Lecture 2:

Introduction to Animal Reproductive Biology

Jyh-Cherng Ju, PhD, Professor

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Lessons from last Lecture
One is roots and the other is wings.

Roots: to grow and set the foundation/concept

Wings: to fly & enjoy the journey
| CHAPTER 8 | Reproductive Cyclicity - The Follicular Phase |
| CHAPTER 9 | Reproductive Cyclicity - The Luteal Phase |
| CHAPTER 10 | Endocrinology of the Male and Spermatogenesis |
| CHAPTER 11 | Reproductive Behavior |
| CHAPTER 12 | Spermatozoa in the Female Tract - Transport, Capacitation and Fertilization |
| CHAPTER 13 | Early Embryogenesis and Maternal Recognition of Pregnancy |
| CHAPTER 14 | Placentation, the Endocrinology of Gestation and Parturition |
| CHAPTER 15 | The Puerperium and Lacation |
Successful reproduction is an orderly sequence of events. The major events of reproductive process are puberty, cyclicity, copulation, pregnancy, and postpartum recovery/lactation. This figure illustrates the overall lifetime sequence of these reproductive events, in which the majority of the reproductive budget is associated with the female.
Further PHENOMENA for Fertility
"Please swear on your testicles..."

The word "testis" is derived from Latin and meant "witness" or "spectator." English words "testify" and "testament" were derived from testis.

It has been proposed that the testes were witnesses to virility. **Romans required that a witness be an adult intact male.** Prepubertal boys, women or eunuchs could not serve as witnesses. Placing a hand on the testicle (or someone else's testicles) was a requirement while testifying in some cultures.
"Some female spiders can be so mean"

Some spiders have no penis. They eject sperm from their abdomen onto their web. The male spider picks up the ejaculate with a special set of antennae and searches for a receptive female who produces a pheromone. The male has to be very careful and deposit the semen by surprise because the female will eat him if she catches him.
"Milk Bar"

Infant kangaroos in their mother's pouches nurse from two nipples, and two babies of different ages commonly nurse at the same time. So, the mother kangaroo produces two kinds of milk - on one side, fully rich for the younger and on the other side, a sort of skim for the elder.
Reproductive Biology/Physiology related field of studies

Theriogenology:
   Animal reproductive system (vet med)

Andrology:
   Male reproduction in humans & animals

Gynecology: Woman reproductive issues

Obstetrics:
   Problems of parturition in animals & humans
The historical development:
Major historical events of reproductive biology:

Aristotle (384-322 BC): proposed the fetus originates from menstrual blood
Fallopian (1562): discovered and described the oviduct
Coiter (1573): discovered and described the corpus luteum (CL)
de Graaf (1672): discovered and described the antral follicle
van Leeuwenhoek (1678): discovered and described spermatozoa in semen
Spallanzani (1780): hypothesized spermatozoa were the fertilizing agents & successfully AI a dog
Dumas (1825): proved that spermatozoa were the fertilizing agents
Pheromones are olfactory cues that aid communication of the social and reproductive status of members of a species.

In vertebrates, pheromones are recognized by neurons located in two sensory tissues in the nasal cavity.

(1) Main olfactory epithelium (MOE):
   For chemoinvestigation (anogenital sniffing), mating and aggressive behaviors

(2) Vomeronasal organ (VNO):
   For aggressive behavior and identifying the sex of conspecifics.
Beginning of modern reproductive physiology (1855-present)

- Estrous synchronization
- Artificial insemination
- Embryo culture/transfer
- Frozen semen
- Endocrinology
- Sex selected semen and embryos
- Biochemical pregnancy detection
- In vitro fertilization
- Contraception
- Cloning
<table>
<thead>
<tr>
<th>Reproduction</th>
<th>New chapters: e.g.</th>
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<tbody>
<tr>
<td>Endocrinology:</td>
<td>Reproduction in</td>
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<tr>
<td>Physiology:</td>
<td>Llamas and Alpacas</td>
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<tr>
<td>Lactation:</td>
<td>Genetic engineering</td>
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<td>Genetics:</td>
<td>Pharmacotoxicologic</td>
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<tr>
<td>Breeding:</td>
<td>factors &amp; reproduction</td>
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<tr>
<td>Anatomy:</td>
<td>Immunology of</td>
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<tr>
<td>Others:</td>
<td>reproduction</td>
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<td>Vet medicine, Nutrition, etc.</td>
<td>Molecular biology of reproduction</td>
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</table>
When does our life begin?

The metabolic view: no beginning point
The genetic view: at fertilization.
The embryological view: fixation (~day 12)
The neurological view: human EEG (27 wks)
The ecological/technological view:
A premature infant can survive at 25 wks

The immunogogical view:
When self and non-self can be distinguished.

The integrated physiological view:
When the baby is independent of the mother.
Historical Development of Reproductive Biology
Reproduction has interested philosophers as well as the general population throughout recorded history.

(even those without scientific background)
It is an old science

The study of “Reproductive Biology” started with Aristotle (384-322 BC) around 350 BC.
Aristotle: a Greek philosopher.

He is a pupil of Plato and the tutor of Alexander the Great.

He is also an author of works on logic, metaphysics, ethics, natural sciences, politics, and poetics, which profoundly influenced Western thought.
Two theories were formulated by Aristotle:

Epigenesis

Preformationism

(Aristotle turned superstition to observation)
Epigenesis

The organs of the embryo are formed *de novo* (from scratch) at each generation.

Supported by Aristotle and William Harvey (an English anatomist).
“Generation of Animals”
-----a book by Aristotle

The fetus arose from menstrual blood.

The conversion was initiated by seminal fluid.

Semen is derived from all part of the body.
Mammals

**Eutherias** *(placental mammals):* mice & humans

**Metatherias** *(<10%):*  
- Monotremes *(Monotremata):* platypus & echidnas  
- Marsupials *(Marsupialia):* kangaroo, koalas, opossums

Platypus  
Echidna  
Tammar wallaby
Aristotle also first figured out the functions of the placenta and the umbilical cord.
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See Figs. 1-2 (1st Ed.) or Figs. 1-3 (2nd Ed.), P5, Chapter 1.
William Harvey concluded that all animals originate from eggs in “On the Generation the Living Creatures”.

W. Harvey, an English anatomist (1578-1657)

All from the egg (Ex ovo omnia) but not from mud/excrement.
Harvey also is the first to see the blastoderm and the islands of blood cells of the chick embryo.

Harvey suggested that the amnionic fluid might function as a shock absorber for the embryo.
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<td>Antoni van Leeuwenhoek (Dutch) invented microscope some time before 1668. He and Nicolas Hartshoeker co-discovered and described spermatozoa in semen.</td>
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Preformationism

All organs were prefigured, embryonic development merely required the growth of existing structures.

(lack of changes between generations)
**Emboîment** (encapsulation):

The adult organism was prefigured in the germ cells, another generation already existed in a prefigured state within the germ cells of the first prefigured generation.

**Russian nesting dolls**
*(Matryoshka)*
van Leeuwenhoek (1632-1723) invented simple microscope some years before 1668

A Dutch microscopist and naturalist
After invention of microscope, Leeuwenhoek and Hartshoeker (1677-1678) found “animalcules” in the semen:

They believed:

Sperm were parasitic animals living within the semen which have nothing to do with reproduction.

Animalcules: meaning micro animals; spermatozoa: meaning sperm animals
The preformationism

1. During 17-18th century, spermists believed a sperm contains a miniature human being (“homunculus”).

2. Some microscopists claimed to see fully formed human miniatures within the sperm or egg.

3. Sperm were “seeds”.
4. The ovism/the ovists

The egg contains a *miniature*, fully formed embryo.

Bonnet (1745) stated that the embryo must also *contain similar preformed eggs* for future generations.
Kaspar F. Wolff confirmed Epigenesis by observing chick embryos (1759-1769), but the concept was not accepted by a majority of biologists until early nineteenth century.

The vis essentialis (essential force) organize embryonic development (like gravity or magnetism).
Organ systems develop at **different rates** and the embryonic structures **need not** be in the same place as those in the newborn.

“Nature works as small as it wishes.”

*(Alberecht von Haller & Charles Bonnet)*
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Sperm are not parasites but the agents of fertilization:

(1) Sperm universally existed in sexually mature males.
(2) No sperm were found in the sterile mule.

(They proposed that “sperm entered the egg”)

Dumas proved that sperm were fertilizing agent in 1825 using rabbit model.
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<td>1839</td>
<td>Schwann recognized the egg is a cell.</td>
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<td>1840s</td>
<td>Avon Kolliker described the formation of sperm from cells within the adult testes. They still believed that sperm excited the egg to develop without physical contact (magnet &amp; iron).</td>
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<td>The cellular nature of the sperm was determined by Schweigger-Seidel and St. George.</td>
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<td>1876</td>
<td>Oscar Hartwig &amp; Herman Fol demonstrated sperm entry into the egg and the union of those cell nuclei.</td>
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<td>1883</td>
<td>Van Beneden first described chromosome behavior in a fertilized egg using nematodes: “After division, each nucleus received an equally number of paternal and maternal chromosomes”</td>
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<td>1896</td>
<td>Wilson concluded the nucleus is the bearer of heredity &amp; 2 sexes play equal parts in heredity transmission.</td>
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Reproduction is a relative new science!

The era of modern Reproductive Biology

(1855-present)
Reproduction

Endocrinology:
Physiology:
Lactation:
Genetics:
Breeding:
Anatomy:
Others:

*Vet medicine, Nutrition, etc.*

New biology: e.g.

- Cell Biology
- Genetic Engineering
- Pharmacotoxicologic factors
- Immunology
- Molecular Biology
Beginning of modern reproductive technology (1855-present)

- Estrous synchronization/Endocrinology
- Artificial insemination
- Frozen semen
- Assisted reproductive technology (ART)
- Superovulation/embryo transfer (MOET)
- Sexing (semen and embryos)
- Biochemical pregnancy detection
- Contraception
- Culture of oocytes & embryos (IVMFC)
- Cloning (SCNT)
Landmarks in applied research that enabled AI to become the most useful biotechnology applied to animal agriculture.

1940 Phillips developed phosphate-buffered egg yolk for preserving bull sperm

1941 Salisbury et al. developed citrate-buffered egg yolk, a semen extender with glycerol used widely today for preserving bull sperm.

1948 Almquist and Foote reported independently on the value of antibiotics in semen extender to control microorganisms and increase fertility.
Beginning of modern reproductive technology (1855-present)

- Estrous synchronization/Endocrinology
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- Superovulation/embryo transfer (MOET)
- Biochemical pregnancy detection
- Contraception
- Culture of oocytes & embryos (IVMFC)
- Cloning and stem cells (SCNT)
1949  Polge et al. discovered that glycerol protected sperm during freezing.

1950s  Powerful tools for progeny testing were developed by Henderson and Robertson.

1957  Efficient LN$_2$ tanks used throughout cryobiology were developed initially for frozen bull sperm (supported by American Breeders Service).
1963  Davis et al. developed Tris-buffered egg yolk-glycerol for fresh & frozen sperm, the most wildly used semen extender today for many species.

1970  AI was used commercially for super-ovulated cows, and ET provided the initial framework for many breeding strategies.
Beginning of modern reproductive technology (1855-present)

Estrous synchronization/Endocrinology
Artificial insemination
Frozen semen
Sexing (semen and embryos)
Assisted reproductive technology (ART)
Superovulation/embryo transfer (MOET)
Biochemical pregnancy detection
Contraception
Culture of oocytes & embryos (IVM/FC)
Stem cells & somatic cell cloning (SCNT)
Some major achievements speed up the development:

1. The anterior pituitary controls the function of the gonads.

2. Gonads produce steroid hormones that alter the function of the reproductive tissues.

3. Females experience reproductive cyclicity and that ovulation is predictable.
4. Worldwide success of AI was due to the understanding of sperm physiology during 1940s to 1950s.

5. PGF2α regulated the length of the estrous cycle in females (1960s).

6. Development of RIA for hormone analysis.

7. Development of the techniques for XY-sperm separation, ET, cryopreservation, and electronic estrous detection, etc.
Reproductive biotechnology ladder, starting with AI and proceeding somewhat chronologically and technologically up the ladder.

(Foote, 1999)
By the end of the 20th century, mankind finally discovered the mysterious stem cells that Aristotle mused about.

Let's hope that we don't waste another 2000 years figuring out what to do with them.
As we seek to understanding the biology of life, we are also called to understand the meaning of life.

(Foote, 1999)
Take Home Message

Reproduction is a sequence of events beginning with development of the reproductive system in the embryo. After the animal is born, it must grow and achieve puberty, by acquiring the ability to produce fertile gametes. This ability must be accompanied by reproductive behavior and copulation. After copulation, fertilization occurs and it is followed by development of the preattachment embryo. The conceptus attaches to the uterus by the placenta. It allows the conceptus to grow and develop to term. The fully developed fetus is born and the female giving birth to it must reestablish cyclicity before she can become pregnant again.
Reproductive biology is a relatively new science and most of our knowledge of the subject has been generated during the past 75 years. Both poor and high reproductive efficiency are costly. Poor reproductive efficiency results in suboptimal production of animal products. High reproductive efficiency in humans and vermin results in excessive population growth. Knowledge and understanding of the reproductive process will become increasingly important as the human population continues to grow and resources become increasingly scarce. (Senger, P. L., 1997)
Next Lecture: Endocrinology

Chapter 5:
Regulation of Reproduction