**SCIENCE 11 Module number 4 (Ivan Marcelo A. Duka; UP Los Banos)**

 **CYCLES AND PATTERNS (revised July 17, 2018)**

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Seminal readings:

1. Life cycle of a system: [http://gilburgleadership.com/uploads/images/Life%20Cycle%20of%20a%20System(1).pdf](http://gilburgleadership.com/uploads/images/Life%20Cycle%20of%20a%20System%281%29.pdf)
2. The life cycle of organisations as living systems: <https://www.linkedin.com/pulse/life-cycle-social-enterprise-heidi-de-wolf>
3. Interpreting the dynamics and patterns of living systems: https://academic.oup.com/bioscience/article/63/9/721/260600

**LEARNING OUTCOMES**

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**INTRODUCTION**

Hello and welcome again to the living world! You and I are integral components of other living systems which may be as small as a single cell or as big as the Earth in which we live, the Biosphere- the global ecosystem. Cycles and patterns govern living systems. Can you think of some?

 In the previous module, you were exposed to different biogeochemical cycles. These cycles are but a few in the world of life. A quick look at the web takes one to a listing of cycles- the Citric acid cycle, the Calvin cycle, water cycle, reproductive cycles, population and community successions. Even the Earth is said to have undergone ice age and global warming cycles. Cycles in living systems result to patterns which could be cyclical in nature. From the molecular to cellular, organismic and ecosystem levels, we are all part of the cycles and patterns by which life continues in the struggle for survival.

 A short overview of biological cycles can be read from [https://encyclopedia2.thefreedictionary.com/Biological+Cycles](https://encyclopedia2.thefreedictionary.com/Biological%2BCycles) while an article on “Interpreting the Dynamics and Patterns of Living Systems” by Kumar Selvarajoo may be read from BioScience. Vol. 63, No. 9 (September 2013), pp. 721-722 (**https://academic.oup.com/bioscience/article/63/9/721/260600).**

 In this module, we will take a journey to the most exciting aspect of one’s existence: reproduction. Isn’t this your favourite topic since grade school? Reproduction requires proper development of sex cells. Development and growth of organisms lead to reproduction in order to perpetuate the species. In many ways development and reproduction like cycles and patterns are intertwined. Genes are passed on to offsprings in various Mendelian and non Mendelian patterns. Conscious or sub conscious, the innate goal of a living system is to avoid extinction. It is ok to find a mate and produce babies. Do you agree?

In this module we will first review the cell cycle then move on to reproductive cycles and other patterns in living systems.

**Learning Outcomes:**

At the end of this module, you should be able to:

1. Discuss the stages of the cell cycle, mitosis and meiosis
2. Explain the life cycles of selected organisms
3. Differentiate reproductive processes in flowering plants and humans
4. Appreciate some patterns governing living systems

**REVIEW: The cell cycle- mitosis and meiosis**

Recall from high school that the cell is the basic unit of life. It is the smallest structure that exhibits almost all known properties/attributes of “being alive”. Reproduction and developmental processes depend on Mitosis and Meiosis. This concept is one of the postulates of the Cell Theory, i.e. “Cells arise from the division of other pre-existing cells”. In this module, you will take a journey into how cells and organisms reproduce, what cycles they undergo and what common patterns govern living organisms as to reproduction and development.

ACTIVITY 1: Watch the following video on Mitosis: ( approximately 10 minutes) <https://www.youtube.com/watch?v=mXVoTj06zwg>

Guide questions:

1. Describe each stage of the cell cycle.
2. What type of cells undergo the G0 aspect of the cell cycle?
3. What is the importance of the centrosome during mitosis?
4. Why is Interphase not a stage of Mitosis?
5. Describe each of the phases of Mitosis.
6. How does mitosis maintain the chromosome number in each generation of the cell cycle?

Optional ACTIVITY 1: Do you want an online game? (around 15 minutes) Here’s one on the cell cycle: <http://www.biology.arizona.edu/cell_bio/activities/cell_cycle/cell_cycle.html>

This will challenge you to correctly identify the stages of Mitosis in actual onion root tip cells as viewed in the microscope. Try it!

*Questions for further research:*

1. *What are some control points for cell division?*
2. *At what point in the cell cycle can a cell commit to uncontrolled growth, i.e cancer?*

For other related topics and applications of Mitosis such as tumor suppressor genes and stem cell biology, you may read: <https://www.nature.com/scitable/topic/cell-cycle-and-cell-division-14122649>

Other videos on the cell cycle are found on the following sites:

<https://ocw.mit.edu/courses/biology/7-014-introductory-biology-spring-2005/video-lectures/22-mitosis-and-meiosis/>

ACTIVITY 2: Watch a video on Meiosis on this site: (approximately 10 minutes) https://www.youtube.com/watch?v=16enC385R0w

Guide questions:

1. Describe the stages of Meiosis.
2. What events in Meiosis account for variation in the resulting daughter cells? Although you have the same parents, explain why you are not an exact replica of your brother or sister.
3. Why does Meiosis II exhibit the same chromosome behaviour as Mitosis?

For further reading on the development of sex cells by meiosis, please go to the following link: <https://www2.le.ac.uk/projects/vgec/highereducation/topics/cellcycle-mitosis-meiosis>

*Questions for reflection: What happens when a sex cell does not undergo proper Meiosis? What will happen if this cell fuses with another unreduced gamete?*

Optional ACTIVITY 2: Search for human conditions that result due to abnormal Meiosis. Tabulate your findings. Discuss these with your classmates and teacher.

Now that you have reviewed the importance of Mitosis and Meiosis, let’s take a look into some reproductive cycles and patterns. These events are applicable in algae, protists, fungi, plants and animals.

**Reproductive cycles.** In eukaryotic organisms, there are three major reproductive cycles: haplontic, diplontic and diplohaplontic cycles. Are you familiar with the term “alternation of generations”? This is the same as having a diplohaplontic life cycle.

**HAPLONTIC LIFE CYCLE**

ACTIVITY 3: Some organisms that exhibit the Haplontic life cycle are the unicellular chlorophyte *Chlamydomonas* and the cellular slime mold. Study the following diagrams in <https://bio113portfolioleighhobson2.weebly.com/life-cycles4.html> (around 7 minutes)

Guide questions:

1. Describe the sexual phase in the life cycle of these organisms.
2. How are gametes formed?
3. How is reproduction without sex made possible?
4. In the life cycle of the cellular slime mold, what triggers the individual cells (amoeba) to stick together and act as one (multicellular entity)?

 In the **haplontic** life cycle, the zygote is the only diploid cell which undergoes Meiosis. The resulting haploid cells are called spores. They can grow and are considered fully functional organisms. Imagine a haploid cell as an independent functioning organism! The best example is in the life cycle of Chlamydomonas, a unicellular green algae. This life cycle is also called zygotic meiosis. Individual gametes are released and fuse with another gamete to form a zygote.

**DIPLOHAPLONTIC LIFE CYCLE**

ACTIVITY 4: Study the diagrams on the life cycles of Ulva and Laminaria in this site: <http://www.plantscience4u.com/2014/05/diplohaplontic-life-cycle-in-algae.html#.Wli68KiWbIU> ( around 10 minutes)

Guide questions:

1. Describe how generations alternate in the life cycles of Ulva and Laminaria.
2. What is the dominant phase in the life cycle of the organism?
3. How would you distinguish isomorphic versus heteromorphic alternation of generations?
4. What are isogamous gametes?
5. In the life cycle of Laminaria, why is the egg cell dependent on the female gametophyte?

Discussion: Thediplohaplontic life cycle is also referred to as **alternation of generations**. Both sporophyte and gametophyte are multicellular and fully functioning individuals. They can both be macroscopic or microscopic and may be equally predominant forms of the organism.

This kind of life cycle occurs in algae, protists, fungi and primitive plants. The sporophyte is in the diploid condition while the gametophyte is in the haploid state, i.e all cells have a haploid chromosome number. So how are gametes formed? Earlier in this module it was mentioned that Meiosis produces gametes. Well, this is true for higher forms of organisms. In this case, the Gametophyte releases tiny individual cells by Mitosis and since they are already haploid, they act as gametes. A gamete from one individual fuses with another one to from a zygote. The fertilized egg divides by mitosis and eventually becomes the Sporophyte. From the body of the Sporophyte, certain tissues undergo Meiosis which produces haploid gametes. The resulting cells are called spores. A spore divides into many cells and produces the Gametophyte. The life cycle of the fern exhibits the diplohaplontic type of life cycle.

Take home assignment: Make a table comparing the life cycles of Ulva, Laminaria, a fungus and pine tree. Explain the similarities and differences.

**DIPLONTIC LIFE CYCLE**

ACTIVITY 5: Read the following open educational resource (approximately 10 minutes): <https://www.oercommons.org/courseware/module/14992/overview>

Guide questions:

1. What are the main features of the human reproductive cycle?
2. How is reproduction connected to some ecological and evolutionary concepts?
3. Describe the Red Queen hypothesis.

In the diplontic life cycle the organism is in the diploid condition, i.e. each body or somatic cell has a diploid chromosome number. Humans have a diploid chromosome number of 2n=46. In the 23 pairs of chromosomes, one half came from the mother and the other half was contributed by the father.

You and I are in the diplontic life cycle. The only haploid cells are the gametes. A gamete can unite with another one and form a diploid zygote. This zygote grows by Mitosis to form a fully functional multicellular organism.

Majority of plants and animals around us follow the diplontic life cycle. At one point in the life cycle, Meiosis occurs in particular tissues to produce haploid gametes..and the cycle goes on. This life cycle is also called gametic meiosis. This term implies that gametes are produced by Meiosis. Do you agree?

Optional ACTIVITY 3: A short presentation on human reproduction, role of hormones and human genetics can be studied using the following site: <https://www.slideshare.net/eLearningJa/new-int-sc-m3u7l7-sexual-reproduction-in-humans>

Guide questions:

1. Describe the function of each structure in the human male and female reproductive systems
2. Discuss the hormonal control of the human male and female reproductive cycles.
3. Illustrate how Meiosis occurs in spermatogenesis and oogenesis.
4. Explain the events in the female monthly cycle (ovarian; uterine).

Human life cycle. Like in most diploid organisms, the human life cycle starts with fertilization. A zygote is an egg cell whose chromosome set has combined with those from the sperm. The cytoplasm of the zygote serves to nourish it for succeeding events that require energy. Can you name some organelles in the cytoplasm? Structures in the cytoplasm influence the proper development of the organism via expression of genes.

A zygote divides into 2, 4, 8, 16, 32…. until it becomes a blastocyst ready to be implanted in the mother’s uterine lining called the endometrium. Tissues and blood vessels are formed and interconnect. The embryonic blastocyst derives nourishment from the mother. A tiny fetus grows in size gradually and later, tremendously during the last stages of pregnancy (Figure 6). Fetal growth pattern (Figure 4) appears to be common in all vertebrates. This has strengthened the hypothesis that all vertebrates share a common ancestor. What common features are obvious in all vertebrate embryos? Do you see a pattern?

Finally, a baby is born and still nourished by the mother. Parental care and protection of the young are also common patterns of behaviour in the animal kingdom. Subsequent growth into maturity repeats the cycle as meiosis in sex cells are initiated to complete spermatogenesis and oogenesis. Fertilization produces the zygote and mitotic cell divisions continue to develop the mature, multicellular individual.

For discussions and videos on animal reproductive systems and asexual reproduction, view the following link: <http://karnatakaeducation.org.in/KOER/en/index.php/Reproduction_in_Animals>

Angiosperm life cycle. Plants that bear flowers are Angiosperms. They are the predominant plants we see around us. Grasses like rice and domesticated vegetables are also flowering plants. For a comprehensive discussion on the Angiosperm life cycle, open and study the following site: [https://en.wikiversity.org/wiki/Educational\_Media\_Awareness\_Campaign/Biology:\_General/POTD\_4#/media/File:Angiosperm\_life\_cycle\_diagram-en.svg](https://en.wikiversity.org/wiki/Educational_Media_Awareness_Campaign/Biology%3A_General/POTD_4#/media/File:Angiosperm_life_cycle_diagram-en.svg)

Optional ACTIVITY 4: Use the internet to search how flowers of some common vegetables look like.

Development of functional gametes make reproduction in flowering plants successful. In flowers, the male part is the stamen which consists of the anther and the filament. In the anther, there are pollen sacs that house pollen grains. One pollen grain contains sperm nuclei and a tube nucleus which develop through microsporogenesis. The female part of the flower is the carpel which consists of the stigma, style and the ovary. The ovary contains the ovules which contain the female megagametophyte. Megasporogenesis produces eight nuclei and these are: egg nucleus, fused polar nuclei, synergids and antipodals.

Guide questions:

1. What is double fertilization?
2. What are the parts of a typical dicot seed? Monocot seed?
3. Describe the development of a dicot seed.
4. Explain the events during plant seed germination.
5. What factors may inhibit plant growth and development?
6. Describe the general pattern in plant development.
7. Discuss the effect of some hormones in plant development.

**PATTERNS IN LIVING SYSTEMS**

As you go through your life as a student, friend, family member, can you think of patterns you encounter daily? From sunrise to sunset, you and I are part of the patterns and cycles that govern and define how it is to be “alive”. There is a pattern by which we procure and process nutrients. There is a pattern how plants and animals interact, behave, and reproduce among many other phenomena. You will recall that in K to 12, there are patterns of inheritance. Can you name some?

Optional ACTIVITY 5: Use the following link to review patterns of inheritance in Genetics (30 minutes):

[https://commons.wikimedia.org/wiki/Category:Genetics](https://commons.wikimedia.org/wiki/Category%3AGenetics)

Guide questions:

1. With complete dominance, what are the expected F2 genotypic and phenotypic ratios in a monohybrid cross? What about in a dihybrid cross?
2. What are some of the ratios and genetic patterns that result due to non Mendelian crosses/ gene interactions?

Questions for further research:

1. Describe some common sex linked traits. Make a list in your notebook.
2. What is the pattern of transmission of the trait?

Other than those for genetics, patterns are displayed by living systems such as in phyllotaxis, bird flying formation, spotted animals, shell patterns and even growth of bacteria in colonies. Please refer to the following links:

1. Leaf arrangement (phyllotaxis):<https://en.wikipedia.org/wiki/Phyllotaxis#/media/File:Aloe_polyphylla_1.jpg>
2. Flying formation in birds: [https://commons.wikimedia.org/wiki/File:CanadianGeeseFlyingInVFormation.jpg](https://commons.wikimedia.org/wiki/File%3ACanadianGeeseFlyingInVFormation.jpg)
3. An animal with spots: [https://commons.wikimedia.org/wiki/Category:Spotted\_mammals#/media/File:Cheetah\_Umfolozi\_SouthAfrica\_MWegmann.jpg](https://commons.wikimedia.org/wiki/Category%3ASpotted_mammals#/media/File:Cheetah_Umfolozi_SouthAfrica_MWegmann.jpg)
4. Patterns in a shell: [https://commons.wikimedia.org/wiki/File:Aviculopecten\_subcardiformis01.JPG](https://commons.wikimedia.org/wiki/File%3AAviculopecten_subcardiformis01.JPG)
5. Patterns in a bacterial colony: [https://commons.wikimedia.org/wiki/File:Paenibacillus\_vortex\_colony\_pattern.JPEG](https://commons.wikimedia.org/wiki/File%3APaenibacillus_vortex_colony_pattern.JPEG)

ACTIVITY 6- Answer the following guide questions ( 20 minutes):

1. Find out the causes of the patterns shown above. Are these due to random events and chances?
2. Could adaptation and evolution influence such patterns?
3. What are some genetics principles and biophysical laws that govern these patterns?

Let’s discuss some common biological patterns in relation to the topic on reproduction. These are reproductive patterns and pattern formation in developmental biology.

**Reproductive patterns.**

 Cycles in living systems are interspersed with patterns. What common patterns in reproduction did you realize from studying the life cycles mentioned above? You will recall from K to 12 that reproduction may be sexual or asexual. Apomixis occurs in some plants. The gamete doubles in chromosome number and becomes the precursor for a new life. There is no need for fertilization. Consult the following link for apomixis: [https://commons.wikimedia.org/wiki/File:Poa\_bulbosa,\_vegetative\_apomixis.jpg](https://commons.wikimedia.org/wiki/File%3APoa_bulbosa%2C_vegetative_apomixis.jpg)

More reproductive patterns are exhibited by animals and these include parthenogenesis, hermaphroditism and sex reversal. These patterns are controlled by seasonal and hormonal cues. They are often linked to favourable environmental conditions or energy supplies

In parthenogenesis, an unfertilized egg cell develops into a mature organism. Male bees develop from haploid egg cells. In these organisms, egg cells may also be fertilized and develop into mature organisms. The komodo dragon and *Daphnia* species also exhibit this kind of reproductive pattern.

In *Daphnia,* sexual reproduction occurs but parthenogenetic “sons” and “daughters” may also be produced. What is the advantage of such sexual behaviour?

In hermaphroditism, an individual has functioning male and female reproductive systems. Sperms and eggs are produced in the same organism but self fertilization does not occur commonly. Mating is required to fertilize both organisms. These organisms are in deep soil or mud or in some parasities. In their environment, the opposite sex is difficult to find. As a coping mechanism and for the survival of the population, both male and female reproductive tissues are evolved such as in an earthworm.

The hermaphrodite receives functional sperm cells from a male. There could be slight modifications across the animal kingdom. In some cases, only one gonad produces a functional gamete. In persons born with such conditions in humans, both reproductive tissues are non functional.

A different situation occurs in organisms that undergo sex reversal. We all know that in animals, there is a distinction as to females and males. Females possess an ovary and develop egg cells while males have testis and develop sperm cells. In some organisms like fish and oysters, sex reversal occurs throughout the lifetime, a pattern known as sequential hermaphroditism. This is due to various factors eg. in response to the environment. Protandrous species are born as males but they become females. In protogyny, an individual is first a female, then becomes a male.

Optional ACTIVITY 6: Search the web for some examples of animals that reverse their sex. Find out the causes for such changes. (10 minutes)

Sexual reproduction is an innate characteristic of animals in order to pass on genes to the next generation, promote variability and avoid extinction. Reproductive patterns are also common during courtship and mating behaviour in animals. Courtship and mating displays are important to ensure success of sexual reproduction, eg. sperm and egg production can be triggered by sexual displays, rituals and courtship behaviour.

ACTIVITY 7: Search the web for examples of animals that perform courtship behaviour. Write them down in your notebook. Which animals are more colourful? Why do these animals express aggressive behaviour? (15 minutes)

 **Pattern formation in animal development.**

 Different animals have extensive variations as to their development. From sponges to mammals, variations in life cycles and developmental patterns are due primarily to the differential expression of genes in specific cells and tissues. Studies in the fruit fly are being used to explain patterns of gene expression in animals. An example of such pattern is in the expression of homoebox genes in insects.

Guide questions:

1. Explain the function of each homeobox gene.
2. What genetic mechanisms are responsible for developmental patterns in plants and animals?

**Social organizations/ Social Insects**

 Are you a member of a school organization? What are some of the associations and groups to which your family members belong? Do you know how a town mayor administers his/her constituents?

 We all belong to a social organization: family, club, barangay. There is always a leader and members. It is interesting to note that animals like social insects behave more efficiently in gathering food, for instance than us humans. They assume roles and follow rules. They cooperate for survival. The best example is the phenomenon of eusociality.

 One of the major objectives of taking a GE course is for one to hone critical, scientific and creative thinking. Humans study complex systems like the bee colony and other social animals in order to understand the interactions that evolved in these systems. We can all learn from Nature. Social interactions may affect the way genes behave or become expressed. The converse is true. Genes may affect certain behaviors that determine an organism’s success in life and survival via adaptations. The army ants shown below are well established models for social evolution and behavioural genetics among others.

Optional ACTIVITY 7: Read the following link for this topic ( 15 minutes): [https://commons.wikimedia.org/wiki/Category:Society](https://commons.wikimedia.org/wiki/Category%3ASociety)

<https://en.wikipedia.org/wiki/Eusociality>

[https://commons.wikimedia.org/wiki/File:Diagram\_of\_Eusocial\_Species.png](https://commons.wikimedia.org/wiki/File%3ADiagram_of_Eusocial_Species.png)

Some guide questions:

1. Describe the organization in a bee colony.
2. What are the causes of eusociality? Describe the criteria for eusociality.
3. What are the theories on eusociality?

**CONCLUSIONS**

 This module on Cycles and Patterns illustrate that all living systems are interrelated. Cycles and patterns allow for adaptation and survival of the species. From the cell cycle to reproductive cycles and genetic patterns, there seems to be a unifying thread that connects all living things.

 Concepts and principles in living systems also apply to other disciplines, eg. competition, survival, adaptation. Works of art are based on appreciation of living systems from the sculpture of the human body to paintings depicting numerous plants, animals, communities and ecosystems.

 There are lessons to be learned from the study of nature and living systems interacting as a whole or as part of a bigger universe.

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**July 19, 2018**