



Maximizing Odds of Pregnancy with Artificial Insemination (AI)

Reproduction Unit

Grade Level

9-12

Lesson Length

2 periods x 55 minutes

STEM Careers

- Reproductive Physiologist
- Embryologist
- Veterinarian

Next Generation Science Standards

- MS-LS1-4
- HS-LS1-4

Inquiry-Learning Activity and Lesson Plan Authors (2022)

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These lessons aim to bring the science, skills of inquiry, critical thinking, and problem solving to life through an agricultural context.



Learning Objectives

By the end of this unit, students should be able to:

- Compare and contrast advantages & disadvantages of AI.
- Describe the reproductive role of the follicle.
- Describe the reproductive functions of estrogen.
- Describe the reproductive role of the corpus luteum.
- Describe the reproductive function of progesterone.
- Propose a training program to improve AI pregnancy rates.

Materials List

- Computer that will run Microsoft Excel, Macros enabled.
- Simulation Workbook
 - “Maximizing the Odds of Pregnancy with AI”
- 3D-printed cervix
- Bovine AI rod with sheaths



Introduction (Interest Approach that Aligns with the Investigation)

To introduce students to the “journey and hardships” of spermatozoa through the reproductive system to facilitate fertilization, show the following video titled “Fertilization”. Please note that the focus of this video is on human reproduction, but the concepts related to sperm survivability are applicable to other mammalian species.

- <https://www.youtube.com/watch?v=5OvgQW6FG4> (5:42)

Within an agricultural context, the bull (male bovine) will produce 800 million to 2 billion spermatozoa per ejaculate. However, less than 0.01% (Hawk, 1987) reaches the oviduct (i.e., fallopian tube) or site of fertilization.

Essential Questions

- *Why is AI so popular, despite lowered conception rates associated with usage of AI?*
- *Technically and biologically, how can we maximize the probability of pregnancy?*

Learning Activity 1: [PowerPoint Discussion]

Please use the provided information and/or associated PowerPoint to introduce students to concepts related to reproductive physiology and artificial insemination. If teachers prefer to show a recording, that is available at ... <https://use.vg/JJzv7C>.

There are two approaches that could be used with this lesson, dependent on teacher discretion. The first approach would be to provide an introductory lesson and background information to students before they work through the simulation (Learning Activity 2). This approach represents a traditional teaching method and likely will give students confidence in being able to answer activity related questions. The second approach would be to have students conduct the simulation (Learning Activity 2) first. As students attempt to answer related questions, they will likely struggle more, but if working in teams, it may engage greater discussion and potential generation of additional questions. Once complete, provide the related lecture and facilitate further discussion.

Learning Activity 2: Maximizing Odds of Pregnancy with Artificial Insemination

There are numerous advantages associated with usage of artificial insemination (AI) in animal agriculture, including (but not limited to) ...

- increased rate of genetic improvement through access and usage of superior sires,

- decreased rate of disease transmission (especially reproductive diseases),
- and enhanced safety for farm/ranch personnel with fewer intact breeding males needed.

However, increased pregnancy rate is NOT an advantage associated with artificial insemination. Natural service pregnancy rates almost always exceed those of artificial insemination, even with experienced technicians. Why is this, and how can we maximize the odds of pregnancy when using artificial insemination?

The following simulation is designed to help students understand the physiology of reproduction along with numerous other factors that influence the probability of pregnancy with usage of artificial insemination. Throughout the simulation, everything will be related to the bovine species (bulls and cows) as our model, but most of what will be discussed and learned is applicable to other mammalian species.

The first reason that AI pregnancy rates often fall below that of natural service is simple math and probability ...

- The bull produces only 3-8 ml of semen per ejaculate, but
- it's extremely concentrated ... 800 million to 2 billion spermatozoa per ml. That's ...
- 2.4 to 16.0 billion spermatozoa (give or take a couple hundred million, 😊) per ejaculate!

With usage of AI, merely 20 million sperm are commonly placed into a straw of commercial frozen semen. That's less than 0.25% of what the bull would naturally deliver. If working with sexed semen, only 4 million spermatozoa are placed in the straw!

Step 1: AI Technique, Questions 1-6 (Preparation)

- Working individually (or in pairs at teacher discretion), on the simulation spreadsheet, students will answer Questions 1-6 on the AI Technique worksheet (part of the Excel Workbook).

Step 2: AI Technique, Question 7 (Hands-on)

- Each student will be given 1 minute to thread the AI rod (with sheath covering) through the 3-dimensional cervix model. Students should stop when 1) they believe they are at the proper location for semen deposition via AI, or 2) time has elapsed.
- Once the student believes they are at the proper point of semen deposition, measurements may be taken
 - If the AI rod and sheath have been passed through the cervix, measure how far it extends beyond the end of the cervix.
 - 1 inch or less
 - More than 1 inch
 - If the AI rod is in the cervix, but has not been passed through, how many marks are present on the sheath?
 - Note if you can see 1 or 2 marks

- This information will be input into the spreadsheet simulation for Question 7.

Step 3: AI Technique, how can I improve?

- Input results of the hands-on component as your answer for Question 7.
- Acknowledge that “nature is cruel”; select “A” (that’s your only choice, 😊) for Question 8.
- Once all answers have been input, the program will return the projected number of spermatozoa expected to reach the ovulating egg (cell C6) and the probability of pregnancy via your artificial insemination (cell C7, **bordered in red**).
 - What projected pregnancy rate did you achieve?
 - Now, what might you change, if anything, to increase the projected pregnancy rate? For changes made, provide an explanation for why that increased pregnancy rate?
 - Water bath temperatures used to thaw semen: **The optimal thawing temperature that minimizes time required to thaw but maximizes survivability of spermatozoa is 95°F. Lower thaw temperatures take more time to thaw and provide greater risk of cold shock. Higher temperatures risk heat shock.**
 - Does water need to be wiped off? **YES. Water is toxic to the spermatozoa, and while all sperm in the straw will not contact this water, those that do (after cutting open the straw) will likely die.**
 - Should one shake down the straw? **YES. The purpose of “shaking” down the straw is to push the thawed semen away from where the straw will be cut allowing the semen to eventually be dispelled from the straw. If not done, some semen will be lost when the straw is cut.**
 - On what end should the straw be cut? **The straw should be cut on the crimped end. Otherwise, the plug will be lost, and the plunger component of the AI rod will not be able to push semen out of the straw.**
 - How much of the straw should be removed? **3/8 to 1/2 inch. If shorter, the straw is too long and the sheath will not fit tightly over the straw and AI rod. If longer, some semen will be lost when the straw is cut.**
 - Transport of AI rod to the cow: **AI rods should be placed inside the technician’s shirt, next to the skin. Think about it ... your body temperature is ~98.6°F. This is a temperature that should facilitate maximal survivability.**
 - Now, for some additional discussion, and for those students who think they’re really smart ...
 - What is the body temperature of a cow? **101.5°F.**
 - So, how is 98.6°F an optimal temperature? **For maximal survivability, the male strives to maintain temperature of the spermatozoa slightly BELOW body temperature!**
 - What is the proper location of semen deposition? **The bull will deposit most semen in the vagina or cervix, but with AI, the recommended semen deposition site is in the uterine body. Again, it’s all about numbers, 98% of semen deposited posterior to the uterine body will NOT reach the uterus.**

Given that a conventional semen straw contains only 20 million spermatozoa (0.25% of what the bull will deposit), it's imperative to deposit the semen as close to the point of ovulation as possible. However, if the AI technician extends the rod too far past the anterior end of the cervix, the semen may be deposited in one of two uterine horns. Remember, we have no idea from which side of the uterus she will ovulate the egg. The cow's reproductive tract has two uterine horns, and at the end of each uterine horn is an ovary with follicles, from which the egg may be released.

- What appears to be the maximal pregnancy rate that can currently be attained through usage of AI, even with exceptional technique? 60%

Step 4: Biological State of the Cow.

- Regardless of technique, the probability of pregnancy is highly dependent on timing and reproductive physiological state of the cow at the time of insemination.
- For each of the four biological scenarios provided, select the answer which you believe will provide the greatest probability of pregnancy.
 - If you did not achieve maximal probability of pregnancy (should equal the value in cell C7, **bordered in red**) for each of the biological states, try again.
 - Describe behavioral and biological states that maximize probability of pregnancy.
 - Day of Estrous Cycle: Day 0, breed 12 hrs after telltale signs of estrus.
 - The normal estrous cycle of the cow (from estrus to estrus, or from ovulation to ovulation) is 21 days. Unless the cow is pregnant, every 21 day, on average, she will come back into estrus and be receptive to mating.
 - With AI and the limited number of spermatozoa, timing is paramount. The cow ovulates approximately 12 hrs AFTER the end of estrus (the period of time when she shows estrous or mating behavior). Thus, to maximize the probability of pregnancy, with AI, the semen should be deposited as close to the time of ovulation as possible.
 - Hence, the "AM/PM rule" is often used – If you see the cow being ridden in the evening, breed in the morning; if you see the cow being ridden in the morning, breed in the evening.
 - Behavioral Signs: Cow stands to be mounted by other cows.
 - For nearly all mammalian animals, the telltale sign of estrus (receptivity to mating) is that the female will stand to be mounted. While cows who are in estrus may exhibit a mucous discharge from the vulva, may sniff or show interest in other cows, and may even ride other cows, those signs may be present as the cow is coming into or going out of estrus. Timing AI, based on these latter signs, will provide poor and inconsistent results.

- What hormone profile facilitates maximal probability of pregnancy?
 - As the follicle (which contains the egg) grows, it secretes estrogen. The larger the follicle becomes, the more estrogen it secretes.
 - Progesterone is secreted by the corpus luteum, a structure that rises after lysing or ovulation of the follicle. Its function is to maintain the pregnancy and keep estrus from recurring. If the cow is pregnant, there is no reason for her to ovulate another egg and/or to show estrous behavior.
 - Thus, at the time of breeding, estrogen should be HIGH, and progesterone should be LOW.
- What reproductive structures should be present and functioning to facilitate maximal probability of pregnancy?
 - Large pre-ovulatory follicle that contains an egg about to be release.
 - There will be no active corpus luteum present.

Learning Activity 3: Industry & Career Video – Reproductive Technologies

Show the industry and career video that discusses “real world” application of these basic scientific concepts, while also introducing students to career possibilities that function to bridge science and agriculture.



Reflection

Using the prompts below to facilitate reflection, allow each student to respond in writing to the prompts and then facilitate a whole class discussion.

1. If pregnancy rates are typically reduced with usage of AI, why is AI so popular?
 - Usage of superior sires, to facilitate genetic improvement
2. What key factors function to maximize the probability of pregnancy with usage of AI?
 - Exceptional AI technique
 - Identifying cows who are in the proper biological state of reproduction
3. How can you most effectively identify cows who are in the proper biological state of reproduction?
 - Observe behavioral signs of estrus and identify cows who stand to be mounted.
4. What structure on the ovary contains the egg to be ovulated?
 - Follicle

5. As a follicle grows and approaches ovulation (release of the egg), it secretes more estrogen. Given that nature strives to maximize pregnancy rates, identify two related functions of estrogen.
 - One can generally hypothesize the function of specific hormones within a cascade of hormones by thinking about what must happen next within the process.
 - After release of the egg, what must happen next? It needs to be fertilized, and in nature, that requires the female to attract the male. Thus, estrogen facilitates estrous or mating behavior.
 - Assuming the egg will be fertilized, estrogen functions to prepare the uterus for receipt and development of the fertilized egg.
6. What is the purpose of the corpus luteum and the hormone progesterone?
 - From the biological aspect of the simulation, you should have seen that progesterone levels must be LOW at the time of ovulation and breeding. However, after the egg has been ovulated, the corpus luteum will develop from the ruptured cells of the lysed follicle. The corpus luteum secretes progesterone, and progesterone functions to sustain life of this developing embryo and fetus by NOT allowing any additional follicles to grow and develop.



Apply

Use the prompts below to facilitate small group and whole class discussion.

1. What is the most important factor associated with “success” when using AI?
 - a. Unless cows are in the proper biological state of reproduction, the probability of pregnancy, even with exceptional AI technique, will be extremely low.
2. Given what you have learned about the reproductive function of progesterone, how might you synchronize heifers, so they all show estrus (mating behavior) at approximately the same time?
 - a. Estrous synchronization is a valuable reproductive technology often used in conjunction with AI.
 - b. If progesterone functions to keep follicles from growing, administer progesterone to “trick” cows into thinking they’re pregnant. When progesterone is removed (from all cows at the same time), their individual estrous cycles will be reset to the same starting point.
 - c. Commercially, this is done with insertion of a vaginal implant called a CIDR. The CIDR releases progesterone that functions to simulate a hormonal state of pregnancy. When the CIDR is removed, the progesterone levels drop, and follicles begin to develop so that all cows come into estrus at approximately the same time.

References:

- Fertilization. <https://www.youtube.com/watch?v=5OvgQW6FG4>.
- Hawk, H.W. 1987. Transport and fate of spermatozoa after insemination of cattle. J. Dairy Sci 70:1487-1503, [https://doi.org/10.3168/jds.S0022-0302\(87\)80173-X](https://doi.org/10.3168/jds.S0022-0302(87)80173-X).

Maximizing Odds of Pregnancy with Artificial Insemination

(Student Instructions)

Objectives:

1. Discuss advantages and disadvantages of AI.
2. Describe the reproductive role of the follicle.
3. Describe the reproductive functions of estrogen.
4. Describe the reproductive role of the corpus luteum.
5. Describe the reproductive function of progesterone.
6. Discuss factors that influence AI pregnancy rates.

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Name:

Maximizing Odds of Pregnancy with Artificial Insemination (Student Answer Sheet)

1. BEFORE starting, write down 2 advantages of artificial insemination with domestic farm animals.

2. After answer all questions associated with the AI Technique worksheet on the Excel spreadsheet, answer the following related questions.
 - a. What was YOUR probability of pregnancy?

 - b. For each step of the process, describe the “technique” (i.e., answer to each question) that results in the LEAST sperm loss and greatest probability of pregnancy. Start with Question 1 and click possible responses until you identify the answer associated with the least loss. Then, speculate on WHY this answer is best.
 - i. What is the proper water bath temperature?

 - ii. Does water need to be wiped off straw?

 - iii. Should one shake down the straw?

 - iv. At what end should the straw be cut?

 - v. How should the properly loaded AI rod be transported to the cow?

 - vi. With AI, where should the semen be deposited?

 - c. What is the projected maximal probability of pregnancy if everything is done correctly?

Lab Report

Please complete the following report during the design and implementation of your experiment.

Research Problem

- Describe what you are investigating and justify why you are investigating the problem.

Hypothesis

- Formulate one or more hypotheses for your experiment.

Procedures

- Create the steps you will follow for your experiment.

Data Collection

- Describe the data that you will collect during your experiment.
- Provide graphs, tables, charts, and raw data as necessary.

Results

- Explain your results.

Conclusion

- Based on your data:
 - What can you conclude?
 - Were your hypotheses supported?
 - Were their limitations to your experiment?
 - What are new research questions that derived from this study?