The Reproductive System

Anatomy and Physiology of the Male and Female Reproductive Systems
Introduction

• Sexual reproduction produces new individuals
  – Gametes (sperm & egg) formed by testes and ovaries
  – Fertilization produces one cell (a zygote) with one set of chromosomes from each parent
  – Creates genetic variation

• Gonads produce gametes & secrete sex hormones

• Reproductive systems
  – Gonads, ducts, glands & supporting structures
  – Gynecology is study of female reproductive system
  – Urology is study of urinary & male reproductive system
Male reproductive system

- Peritoneum
- Seminal vesicle
- Ampulla of ductus deferens
- Ejaculatory duct
- Rectum
- Prostate gland
- Bulbourethral gland
- Anus
- Bulb of penis
- Ureter
- Urinary bladder
- Ductus deferens
- Prostatic urethra
- Pubis
- Membranous urethra
- Urogenital diaphragm
- Corpus cavernosum
- Corpus spongiosum
- Spongy (penile) urethra
- Epididymis
- Testis
- Scrotum
- Glans penis
- Prepuce
- External urethral orifice
Scrotum

- Sac of loose skin, fascia & smooth muscle divided into two pouches by a septum

- Temperature regulation of testes
  - Sperm survival requires 2-3 degrees lower temperature than core body temperature
  - Muscle in scrotum
    - Elevates testes on exposure to cold & during arousal
    - Warmth reverses the process
Testes

- Each testis is about 2.5cm x 4 cm in size, within scrotum
- Dartos and cremaster muscles move testes in response to hot or cold
- Serous sac partially encloses each testis: the *tunica vaginalis*
  - Develops as outpocketing of peritoneal cavity
- Just deep to tunica vaginalis is *tunica albuginea* - fibrous capsule
  - Septal extensions of it divide testis into 250-300 lobules
  - Each lobule contains 1-4 coiled seminiferous tubules: make sperm
- Testes (singular testis) or testicles: the gonads
  - In embryo, first develop in posterior abdominal wall, then migrate
  - Internal body temp too hot for viable sperm
  - Temp cooler in the scrotum because of superficial position
Testes

- Internal oblique muscle
- Aponeurosis of external oblique muscle (cut)
- Suspensory ligament of penis
- Penis (cut)
- Middle septum of scrotum
- Cremaster muscle
- External spermatic fascia
- Scrotum containing dartos muscle
- Skin

- Superficial inguinal ring (end of inguinal canal)
- Spermatic cord
- Ductus (vas) deferens
- Autonomic nerve fibers
- Pampiniform plexus of testicular veins
- Testicular artery
- Epididymis
- Tunica vaginalis (from peritoneum)
- Tunica albuginea of testis
- Internal spermatic fascia

* Asterisks indicate important structures.
• Just deep to tunica vaginalis is **tunica albuginea** - fibrous capsule
  – Septal extensions of it divide testis into 250-300 lobules
• Each lobule contains 1-4 coiled **seminiferous tubules**: make sperm
  – Converge to form straight tube (tubulus rectus), then conveys sperm into rete testis
• Sperm leave testis through efferent ductules which enter **epididymis**
• Blood supply: **pampiniform plexus**: from L2 not pelvic level, since descended from abdomen

*Pampiniform plexus* (lateral views)
Seminiferous Tubules

- Seminiferous tubules contain
  - Sperm forming cells
  - Sertoli cells (supporting cells)
- Interstitial cells in between tubules secrete testosterone
Sertoli Cells and Sperm Cells

- Sertoli cells -- extend from basement membrane to lumen
  - form blood-testis barrier
  - support developing sperm cells
  - produce fluid & control release of sperm into lumen
  - secrete inhibin which slows sperm production
SPERMATOGENESIS

- 1st stage: formation of spermatocytes
  - Spermatogonia are stem cells
    - Least differentiated (earliest in the process)
    - Lie in basal lamina
  - Divide continuously by mitosis (result 2n or diploid): daughter cells A (remains a stem cell) or B (goes on)
  - When start to undergo meiosis are by definition called spermatocytes
SPERMATOGENESIS

- 2nd stage: meiosis I
  - Each primary spermatocyte (2n) undergoes meiosis I to become 2 secondary spermatocytes:
  - Each secondary spermatocyte undergoes meiosis II to become 2 spermatids
  - Therefore 4 total spermatids from each spermatogonium
SPERMATOGENESIS

- 3<sup>rd</sup> stage: spermiogenesis
  - Spermatids differentiate into sperm
Sperm Morphology

- Adapted for reaching and fertilizing the egg
- Head contains DNA and the acrosome with enzymes for penetrating the egg
- Midpiece contains mitochondria to form ATP for energy
- Tail is flagellum used for locomotion
Hormonal Control of Male Physiology

- Hypothalamus secretes gonadotropin releasing hormone (GnRH)
- Anterior pituitary secretes FSH and LH
- FSH causes Sertoli cells to secrete ABP and inhibin
- LH causes interstitial cells to secrete testosterone
- ABP and testosterone stimulate spermatogenesis
- Control is Negative FB by ↑testosterone and inhibin
Male Glands

Seminal Vesicles
Secrete 60% of clear, alkaline seminal fluid, with fructose sugar, ATP and prostaglandins for normal sperm nutrition & function.

Prostate
Secretes 30% of milky, slightly acidic seminal fluid with an antibiotic to kill bacteria.

Cowper’s Glands
Secrete clear, alkaline mucus to buffer and lubricate urethra.
Semen

- Mixture of sperms and seminal fluid
- 60% from seminal vesicles, 30% from prostate
- Slightly alkaline, milky appearance and sticky
- Contains nutrients, clotting proteins & an antibiotic to protect the sperms
- Typical ejaculate is 2.5 to 5 ml in volume
- Normal sperm count is 50 to 150 millions/mL
  - Actions of many sperm are needed for one to enter
  - If less than 20 millions/mL sterile
The Prostate

- Size & shape of a chestnut
- Encircles 1st part of urethra
- 3 types of glands
  - Contribute to semen (milky fluid and enzymes)
  - PSA measured as indicator of prostate cancer (“prostate specific antigen”)
- Fibromuscular stroma
THE PENIS

- 3 parts
  - Root (attached)
  - Free shaft or body
  - Enlarged tip called *glans penis*

- Skin of penis is loose
  - Prepuce or foreskin
    - Cuff around glans
    - Removed if circumcision

- See cross section, penis
  - Urethra (called spongy or penile urethra here)
  - 3 erectile bodies (*parasympathetic* stimulation during sexual excitation causes engorgement with blood allowing erection):
    - *Corpus spongiosum*
    - *Pair of corpora cavernosa*
  - Vessels and nerves
Erection

- Sexual stimulation
- Parasympathetic nervous system reflex
- Dilation of the arterioles supplying the penis
- Blood enters the penis
  - Fills the corpus cavernosa
  - Compresses the veins so that the blood is trapped.
- Blood sinuses of penis engorge with blood
Emission and Ejaculation

• Emission
  – Muscle contractions close sphincter at base of bladder
  – Fluids propelled through ductus deferens, seminal vesicles, & ejaculatory ducts into bulb of penis
  – Prostatic fluid secreted into urethra

• Ejaculation
  – Sympathetic nervous system reflex
  – Skeletal muscles squeeze semen out through urethra
  – Ejaculation caused by sympathetic nerves
    • Contraction of smooth muscle of ducts and penis
Refractory Period

A period following ejaculation and lasting anywhere from 10 minutes to a few hours, impossible to attain another erection and orgasm.
Female Reproductive System

Introduction

- Ovaries produce eggs (oöcytes) & hormones
- Uterine tubes transport the eggs
- Uterus where fetal development occurs
- Vagina or birth canal
- External genitalia constitute the vulva
- Mammary glands produce milk
The Vagina

- Passageway for birth, menstrual flow and intercourse
- 4 inch long fibromuscular organ ending at cervix
- Orifice partially closed with membrane (hymen)
- Thin-walled tube
- Inferior to uterus
- Anterior to rectum
- Posterior to urethra & bladder
- “Birth canal”
- Highly distensible wall: 3 layers
  - Adventitia
  - Muscularis
  - mucosa
The Vagina

- “Bead-like” excretions from the mucosa layer provide moist environment for bacteria and vaginal health
  - Increased production during sexual stimulation.

- pH of 3.5-4.5; Slightly acidic

- Vaginal Flora
  - Beneficial Bacteria in vagina
    - Up to 50 different species.
    - *Lactobacilli* is most common
External female genitalia aka vulva or pudendum

- **Mons pubis**: fatty pad over pubic symphysis
  - Covered with hair after puberty
  - Functions:
    - Keeps vagina warmer
    - Maintain proper moisture levels
    - Limit unhealthy bacteria and dirt from entering vagina
    - Reduces friction during daily life and intercourse

- Anatomy
  - Courser than regular hair
External female genitalia aka vulva or pudendum

- **Labia (lips) majora**: long fatty hair-covered skin folds
- **Labia minora**: thin, hairless, folds enclosing vestibule
- **Vestibule**: houses external openings of urethra and vagina
  - Urethra is anterior (drains urine from bladder)
  - Baby comes out through vagina (vaginal orifice in pic)
- **Clitoris**: anterior, homolog of penis (sensitive erectile tissue)
- **Perineum**: diamond shaped region
The Ovary

- Pair of organs, size of unshelled almonds in upper pelvic region

- Histology
  - Capsule of dense CT
  - Cortex just deep to capsule contains follicles with egg cells (oöcytes)
  - Medulla is middle region composed of connective tissue, blood vessels & lymphatics
  - Germinal epithelium is peritoneal membrane covering the ovary
Ovarian Follicles

- Ovarian Follicles
  - Contain oöcytes (egg cells) in various stages of development
  - Secrete estrogens that function for:-
    - Growth and repair of uterine lining
    - Regulation of monthly female cycle
    - Female sexual characteristics
    - Maintenance of bone and muscle
  - Mature (Graafian) follicle releases an oöcyte each month during ovulation
Ovarian Follicles

- Oöcytes (egg cells) develop within follicles
- Stages of follicular development
  - Primordial follicle
    - Single layer of squamous cells around the oöcyte
  - Primary follicle
    - Layers of cuboidal granulosa cells around the oöcyte
    - Granulosa cells secrete estrogens
Ovarian Follicles

- Secondary follicle
  - Antral cavity forms

- Graafian follicle
  - Follicle mature ready to ovulate oöcyte

- Ovulation
  - Follicle ruptures releasing oöcyte
Corpus Luteum

- After ovulation, empty follicle becomes a corpus luteum
  - Corpus Luteum secretes:
    - **Progesterone** – completes the preparation of uterine lining
    - **Estrogens** – work with progesterone
    - **Relaxin** – relaxes uterine muscles and pubic symphysis
    - **Inhibin** – decreases secretion of FSH and LH

- Corpus albicans is a white scar tissue left after the corpus luteum dies.
Oögenesis – Oögonia to Oöcytes

• Germ cells from yolk sac migrate to ovary and become potential egg cells called oögonia.

• In fetus, million of oögonia produced by mitosis but most of them degenerate (atresia).

• Some develop into immature egg cells called primary oöcytes during fetal development.
  – 200,000 to 2 millions present at birth.
  – 40,000 remain at puberty but only 400 mature during a woman’s reproductive life.

• Each month about 20 primary oöcytes become secondary oöcytes but usually only one survives to be ovulated from Graffian follicle.
Oögenesis

Egg forming cells (oöcytes) go through two divisions

1° = primary

2° = secondary

• Starts with a 2n=46 1°oöcyte that divides, resulting in two n=23 cells, but one is a large 2° oöcyte and one is a small 1st polar body that may itself divide

• Second division only occurs if 2° oöcyte is fertilized. Results in one large n=23 ovum (egg) and one small n=23 2nd polar body

• Thus oögenesis results in one large fertilized egg (zygote) and possibly three small polar bodies
Uterine or Fallopian Tubes

• Narrow, 4 inch tube that extends from the ovary to uterus
  - Infundibulum is open, funnel-shaped portion near the ovary
  - Fimbriae are moving finger-like processes
  - Ampulla is central region of tube
  - Isthmus is narrowest portion joins uterus
Uterine or Fallopian Tube

- Functions -- events occurring in the uterine tube
  - Fimbriae sweep oöcyte into tube
  - Cilia and peristalsis move it along
  - Sperm reaches oöcyte in ampulla
  - Fertilization occurs within 24 hours after ovulation
  - Zygote reaches uterus about 7 days after ovulation
Anatomy of the Uterus

- Site of menstruation & development of fetus
- Description
  - 3 inches long by 2 in. Wide and 1 in. Thick
  - Subdivided into fundus, body & cervix
  - Interiorly contains uterine cavity accessed by cervical canal
Histology of the Uterus

• **Endometrium**
  – Simple columnar epithelium
  – Stroma of connective tissue and endometrial glands
    • Functional layer
      – Shed during menstruation
    • Basal layer
      – Replaces functional layer each month

• **Myometrium**
  – 3 layers of smooth muscle

• **Perimetrium**
  – Visceral peritoneum
Mammary Glands

- Modified sweat glands that produce milk (lactation)
  - Amount of adipose tissue determines size of breast
  - Milk-secreting mammary glands alveoli open by lactiferous ducts at the nipple
  - Areola is pigmented area around nipple
  - Suspensory (Cooper’s) ligaments suspend breast from deep fascia of pectoral muscles
Physiology of the Breast

• Milk production and secretion
  – **Estrogens** develop the ducts system in the breasts
  – **Progestrone** develop the milk-secreting glands which are called alveoli
  – **Prolactin** stimulate milk synthesis in the alveoli
  – **Oxytocin** stimulate milk ejection from the alveoli
Physiology of Mammary Glands Continued

• Milk ejection (release from glands)
  – Nursing stimulates the hypothalamus to produce oxytocin
  – Oxytocin secreted from the posterior pituitary
  – Oxytocin causes smooth muscles around alveoli to contract and squeeze milk into lactiferous ducts, lactiferous sinuses and into the nipple
  – Operated by positive feedback
Female Reproductive Cycle

- Controlled by monthly hormonal cycle from the hypothalamus, anterior pituitary and ovary
- Monthly cycle of changes in ovary and uterus
- **Ovarian cycle**
  - Changes in ovary during and after maturation of the follicle and oocyte
- **Uterine cycle** (menstrual cycle)
  - Preparation of the uterus to receive fertilized ovum
  - If implantation does not occur, the functional layer of endometrium is shed during menstruation
Hormonal Regulation of Reproductive Cycle

• Gonadotropin Releasing Hormone (GnRH), secreted by the hypothalamus, controls the female reproductive cycle
  – Stimulates anterior pituitary to secrete Follicle Stimulating Hormone (FSH) & Luteinizing Hormone (LH)

• FSH & LH target the ovaries and drive the ovarian cycle (monthly changes in the ovary)

• Estrogens and progesterone from the ovaries drive the uterine cycle (monthly changes in the uterus)
Phases of Ovarian Cycle

• **Follicular Phase**
  - FSH from anterior pituitary stimulates follicle growth
  - Follicles grow into Graafian (mature) follicle
  - Granulosa cells of follicle secrete estrogens and inhibin
  - Increasing levels of estrogens and inhibin inhibit FSH
  - Increasing estrogens also stimulates secretion of LH

• **Ovulation**
  - LH stimulates rupture of the Graafian follicle and release of oöcyte from ovary into the pelvic cavity
  - Fimbriae of Fallopian tube picks up the ovulated oöcyte
Phase of Ovarian Cycle

- **Luteal phase** (postovulatory phase)
  - LH stimulates development of Corpus luteum from ovulated or ruptured follicle
  - Corpus luteum secretes mostly progesterone & some estrogens
  - Progesterone prepares endometrium for possible pregnancy
Phases of Uterine Cycle

• **Proliferative phase**
  - Rising estrogen levels from the growing follicle stimulates growth of the functional layer of endometrium to 4-10 mm thickness

• **Secretory phase**
  - Corpus luteum of ovary secretes progesterone
  - Progesterone stimulates
    • Increased thickening of the functional layer of endometrium to 12-18 mm
    • Increased blood supply into the endometrium
    • Growth of endometrial glands and secretion of uterine milk
Phase of Uterine Cycle

- **Menstruation phase** (menses)
  - Decline in progesterone levels causes functional layer of endometrium to discharge resulting in vaginal bleeding called menstruation
  - Mark the beginning of the next cycle
Summary of Ovarian and Menstrual Cycles

- **Ovarian cycle**: Primordial follicles, Primary follicles, Secondary follicle, Mature (Graafian) follicle, Ovulation, Corpus luteum

- **Menstrual cycle**: Menstruation, Proliferative phase, Preovulatory phase, Menstruation

- **Uterine functionalis**: Days 1-28

- **Uterine basalis**: Days 1-2

- **Progestogen and estrogens**

- **Hormones**: GnRH, Anterior pituitary gland, FSH, LH, Corpus luteum
Negative Feedback Controls Cycle

• **If no pregnancy**
  – Increasing levels of progesterone cause negative feedback that inhibits LH secretion
  – After about two weeks corpus luteum atrophies to corpus albicans (white body)
  – Progesterone and estrogen levels decline
  – Functional layer of endometrium discharged into first five days of next cycle
Negative Feedback

• **Starting the next cycle**
  – With the decline in progesterone, estrogens and inhibin secretion:-
    • Inhibition of GnRH, FSH and LH stops
    • Renewed secretion of these hormones starts a new cycle of growth and preparation in ovaries and uterus
Pregnancy

• If fertilization occurs:-
  – Embryo implants in endometrium
  – Must maintain levels of progesterone to maintain the endometrium and pregnancy
  – Since corpus luteum secretes progesterone, it must be maintained
  – LH normally maintains the corpus luteum, but LH is inhibited by high progesterone levels
  – What maintains the corpus luteum during pregnancy?
  – What was not present before?
Fetal Development:

Conception to Birth
Fertilization: the sperm and egg join in the fallopian tube to form a unique human being. 46 chromosomes combine, 23 from each parent, which pre-determine all of a person's physical characteristics and even some personality characteristics.
Fertilized egg:

• This picture is of a fertilized egg, only thirty hours after conception.

• Magnified here, it is no larger than the head of a pin.

• Still rapidly dividing, the developing embryo is called a zygote at this stage.

• The embryo floats down from the fallopian tube and towards the uterus, where it attaches at approximately day 4 to 5 post-conception.
5 weeks –

• Embryo is the size of a raisin.

• By day twenty-one, the embryo's tiny heart has begun beating.

• The neural tube enlarges into three parts, soon to become a very complex brain.

• The placenta begins functioning.

• The spine and spinal cord grows faster than the rest of the body at this stage and give the appearance of a tail.

• This disappears as the child continues to grow.
Embryo at about 6 weeks: Notice the large neural tube and the formation of the heart and other internal organs.
Embryo at approximately 7 weeks:

Eyes, fingers, toes and most internal organs have formed, but are not yet fully functional.
7 weeks –

• Facial features are visible, including a mouth and tongue.

• The eyes have a retina and lens.

• The major muscle system is developed and the unborn child moves as if practicing.

• The child has its own blood type, distinct from the mother's.

• These blood cells are produced by the liver now instead of the yolk sac.
Embryo in Amniotic sac
Embryo at 8 weeks

Amniotic Sac

Placenta
8 weeks –

• The unborn child, called a fetus at this stage, is about half an inch long.

• The tiny baby is protected by the amniotic sac, filled with fluid.

• Inside, the child swims and moves gracefully.

• The arms and legs have lengthened, and fingers can be seen.

• The toes will develop in the next few days.

• Brain waves can now be measured.
10 weeks –

- The heart is almost completely developed and very much resembles that of a newborn baby.

- An opening the atrium of the heart and the presence of a bypass valve divert much of the blood away from the lungs, as the child's blood is oxygenated through the placenta.

- Twenty tiny baby teeth are forming in the gums; some babies are even born with teeth emerging from the gums.
The baby at 12 weeks: notice the webbing on the fingers, with the digits still fused
Fetus at 12 weeks

• Vocal chords are complete, and the child can and does sometimes cry silently.

• The brain is fully formed, and the child can feel pain.

• The fetus may even suck his thumb.

• The eyelids now cover the eyes, and will remain shut until the seventh month to protect the delicate optical nerve fibers.

• Notice head size and chest size in comparison to an adult.
14 weeks –

• Muscles lengthen and become organized.
• The mother will soon start feeling the first flutters of the unborn child kicking and moving within.

15 weeks –

• The fetus has an adult's taste buds and may be able to savor the mother's meals.
• Foods the mother eats can affect movement of the baby
Fetus at 4 months or about 16 weeks

• Face is fully developed and

• A downy hair covers the skin.

• Face is fully formed.

• Eyes are fully formed but not yet functional.
16 weeks –

• Five and a half inches tall and only six to 1- ounces in weight

• Eyebrows, eyelashes and fine hair appear.

• The child can grasp with his hands, suck her thumb, kick, or even somersault.
20 weeks –

• The child can hear and recognize her mother's voice.

• Though still small and fragile, the baby is growing rapidly and could possibly survive if born at this stage.

• Fingernails and fingerprints appear.

• Sex organs are visible.

• Using an ultrasound device, the doctor can tell if the child is a girl or a boy. This is a baby girl.
5 months old

• Beginning to form hair on all body parts

• Definite sleep/awake cycles now.

• REM sleep occurs.
Again at 5 months

• Approximately 8-10 inches long and 1 to 2 pounds

• Body position is often still “head up”

• Baby is viable at this point with at least a 50/50 chance of survival outside the womb.
24 weeks –

• Seen here at six months, the unborn child is covered with a fine, downy hair called lanugo.

• Its tender skin is protected by a waxy substance called vernix.

• Some of this substance may still be on the child's skin at birth at which time it will be quickly absorbed.

• The child practices breathing by inhaling anionic fluid into developing lungs.
30 weeks –

• For several months, the umbilical cord has been the baby's lifeline to the mother.

• Nourishment is transferred from the mother's blood, through the placenta, and into the umbilical cord to the fetus.

• If the mother ingests any toxic substances, such as drugs or alcohol, the baby receives these as well.
7 months.

• Room is getting tight at this point.
  • The baby is less able to move, squirms and pushes more than flutters and kicks.
  • Most babies begins to get into a head down position getting ready for birth.
32 weeks –

• The fetus sleeps 90-95% of the day with REM sleep dominating the sleep cycle, an indication of dreaming.

• The baby is very viable at this point, with a 75% or higher chance of survival.

• If the baby is born, the concerns are with adequate lung development. Final lung development does not occur until about 37 weeks.
Birth at 38-42 weeks

• 40 weeks is normal gestation

• The baby weighs on average 7 lbs. and is 20 inches long.

• At birth the baby can see, hear, move and recognizes the voices of her parents or others who have been near the mother.
Conception

- After ejaculation into the vagina, sperm swim to meet an egg
  - Sperm live 5-7 days (need cervical mucus)
  - Eggs live about 12-24 hours, so conception only occurs during this short window
  - Fertilization occurs in the fallopian tube

**Events leading to fertilization:**
- Sperm binds to receptors on zona pellucida
- Acrosomal reaction – enzymes digest a slit
- Sperm passes through zona
- Fusion of a single sperm’s plasma membrane with oocyte’s plasma membrane
- Cortical reaction: sperm receptors destroyed in zona so no more enter; sperm nucleus engulfed by egg’s cytoplasm

**Fertilization occurs at the moment the chromosomes**
Initial days

- Cleavage (cell division)
- Blastocyst stage by day 4: now in uterus
Implantation

Blastocyst floats for 2 days: “hatches” by digesting zona enough to squeeze out

6-9 days post conception - burrows into endometrium
Embryonic blood circulates within chorionic villi, close to but not mixing with mother’s blood.

Formation of Placenta

Both contribute:
- Trophoblast from embryo
- Endometrial tissue from mother

Not called placenta until 4th month
The “Placental Barrier”

- Sugars, fats and oxygen diffuse from mother’s blood to fetus
- Urea and CO2 diffuse from fetus to mother
- Maternal antibodies actively transported across placenta
  - Some resistance to disease (*passive immunity*)
- Most bacteria are blocked
- Many viruses can pass including rubella, chickenpox, mono, sometimes HIV
- Many drugs and toxins pass including alcohol, heroin, mercury
- Placental secretion of hormones
  - *Progesterone* and HCG (human chorionic gonadotropin, the hormone tested for pregnancy): maintain the uterus
  - *Estrogens* and CRH (corticotropin releasing hormone): promote labor
Childbirth

• Gestational period: averages 266 days
  (this is time post conception; 280 days post LMP)
• Parturition: the act of giving birth: 3 stages of labor
  1. Dilation: 6-12h (or more in first child); begins with regular uterine contractions and ends with full dilation of cervix (10cm)
  2. Expulsion: full dilation to delivery – minutes up to 2 hours
  3. Placental delivery: 15 minutes

(a) Dilation of cervix; head enters true pelvis
(b) Late dilation with head rotation to AP position
(c) Expulsion: head first safest as is largest part
(d) Delivery of the placenta