**Teaching the Concept of Meiosis: A Summary**

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Background Information: Meiosis

Meiosis occurs during sexual reproduction. Sexual reproduction is a process whereby two parents provide the genetic material in order to produce an offspring. This type of reproduction depends on meiosis for cell division. When the genetic material from each parent combines, it produces an offspring that is genetically different from both parents. In addition to this, each offspring thus inherits a unique combination of traits.

Meiosis is unique in that it produces 4 cells, each with half the number of chromosomes as the parent cell. An exception to diploid cell numbers in humans (2n=46) is the sex cells. The sex cells are known as gametes. Each homologous pair gives a single set of chromosomes to each gamete. This type of cell is referred to as haploid because it contains a single set of chromosomes (n=23) in humans. The haploid gametes are produced through meiosis. In animals, meiosis occurs in the sex organs, testes in males and ovaries in females.

Meiosis is characterized by 2 phases, meiosis I and meiosis II. In meiosis I, homologous chromosomes exchange DNA and then separate forming haploid cells. Meiosis II is characterized by the separation of the sister chromatids into 4 haploid daughter cells.

Advanced Preparation/Teaching Ideas

Before learning about meiosis students need to be familiar with other concepts related to genetic processes including: the structure and replication of genetic material, and mitosis. To prepare to teach about this new concept, teachers should begin with a Minds On Activity that actively and mentally engages students at the start of class. Educators can arrange to show an educational video on meiosis from YouTube: Meiosis or through elearning Ontario (see below for website). This video will provide an explanation of the phases and overall purpose of meiosis as stated above. Teachers will need Internet access and a projector or Smart Board to show the video clip.

Once the video clip is shown, the teacher can assist the students in a virtual laboratory. Prior to the lesson, teachers should post the desired website on the board as well as login access for the virtual lab in order to reduce student questions and confusion in the computer lab. The inquiry-based learning approach is best employed for this because it allows students to work independently while exploring the virtual laboratory. The purpose of this laboratory is to give students a virtual representation of the stages in meiosis including: centrosomes, nuclear envelope, chromatin, spindle, tetrad, sister chromatids, centromere, homologous chromosomes, sister chromatids, cleavage furrow, and haploid daughter cells. Students can explore phenomena such as crossing during prophase I and random assortment of chromosomes in metaphase I and II during the virtual lab. This will assist them in a greater understanding of genetic recombination because it provides an audio visual for which students can interact and explore the phases of meiosis.

After the virtual lab session is completed, the teacher would engage students in an inquiry activity. Educators should set up the microscopes and slides prior to the laboratory session. Also, students need to be familiar with safety procedures in the laboratory including: location of safety equipment, what to do in an emergency, and proper handling of laboratory equipment as well as proper laboratory apparel. Students should work in pairs for observing the phases of meiosis in their slides and will submit their own scientific drawings complete with labeled diagram/magnification/title/phase of meiosis. Note to teachers, try to select slides that vary in their phases of meiosis so that students are not copying one another, and are challenged to link their microscopic observation to the phases observed during the virtual lab. Educators can assist the students when they are deciding on which stage of meiosis their slide is illustrating by asking guiding questions such as “how does meiosis I differ from meiosis II?”, “list two differences between anaphase I and anaphase II”, or “when do we see the spindle fibres form?”.

Educators should consider role-play for demonstration of crossing over/genetic recombination with their students. The wresting game allows student participants to act as chromosomes while their limbs act as chromatids. Students can form groups to perform this activity and can also colour coordinate themselves to better illustrate how crossing-over and recombination occur. Teachers can use this as a reinforcement to the main concepts illustrated in meiosis.

Finally, there are several articles available to students and teachers regarding genetic testing, particularly for newborn and prenatal as discussed in this topic (see below for link). A teacher led reading on the ethical issues, and support and opposition for this topic can be used as an assessment opportunity through which students debate about newborn or prenatal testing. It is important to consider that not all students feel comfortable speaking, therefore, teachers should assign a reflection on the topic as a follow up activity.

Curriculum Expectations

D2.2 investigate the process of meiosis, using a microscope or similar instrument, or a computer simulation, and draw biological diagrams to help explain the main phases in the process

D3.1 explain the phases in the process of meiosis in terms of cell division, the movement of chromosomes, and crossing over of genetic material

D3.4 describe some genetic disorders caused by chromosomal abnormalities (e.g., non-disjunction of chromosomes during meiosis) or other genetic mutations in terms of chromosomes affected, physical effects, and treatments

Lesson Sequence

Lesson 1: **Meiosis and Sexual Reproduction**

* + Sex Chromosomes and Phases of Meiosis

Lesson 2: **New Gene Combinations**

* + Crossing Over

Lesson 3: **Atypical Chromosome Numbers**

* + Trisomy, Down Syndrome, Non-Disjunction

Lesson 4: **Damage to Chromosome Structure**

* + Mutation, Translocation, Deletion, duplication, Inversion

Lesson 5: **Genetic Testing**

* + Prenatal Testing, Newborn Screening

Potential Student Difficulties/Possible Solutions

Students may have difficulties distinguishing between the different phases of meiosis as well as between meiosis I and meiosis II. The virtual laboratory may help clarify student concerns and questions regarding the difference between each phase in that they are given the opportunity to explore the process within each phase. However, for students who are still struggling with the different phases of meiosis, an in-class diagram may assist students in their organization of the processes within each phase. For instance, educators can create a word bank for each of the phases with the associated process beside. Teachers can use this as a game and potential discussion tool in the classroom as an indicator of student comprehension.

Having learned mitosis prior to meiosis, some students may be confused between the two divisions. Creating a Venn diagram or T-chart can assist students in organizing the processes associated with each type of division including the similarities such as chromosome duplication in prophase (I). These charts should be placed in an area that is visible to the students during activities, but not assessment due to the high degree of information that will be revealed.

In addition, their confusion and difficulties to remember the sequence of changes in meiosis would be resolved by mnemonics, for example for phases of cell division: Interphase, Prophase, Metaphase, Anaphase and Telophase (IPMATC). Once students remember the sequence, the process will be taught by telling a story for comparison with major intracellular changes and developments that occur during cell division. The wrestling game, in which the participants are chromosomes and chromatids are their limbs, illustrates how crossing-over and recombination occur. Once students have the concept of meiosis, they now can read, analyze, and interpret the differences in the diagrams of meiosis drawn in different books.

Once students are comfortable about mitosis, teaching the concept of meiosis will be easier through analyzing and comparing with meiosis and noting differences. For example, mitosis completes in single phase while passing across IPMATC, whereas meiosis undergoes in two phases, I and II. The process and sequence in both is similar to mitosis in particular phases. In addition, prophase has different subphases Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis/Interkinesis. Taking all first letters, LZPDD as similar in Long Zebra Protects Danger and Death) can assist students in remembering the concept.

Finally, students may have difficulty in remembering chromosome mutations: translocation, deletion, duplication, and inversion. Devising a mnemonic as a class will not only create a differentiated environment where all students can learn, but it also assists the students in remembering what each mutation is in relation to a chromosome. Thus it is through explicit instruction, virtual laboratories, video demonstrations, and laboratory sessions that students will develop their understanding of the process of meiosis and the creation of genetic variation. Considering vivid aspects and styles of learner, different instructional strategies are adopted as explained above. The variation in the types of activities caters to the different types of learners for instance: youtube videos (musical), the wrestling game (kinesthetic), virtual lab (spacial), in-class laboratories (logical), and research articles (linguistic). In addition, mnemonics and Venn diagrams created as a class provide effective instruction for both interpersonal learners because they can contribute effectively to group discussion. The reflection to conclude the debate also invites intrapersonal learners to contribute their thoughts by working independently.

Differentiated assessment

Considering vivid aspects and styles of learner, different instructional strategies are adopted as explained above under Potential Student Difficulties. A variety of assessments types like diagnostic, formative and summative will be considered. The diagnostic assessment will be administered to access prior knowledge about cell structure and meiosis cell division as well as to identify the learning difficulties. Students’ learning will be assessed through formative type and they will be intrinsically motivated. They will also be encouraged to imitate the activities how the crossing-over was demonstrated in the youtube video and wrestling /role-play activity. A summative unit test incorporating the skills set from all areas of achievement chart will be used to evaluate the virtual/in class activities as per developed by the students for laboratories. In addition, the achievement chart will also be used to assess students’ oral and written communication for the debate.

Applications and Societal Issues/Implications

Students will learn how meiosis relates to topics such as genetic testing and damage to chromosome structure. Through virtual labs, research, video clips, and laboratories, students will be exposed to some of the ethical issues surrounding genetic testing including concerns such as, maternal bleeding, miscarriage, or premature birth during prenatal testing (see references for articles relating to this topic). Educators should connect these topics with society in that it fulfills the Ontario Science Curriculum goal of relating science to technology, society, and the environment. Students will be able to explore these topics through inquiry-based activities and class-discussions. See below for articles that relate these topics to real-world situations.

Safety considerations

Considering the nature of adolescents, students should be well monitored while they are executing the virtual lab activity in order to make sure that they are on task. Unsafe websites should be blocked either by appropriate settings on browser or through school’s server. Volunteers who are selected for the role play ( i.e. the wrestling game) should be encouraged to sign a safety contract.

According to the Ontario Science Curriculum (2008) “students demonstrate that they have the knowledge, skills, and habits of mind required for safe participation in science activities and laboratories when they” (Ontario Science Curriculum, 2008):

*• maintain a well-organized and uncluttered work space;*

*• follow established safety procedures;*

*• identify possible safety concerns;*

*• suggest and implement appropriate safety procedures;*

*• carefully follow the instructions and example of the teacher;*

*• consistently show care and concern for their own safety and that of others*

Thus, it is important for teachers to maintain these standards through the review of safety measures in the classroom in order to avoid issues during the laboratory sessions.

Annotated Bibliography

Collier, Roger. 2012. Surge in Down syndrome prenatal testing anticipated. *Canadian Medical Association*. Retrieved July 11, 2012 from <http://www.cmaj.ca/content/184/9/E449.full.pdf+html>

This journal article by Collier (2012) discusses the anticipation of an increase in prenatal screening as a result of cost and safety of the procedure. Teachers can use this article to formulate discussion during lessons on Genetic Testing as it complements the topic. Educators might also consider having the students find their own article pertaining to this topic and presenting it to the class. Alternatively, teachers can also use this topic as a debate session for which students in either group must oppose or support Newborn or Prenatal testing. Teachers can assess the quality of student responses (ethics, personal choice ect.) and have students write a reflection on their opinion.

Ellis, C., Muller, M.R., Panayiotou, H.E., Sharp, J.C., and Webb, P. (2011). *Pearson Investigating Science: Biology Source 11*. Pearson Canada Inc.: Toronto, Ontario.

This textbook served as a source of background information, as well as an organizational tool for the lesson sequence of this assignment. It also provided the questions used for the meiosis laboratory, which were used to guide the students’ thinking and inquiry when observing the stage of meiosis in their slide.

Meiosis Square Dance. Retrieved on July 12, 2012 from <http://www.youtube.com/watch?v=iCL6d0OwKt8>

This video is a good example how to enhance learning through edutainment. This song covers the major changes and processes including synapsis, crossing-over and exchange of chromatin thread.

Ministry of Education. 2007. Unit 2: Meiosis: Creating variation. *Ontario Educational Resource Bank.* Retrieved July 11, 2012, from <https://resources.elearningontario.ca>

This website serves as the virtual lab for the students. It allows students to view the stages of meiosis through animation. This website is useful because it incorporates both audio and visual representations of meiosis. In addition, this virtual lab provides a brief summary for each stage for which student can use to take notes.

Pearson Education. 2012. Lab 3: Mitosis and meiosis. *Lab Bench Activities.* Retrieved July 11, 2012, from <http://www.phschool.com/science/biology_place/labbench/lab3/concepts2.html>

This website is equivalent to that above (elearning Ontario) and can be used as a substitute or reinforcement of meiosis concepts. Students can explore the different stages of meiosis through animations. Each phase provides a description of the processes occurring, which can assist students in taking notes throughout the virtual lab. This website is particularly useful because it provides an animation of meiosis through the production of ascospores. Students can explore the possible arrangements of ascospores through the virtual laboratory. Through inquiry, students can then proceed to answer follow-up questions regarding the production and arrangement of the ascospores. Teachers can use this as an independent or paired assessment tool for the students.

Zimmerman, Stacy. (ND). Lab 10: Chromosome structure and meiosis. *General Biology 101.* Retrieved July 11, 2012, from <http://bio.rutgers.edu/~gb101/lab10_meiosis/meiosis_web/karyotype1/disease1.html>

This website can be used as an alternative to the in class meiosis laboratory or in addition to the in class laboratory. Students can explore the stages of meiosis in the Lily Microsporangia. The website provides information such as “meiosis in the anther starts with the diploid microsporocyte” to guide student thinking throughout the laboratory. Educators can use this website as a way for students to observe microscopic cells and to gain familiarity with identifying the stages of meiosis in microscopic cells, which can be difficult in 2 dimensional slides. Teachers can also request the students to print out their responses to the online questions to assess student thinking and inquiry.