clump of cells that undergoes mitosis to increase the cell number for future growth. After several rounds of mitosis groups of cells then begin to differentiate to form three distinct layers of cells called germ layers. A germ layer is a layer of cells responsible for additional rounds of mitosis and differentiation to form the various organ systems.

The location of cells within the germ layers determines succeeding differentiation. One group of cells influences differentiation of another group of cells through physical contact or chemical signaling. Regulatory genes then determine how the different sections of an organism develop. The cells develop specialized functions based on differences in the types of organelles and cytoplasmic structures. Earlier developmental events are usually called embryonic stages. In later stages the growing baby is called a fetus.

Many factors can affect the outcomes of development with the possibility of producing birth defects in the embryo. The science of developmental toxicity explains how cells in the embryo can be functionally or structurally altered by environmental conditions. These changes can produce irreversible or reversible effects on development, differentiation, growth, and homeostasis. Chemical pollutants, drugs, infectious agents, and radiation are the more common factors that can harm an embryo.

Exposure of pregnant women to harmful chemicals and drugs often leads to lawsuits in which a judge or jury must determine if harm was caused to the embryo. You will be reviewing two case studies of jury trials involving the exposure of pregnant women to chemicals that affect embryonic development. In these cases you will play the role of an expert witness who must determine the types of developmental defects that could occur in an embryo at different times during development.

In humans, the progression of early embryological development is typically divided into Carnegie stages. According to Stedman's Medical Dictionary, the Carnegie stages (kar-nā'gē) are 23 numbered stages of human



Leonardo da Vinci. Views of a Fetus in the Womb, c. 1510-12.
Courtesy of Dreamstime at <http://www.dreamstime.com>

embryonic development are defined by distinct anatomic features such as the appearance of limb buds. Each stage represents a period of cell differentiation that leads to the development and formation of organ systems. Contact with harmful environmental factors inhibits development of the particular Carnegie stage during the time of exposure. A group of chemicals that interfere with development are called teratogens. The most important period that can result in serious damage to an embryo is when cell differentiation and body development are most active. For example, brain development peaks from 3 to 16 weeks after fertilization. Exposure to teratogens during the 3 to 16 week can lead to severe brain damage.

Embryology Resources

The following embryology websites provide images and descriptions of the Carnegie stages of human embryological development.

- **The Visible Embryo Project**
<http://www.visembryo.com/baby/>
- **MedLine Plus –Fetal Development**
<http://www.nlm.nih.gov/medlineplus/ency/article/002398.htm>
- **The Multi-Dimensional Human Embryo website**
<http://embryo.soad.umich.edu/index.html>
- **PBS Odyssey of Life – Morphing Embryo**
<http://www.pbs.org/wgbh/nova/odyssey/clips/>
- **LSUHSC. –The Virtual Human Embryo**
http://virtualhumanembryo.lsuhs.edu/HEIRLOOM/Stages/Stages_intro.html

You may be asked by your instructor to do only one case study for this activity. In addition, you may be assigned only one website to investigate the developmental events that take place during the different Carnegie stages for the case studies. When reviewing the websites, it is important to remember that the Carnegie stages account for the first 50 days of development. It is also important to look through all of the stages to get a general idea about the body parts that develop in each stage. This will make it simpler when researching questions about the stages. You may need to find websites that describe the embryology terms in the embryology websites. On-line science dictionaries such as “Biology-Online Dictionary” link to a variety of resources that explain embryology terms.

You will also have to use the internet to research the effects of harmful chemicals and drugs on cell differentiation and mitosis. Websites such as the Centers for Disease Control and Prevention, Environmental Protection Agency, Food and Drug Administration, and WebMD have search engines for looking up information about harmful chemicals.

Two Case Studies

In this activity you will be asked to serve as an expert witness on one or two lawsuits involving an understanding of human embryology. Every year in North America dozens of courts carry out trials in which chemical manufacturers and drug companies are sued for purportedly harming children who were exposed as an embryo to harmful chemicals or drugs. It is common to use expert witnesses in these trials to educate the jury about the technical information needed to understand a court case.

Expert witnesses in birth defect trials are expected to evaluate whether the birth defect to the child was caused by the exposure or was due to some other factor. Other factors causing birth defects include naturally

occurring birth defects due to DNA mutation or errors in cell communication. Other causes of birth defects could be due exposure to other conditions such as overconsumption of alcohol. As part of being an expert witness you will research the stages of human embryology and make hypothesizes about the types of birth defects that are likely to occur during different stages of embryological development.

The last two pages of this worksheet have note pages to record the information you gathered from the various websites.

Case Study 1 – Bad Air or Bad Luck?



Photo courtesy of EPA

Background

A chemical manufacturing company in Pollutonia, Texas experienced an accidental release of a hazardous chemical into the air. The chemical cloud travelled downwind to a small community where the residents complained of stinging eyes and running noses as the pollution passed over their houses. It was learned that the chemical, tetrachloroethylene, has teratogenic properties. Teratogenic means that the chemical interferes with cell differentiation in embryos. Unfortunately, the chemical absorbs quickly into the blood after it enters the lungs. However, it is rapidly broken down and removed from the body through the urine in several days.

Several months after the tetrachloroethylene release a court case took place between the chemical company and neighboring women who were pregnant during the release. The women were claiming that their children developed birth defects related to the tetrachloroethylene. Plaintiff lawyers defending the women confirmed that five women were exposed to release. Each was exposed to the chemical at a different stage of pregnancy:

- i) Woman 1 was exposed 5 days after fertilization
- ii) Woman 2 was exposed 12 days after fertilization
- iii) Woman 3 was exposed 20 days after fertilization
- iv) Woman 4 was exposed 2 months after fertilization
- v) Woman 5 was exposed 6 months after fertilization

Problem

Assume that you are an expert witness on this trial. What information about embryological development and teratogens would need to know to explain the case accurately and fairly using scientific facts? Answer the following questions to determine if the birth defects in the children would be consistent with the exposure during the particular stage of pregnancy.

1. How do teratogens affect mitosis and differentiation?
2. Which body parts are developing during the following embryonic period based on the Carnegie stage description?
 - 5 days after fertilization
 - 12 days after fertilization
 - 20 days after fertilization
 - 2 months after fertilization
 - 6 months after fertilization
3. Explain what type of defects you would expect in the child.
 - 5 days after fertilization
 - 12 days after fertilization
 - 20 days after fertilization
 - 2 months after fertilization
 - 6 months after fertilization
4. Develop a brief class presentation describing the type of defects you would expect in the child if the women were exposed at their stage of pregnancy. Also, explain what other information you would need to know about each woman to assert if the birth defect was caused by the exposure or by other factors. Your report could use images showing human embryological development or relevant birth defects.

Case Study 2 – Bad Drug or Bad Timing?

Drug Detective

- Her skepticism and insistence on having "all the facts" before certifying the safety of a sleep-inducing drug averted an appalling American tragedy — the birth of many malformed infants.

○ ○ ○ ○ ○ ○

She resisted persistent petitions of commercial interests who presented data supporting claims the inexpensive drug was harmless. The facts finally vindicated Dr. Kelsey, as evidence piled up to show the drug — thalidomide — when taken by pregnant women, could cause deformed births.

Her action won her the President's Award for Distinguished Federal Civilian Service.

FRANCES O. KELSEY, M. D.
Food and Drug Administration

The Federal Civil Service

★★★★★
1883-1963

Four Score Years of Service to America

Photo courtesy of Food and Drug Administration

Background

A woman is in court suing an over-the-counter supplement manufacturer called Nature's Way Hormone Supplements for harm to her child. She claims the company was negligent for not warning her that the dietary supplement she was taking contained phytoestrogens that could cause harm to the embryo. Phytoestrogens can increase the effects of estrogen in the body. Her attorney told her of a similar case involving a drug containing a chemical called thalidomide. Thalidomide produced life-threatening birth defects in children whose mothers' were pregnant when taking the drug. The women's plaintiff attorney affirms that the baby boy was born with a birth defect consistent with embryonic damage caused by certain harmful drugs. At birth the body had incompletely formed genitals, a condition called hypospadias. Scientific evidence shows that hypospadias can be caused by higher than normal estrogen levels in pregnant woman.

Problem

Assume that you are an expert witness preparing for this trial. What information about phytoestrogen and sexual development would need to know to judge the case fairly using scientific facts? Answer the following questions to determine if the hypospadias in the boy is consistent with exposure to the phytoestrogen.

1. At which Carnegie stages does sexual development occur?
2. At which stage is hypospadias likely to occur?
3. What is the role of estrogen in sexual development?
4. How do sex hormones affect the cell differentiation involved in the development of the sexual organs?
5. Develop a brief class presentation describing the human embryonic timeline related to sexual development. Explain how early or late exposure to the phytoestrogens could affect sexual development. Also, explain what other information you would need to know about other factors that could interfere with sexual development in an embryo. Your report could be in the form of a poster. Your report could use images showing human embryological development and possible sexual development birth defects such as hypospadias.

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