SEX DETERMINATION RESOURCE PACKET

By Karla O'Neill, Abington Senior High School,

Lecture 1: Deciphering the Language of Sex

Chapters:

1. Start of Lecture 1.
2. Introduction by HHMI President Dr. Thomas Cech.
3. Introductory interview with Dr. David Page.
4. What was the first thing your parents asked about you?
5. Characteristics of males and females.
6. Electron micrograph of egg and sperm.
7. Embryonic development and the role of gonads.
8. Sex determination can't be explained by the historical idea that heredity is a blending process.
9. Historical ideas on environmental factors affect sex determination.
10. Early 20th Century scientists find sex chromosomes in insects.
11. What might the sex-determining signal be?
12. Sex of fruit flies linked to the number of X chromosomes in 1916.
13. Discovery of how sex chromosomes operate in humans.
14. XX males and XY females suggest key genes for sex determination.
15. SRY, the sex-determining gene, in transgenic mice.
16. Student Question: What are the symptoms of Turner and Kleinfelter Syndrome?
17. Student Question: What causes hermaphroditism in humans?
18. Student Question: Why don't XX males produce sperm?
19. Student Question: What makes XY females to develop as female?
20. Student Question: Does SRY determine whether a person has testes?
21. Student Question: Can Y chromosomal activity be clearly observed in the human body?
22. Student Question: Do XY females have male levels of testosterone?
23. Why does nature have two sexes? Are males really necessary?
24. Description of clonal reproduction.
25. Comparing cloning in Laredo striped whiptail with sexual reproduction in related species.
26. Meiosis is the defining feature of sexual reproduction.
27. Is sex, in an evolutionary sense, good?
28. Demonstration: Fresh fruit and rotting vegetables.
29. Demonstration: Fruit and vegetables with mutations.
30. Demonstration: Meiosis can weed out rotten genes.
31. Animation: Meiosis
32. Animation: Picture sequence of human embryonic development.
33. Animation: How does an X chromosome gain the SRY gene?

34. Student Question: With a recombinant mutation, would a clonal reproducer be better off?
35. Student Question: Is lizard cloning the same as cloning in Dolly the sheep?
36. Closing remarks by HHMI President Dr. Thomas Cech.

Possible areas to use Lecture 1 within the classroom:

1. Genetics course
2. AP or General Biology – after discussing genetics
3. Anatomy & Physiology – human reproduction

Vocabulary List:

1. Gonad
2. Bipotential Gonad
3. Gamete
4. Embryo
5. Gregor Mendel
6. Heredity
7. Genetics
8. Turner's Syndrome
9. Kleinfelter's Syndrome
10. Transgenic
11. Hermaphrodite
12. Meiosis (stages of)
13. Mitosis
14. Haploid
15. Diploid
16. Autosomes
17. Sex Chromosomes
18. Parthenogenesis
19. Recombination (Crossing Over)
20. Chromosome
21. Chromatid
22. Dominant
23. Recessive

Lecture I: Vocabulary definitions

1. Gonad: An organ in animals that produces gametes, especially a testis or ovary.

2. Bipotential gonad: A mass of generative tissue primitively alike in both sexes, but giving rise to either an ovary or a testis.

3. Gamete: A reproductive cell having the haploid number of chromosomes, especially a mature sperm or egg capable of fusing with a gamete of the opposite sex to produce the fertilized egg.

4. Embryo: An organism in its early stages of development, especially before it has reached a distinctively recognizable form. In humans, the prefetal product of conception from implantation through the eighth week of development.

5. Gregor Mendel: Founder of the science of genetics.

6. Heredity: The genetic transmission of characteristics from parent to offspring.

7. Genetics: The branch of biology that deals with heredity, especially the mechanisms of hereditary transmission and the variation of inherited characteristics among similar or related organisms.

8. Turner's Syndrome: A congenital condition of females associated with a defect or absence of an X-chromosome, characterized by short stature, sexual underdevelopment, and other physical abnormalities.

9. Kleinfelter's Syndrome: a chromosomal anomaly in males who have more than one X chromosome (XXY or XXXY instead of XY); marked by small testes and long legs and enlarged breasts and decreased sperm production and mental retardation.

10. Transgenic: An organism whose genome has been altered by the transfer of a gene or genes from another species or breed.

11. Hermaphrodite: An organism that has both testicular and ovarian tissues.

12. Meiosis: The process of cell division in sexually reproducing organisms that reduces the number of chromosomes in reproductive cells from diploid to haploid, leading to the production of gametes in animals and spores in plants.

13. Haploid: An organism or cell having only one complete set of chromosomes.

14. Diploid: An organism or cell having two sets of chromosomes or twice the haploid number.

15. Mitosis: The process in cell division by which the nucleus divides, typically consisting of four stages, prophase, metaphase, anaphase, and telophase, and normally resulting in two new nuclei, each of which contains a complete copy of the parental chromosomes.

16. Autosome: A chromosome that is not a sex chromosome.

17. Sex Chromosome: Either of a pair of chromosomes, usually designated X or Y, in the germ cells of most animals and some plants, that combine to determine the sex and sex-linked characteristics of an individual, with XX resulting in a female and XY in a male in mammals.

18. Parthenogenesis: Process in which an unfertilized egg develops into a new individual.

19. Recombination: The natural formation in offspring of genetic combinations not present in parents, by the processes of crossing over or independent assortment.

20. Chromosome: Threadlike linear strand of DNA and associated proteins in the nucleus of eukaryotic cells that carries the genes and functions in the transmission of hereditary information.

21. Chromatid: Either of the two daughter strands of a replicated chromosome that are joined by a single centromere and separate during cell division to become individual chromosomes.

22. Dominant: An allele that produces the same phenotypic effect whether inherited with a homozygous or heterozygous allele.

23. Recessive: An allele that does not produce a characteristic effect when present with a dominant allele.

Question Bank:

1. After fertilization anatomical gender differences begin to appear during which week?
    a. Answer: 7^{th}

2. In the developing embryo what is the first structure to differ? What is this structure called before differentiation?
    a. Answer: Gonad ; Bipotential gonad

3. Before Gregor Mendel's work was accepted how did people explain traits of their offspring?
    a. Answer: Traits were blended together

4. Back in the 1890s what were some beliefs as to what determined the sex of a baby?
    a. Answer: Mother's diet ; Phase of moon ; State of economy

5. Aristotle believed _____ would determine a baby's sex.
    a. Answer: The male's temperature and level of excitement during intercourse

6. Name the sex chromosomes.
    a. Answer: X and Y

7. In 1916 it was discovered that which of the sex chromosomes determined gender in fruit flies?
    a. Answer: The number of X chromosomes

8. In what year were human chromosomes discovered?
    a. Answer: 1923

9. In 1959 it was determined that the absence/presence of which chromosome determines gender in humans?
    a. Answer: Y

10. Females with XO (only 1 X chromosome) develop what condition?
    a. Answer: Turner Syndrome

11. Males with XXY (an extra X chromosome) develop what condition?
    a. Answer: Kleinfelter Syndrome

12. Name two exceptions to the Y Rule that Dr. Page gives. How often do either of these occur?
    a. Answer: XX males and XY females ; 1 in every 20,000

13. What gene has now been discovered that determines gender? Where is this gene located?
    a. Answer: SRY ; short arm of the Y chromosome

14. Explain the process by which a XX mouse embryo became a transgenic mouse with male characteristics.
    a. Answer: (1) XX embryo was injected with SRY gene. (2) Embryo was implanted in female mouse. (3) Mouse gives birth to transgenic mouse

15. What determines a hermaphrodite?
    a. Answer: Organisms that contain both testicular and ovarian tissue.

16. The SRY gene determines whether the bipotential gonad becomes what?
    a. Answer: Testicles or ovaries

17. Why are XX males sterile?
    a. Answer: It's believed that other genes on the Y chromosome are needed to produce sperm.

18. What is the defining feature of sexual reproduction?
    a. Answer: Meiosis

19. In the short-run is asexual or sexual reproduction better?
    a. Answer: Asexual

20. In the long-run is asexual or sexual reproduction better?
    a. Answer: Sexual

21. What can occur that makes sexual reproduction better than asexual?
    a. Answer: Mutations ; Recombination (crossing-over)

22. How do these help the survival of the species?
    a. Answer: Genetic diversity ; Stability of genes ; Adaptation to changing environment

Name: _____

Deciphering the Language of Sex – Quiz

1. At which week after fertilization does the bipotential gonad differentiate?

2. State ate least two beliefs people had as to how a baby's sex was determined.

3. What gene was discovered that determines maleness?

4. Males can have an XXY chromosomal combination and are found sterile, why is this?

5. Where can recombination (crossing-over) occur on each of the sex chromosomes? Which chromosome benefits the most from this and why?

Lecture II: Hermaphrodites: The Safer Sex

Chapters:

1. Start of Lecture Two
2. Introduction by HHMI Vice-President Dr. Peter Burns
3. Introductory interview with Dr. Barbara Meyer
4. Why do we study model organisms?
5. Introduction to the nematode *Caenorhabditis elegans*
6. Anatomy of *C. elegans*: every cell is known
7. *C. elegans* has two sexes: male and hermaphrodite
8. Video: *C. elegans* mating
9. *C. elegans* sperm
10. Video: Amoeboid sperm of *C. elegans*
11. A behavior gene in *C. elegans* is related to a human gene important to kidney function
12. Life cycle of a hermaphrodite
13. Fertilization mechanism in *C. elegans*
14. Early embryonic development of *C. elegans*
15. Video: From fertilization to egg laying in *C. elegans*
16. Using mutations to study sex determination in *C. elegans*
17. Activation of sex-determining gene
18. Student Question: Why can't human hermaphrodites self-fertilize?
19. Student Question: Why aren't there any female worms?
20. Student Question: Do hermaphrodites use male sperm preferentially?
21. Student Question: Do male sperm permanently displace hermaphrodite sperm?
22. Student Question: Did hermaphrodites evolve from females?
23. Student Question: Can hermaphrodites mate with each other?
24. Student Question: At what stage can you determine the sex of the worm?
25. The basis for sex determination in *C. elegans*
26. Activity of xol-1 sex-determining gene is dependent on the ratio of X chromosomes to autosomes
27. The balance of X signal elements (XSEs) and autosomal proteins regulates xol-1 activity
28. Demonstration: Balance of molecules in XO
29. Demonstration: Balance of molecules in XX
30. Demonstration: Balance of molecules in XX with lower levels of XSEs
31. Demonstration: Balance of molecules in XX with much lower levels of XSEs
32. Review of the central dogma of genetics
33. An X signal element (XSE) represses transcription of xol-1
34. An XSE also acts to prevent proper splicing of xol-1 mRNA transcript
35. Summary of repression mechanisms of xol-1
36. Does xol-1 at low levels have any function?
37. Student Question: What is the purpose of the low level of xol-1 in hermaphrodites?
38. Student Question: Is xol-1 comparable to SRY in mammals?

39. Student Question: What is the difference between the blue and yellow XSEs in the demonstration?
40. Student Question: What do we know about human hermaphrodites?
41. Student Question: Is it possible to produce a worm that lacks xol-1?
42. Student Question: Do all organisms require a gene to be switched on for male development?
43. Student Question: Can you add xol-1 to a hermaphrodite and made it a male?
44. Closing remarks by HHMI Vice-President Dr. Peter Burns

Possible areas to use Lecture II within the classroom:

1. Genetics – genetic pathways; transcription & translation; study of invertebrates
2. General Biology and Anatomy & Physiology – gene expression; transcription & translation; study of invertebrates

Vocabulary List:

1. Hermaphrodite
2. Nematode
3. Gene
4. Autosome
5. Chromosome
6. Protein
7. Anterior
8. Dorsal
9. Posterior
10. Ventral
11. Gonad
12. Spermatheca
13. Embryo
14. Sperm
15. Oocyte
16. Uterus
17. Amoeboid
18. Ovulation
19. Meiosis
20. Self-fertilization
21. Cross-fertilization
22. Polar body
23. Wild-type
24. Haploid
25. Ploidy
26. Diploid
27. Maternal
28. Paternal
29. Transcription
30. Translation
31. Exon
32. Intron
33. Splicing
34. Inducer
35. Repressor
36. Progeny

Lecture II: Vocabulary definitions

1. Hermaphrodite: An organism that contains both testicular and ovarian tissue.

2. Nematode: Any of several worms of the phylum Nematoda, having unsegmented, cylindrical bodies, often narrowing at each end, and including parasitic forms such as the hookworm and pinworm.

3. Gene: A hereditary unit consisting of a sequence of DNA that occupies a specific location on a chromosome and determines a particular characteristic in an organism.

4. Autosome: A chromosome that is not a sex chromosome.

5. Chromosome: Threadlike linear strand of DNA and associated proteins in the nucleus of eukaryotic cells that carries the genes and functions in the transmission of hereditary information.

6. Protein: Any of a large group of nitrogenous organic compounds that are essential constituents of living cells; consist of long strings of amino acids.

7. Anterior: Of or near the head end or toward the front plane of the body.

8. Posterior: Located behind a part or toward the rear of a structure.

9. Ventral: Relating to or situated on or close to the anterior aspect of the human body or the lower surface of the body of an animal.

10. Dorsal: Of, toward, on, in, or near the back or upper surface of an organ, part, or organism.

11. Gonad: An organ in animals that produce gametes, especially a testis or ovary.

12. Spermatheca: A receptacle in the reproductive tracts of certain female invertebrates in which spermatozoa are received and stored until needed to fertilize the ova.

13. Embryo: An organism in its early stages of development, especially before it has reached a distinctively recognizable form. In humans, the prefetal product of conception from implantation through the eight week of development.

14. Sperm: A male gamete or reproductive cell; a spermatozoon.

15. Oocyte: A cell from which an egg or ovum develops by meiosis; a female gametocyte.

16. Uterus: A hollow muscular organ located in the pelvic cavity of female mammals in which fertilized egg implants and develops.

17. Amoeboid: Of or resembling an amoeba, especially in changeability of form and means of locomotion.

18. Meiosis: The process of cell division in sexually reproducing organisms that reduces the number of chromosomes in reproductive cells from diploid to haploid, leading to the production of gametes in animals and spores in plants.

19. Self-fertilization: Fertilization by sperm from the same animals.

20. Cross-fertilization: Fertilization by sperm from a different animal.

21. Polar body: A small cell containing little cytoplasm that is produced along with the oocyte and later discarded.

22. Wild type: The typical form of an organism, strain, gene, or characteristic as it occurs in nature.

23. Haploid: An organism or cell having only one complete set of chromosomes.

24. Ploidy: A multiple of the basic number of chromosomes in a cell.

25. Diploid: An organism or cell having two sets of chromosomes or twice the haploid number.

26. Maternal: Relating to characteristics of a mother or motherhood.

27. Paternal: Relating to characteristics of a father or fatherhood.

28. Transcription: The process by which mRNA is synthesized from a DNA template resulting in the transfer of genetic information from the DNA molecules to the mRNA.

29. Translation: The process by which mRNA directs the amino acid sequence of a growing polypeptide during protein synthesis.

30. Exon: A sequence of DNA that codes information for protein synthesis that is transcribed to mRNA.

31. Intron: A segment of a gene situated between exons that is removed before translation of mRNA and does not function in coding for protein synthesis.

32. Splicing: To join together or insert (segments of DNA or RNA) so as to form new genetic combinations or alter a genetic structure.

33. Inducer: One that induces, especially a substance that is capable of activating transcription from specific genes within a cell.

34. Repressor: A protein that binds to an operator, blocking transcription of an operon and the enzymes for which the operon codes.

35. Progeny: One born of or derived from another; an offspring or a descendent.

Question Bank:

1. What determines whether *C. elegans* is a male or a hermaphrodite?
    a. Answer: The number of X chromosomes

2. What is a hermaphrodite?
    a. Answer: Organisms that contain both testicular and ovarian tissue

3. What are some ways Dr. Meyer mentions that proteins regulate an organism?
    a. Answer: when & how to grow ; fight off stresses ; death

4. List four characteristics of *Caenorhabditis elegans*.
    a. Answer: multicellular ; 1 mm long ; lifespan of 2-3 weeks ; new generation every 3 days

5. When was the genome for *C. elegans* completed? How many base pairs of DNA do *C. elegans* have?
    a. Answer: 1998 ; 99 million base pairs

6. *C. elegans* has 19,099 genes, what percentage of these are equivalent to humans?
    a. Answer: 40%

7. How is being hermaphroditic different between humans and *C. elegans*?
    a. Answer: *C. elegans* can produce both sperm and eggs while humans are sterile.

8. How is the gonad different between a hermaphrodite and a male *C. elegans*?
    a. Answer: Hermaphrodite's gonad is two-armed (two-lobed), the male's gonad is one-armed (one-lobed)

9. The tail is the _____ of the male, while the rays are _____, and the spicules are used to _____.
    a. Answer: mating organ ; sensory structures ; cling to the hermaphrodite

10. Sperm of the *C. elegans* contains a protein that stimulates?
    a. Answer: ovulation and meiosis

11. Self-fertilization of a hermaphrodite results in what percentage of the progeny being male?

a. Answer: 0.2%

12. Cross-fertilization between a hermaphrodite and a male results in what percentage of the progeny being male?
    a. Answer: 50%

13. Oocytes pass through the _____, where sperm is stored, are fertilized and become embryos.
    a. Answer: spermatheca

14. Where the sperm enters the oocyte determines its polarity. The side the sperm enters becomes the _____ and the other side the _____.
    a. Answer: tail ; head

15. The following is a genetic pathway which determines an embryo to become a hermaphrodite. How does this pathway change for an embryo to become a male?

XX	xol-1	sdc-1	her-1	tra-2	fem-1	tra-1	= Hermaphrodite
		Sdc-2		tra-3	fem-2		
		Sdc-3			fem-3		
	OFF	ON	OFF	ON	OFF	ON	

    a. Answer: xol-1 would be turned on, with the following genes being opposite of the hermaphrodite.

16. Will a hermaphrodite tend to use their own sperm or that of a male? Why?
    a. Answer: Male's sperm ; It's bigger and displaces the hermaphrodite's sperm.

17. Is it really only the number of X chromosomes that determines the sex of the *C. elegans*?
    a. Answer: No. It's the ratio of X chromosomes to the sets of autosomes

18. What gene was discovered that determines male fate?
    a. Answer: xol-1

19. When is the sex of the *C. elegans* determined?
    a. Answer: Six hours after fertilization

20. Can two hermaphrodites cross with each other?
    a. Answer: No. Only with themselves, they have no external genetalia.

21. What does XSE stand for? What is their job discussed here?
    a. Answer: X signal elements. They are proteins that turn xol-1 off.

22. If the ratio of X chromosomes to autosomes is 1X:2A what will the sex of the nematode be?
    a. Answer: Male (xol-1 would be turned on)

23. If the ratio of X chromosomes to autosomes is 2X:2A what will the sex of the nematode be?
    a. Answer: Hermaphrodite (xol-1 would be turned off)

24. During splicing what parts of a gene are removed?
    a. Answer: The introns

25. What parts of a gene actually code for the protein that is being made?
    a. Answer: The exons

26. What needs to bind to a gene in order for transcription to occur?
    a. Answer: RNA polymerase

27. What can block transcription from occurring? What in the *C. elegans* is then able to block transcription?
    a. Answer: A repressor protein. ; XSE can act as a weak repressor

28. When would there be a greater rate of transcription occurring, when there is a low level of XSEs or a high level of XSEs?
    a. Answer: When there are low levels of XSEs

29. What gene found in humans is similar to the xol-1 gene found in *C. elegans*?
    a. SRY gene

Lecture III: Sex and Death: Too Much of a Good Thing

Chapters:

1. Start of Lecture III
2. Introduction by HHMI President Dr. Thomas Cech
3. Introductory interview with Dr. Barbara Meyer
4. Too many chromosomes: Down Syndrome
5. How humans deal with having too many X chromosomes
6. How the nematode deals with having too many X chromosomes
7. *Dumpy* (DPY) gene, a dosage-compensation mutant
8. The *sdc* gene affects both dosage-compensation and sex-determination
9. Demonstration: Branched pathway for dosage-compensation and sex-determination
10. Demonstration: The *sdc* gene is turned on in normal hermaphrodite development
11. Demonstration: An *sdc*-mutant hermaphrodite develops as a male without dosage-compensation
12. Demonstration: Block sex-determining branch only
13. Demonstration: Block dosage-compensation branch only
14. How does SDC protein interact with the X chromosomes?
15. How does the male X chromosome avoid dosage-compensation?
16. What happens in an xol-1 mutant?
17. How can you keep a xol-1 mutant from dying?
18. How can you manipulate xol-1 mutants to become male?
19. Student Question: How do you get a 50% reduction in gene activity?
20. Student Question: Does dosage-compensation occur on autosomes?
21. Student Question: Can a nematode get Down Syndrome?
22. Student Question: How can Turner Syndrome have effects if X inactivation occurs?
23. Student Question: What happens in XXX nematodes?
24. Student Question: What actually kills when there is no dosage-compensation?
25. Student Question: How do genes in X chromosomes escape inactiviation?
26. Student Question: Do autosomes have genes that determine sex?
27. Topics to be covered in the second half o the lecture
28. Review of mitotic chromosomal segregation
29. Dosage-Compensation proteins evolved from mitotic proteins
30. MIX-1 protein has roles in both mitosis and dosage compensation
31. How does MIX-1 carry out these two roles and not get confused?

32. Where and when is SMC-4 protein found?
33. SMC-4 is only expressed in mitotic cells
34. Video: Embryonic cellular division in wild-type and SMC-4 mutant
35. Animation: SMC-4/MIX-1 protein in mitosis
36. Animation: SDC/MIX-1 and SMC-4/MIX-1 proteins in dosage compensation and mitosis
37. DPY-28 protein is involved in meiosis
38. Summary of Lecture III
39. Student Question: Can you tag SMC-4 and use it as a marker for mitosis?
40. Student Question: At what developmental stage does dosage compensation start?
41. Student Question: Is the dosage-compensation mechanism similar to cell division in any way?
42. Student Question: How does DPY-28 control the number of crossing-overs?
43. Student Question: Without SMC-4, would the chromosomes stay tangled?
44. Closing remarks by HHMI President Dr. Thomas Cech

Possible uses for Lecture III within the classroom:

Vocabulary List:

Down Syndrome
Trisomy
Barr Body
Dosage Compensation
Chromosome
Transcription
Phenotype
Genotype
Gene
Mutation
Autosomes
Sex Chromosomes
Heterochromatin
Chromatin
Mitosis (Stages)
Spindles
Tubulin
Protein
Histone
Meiosis
Diploid
Haploid
Tetraploid
Homologous Chromosomes
Recombination

Lecture III: Vocabulary Definitions

1. Down Syndrome: A congenital disorder, caused by the presence of an extra 21st chromosome, in which the affected individual has mild to moderate mental retardation, short stature, and a flattened facial profile.

2. Trisomy: The condition of having three copies of a given chromosome in each somatic cell rather than the normal number of two.

3. Barr body: The condensed, inactive X-chromosome found in the nuclei of somatic cells of most female mammals. Also called sex chromatin

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4. Dosage compensation:

5. Chromosome: Threadlike linear strand of DNA and associated proteins in the nucleus of eukaryotic cells that carries the genes and functions in the transmission of hereditary information.

6. Transcription: The process by which mRNA is synthesized from a DNA template resulting in the transfer of genetic information from the DNA molecules to the mRNA.

7. Phenotype: The observable physical or biochemical characteristics of an organism.

8. Genotype: The combination of alleles located on homologous chromosomes that determines a specific characteristic or trait.

9. Gene: A hereditary unit consisting of a sequence of DNA that occupies a specific location on a chromosome and determines a particular characteristic in an organism.

10. Mutation: A change of the DNA sequence within a gene or chromosome of an organism resulting in the creation of a new character or trait not found in the parental type.

11. Autosome: A chromosome that is not a sex chromosome.

12. Sex Chromosome: Either of a pair of chromosomes, usually designated X or Y, in the germ cells of most animals and some plants, that combine to determine the sex and sex-linked characteristics of an individual, with XX resulting in a female and XY in a male in mammals.

13. Heterochromatin: Tightly coiled chromosomal material that stains deeply during interphase and is believed to be genetically inactive.

14. Chromatin: A complex of nucleic acids and proteins, primarily histones, in the cell nucleus that condenses to form chromosomes during cell division.

15. Mitosis: The process in cell division by which the nucleus divides, typically consisting of four stages, prophase, metaphase, anaphase, and telophase, and normally resulting in two new nuclei, each of which contains a complete copy of the parental chromosomes.

16. Spindles: The spindle-shaped achromatic structure, composed of microtubles, along which the chromosomes are distributed in meiosis and mitosis.

17. Tubulin: A globular protein that is the basic structural constituent of microtubules.

18. Protein: Any of a large group of nitrogenous organic compounds that are essential constituents of living cells; consist of long strings of amino acids.

19. Histone: Any of several small, basic proteins most commonly found associated with the DNA in the chromatin of eukaryotes.

20. Meiosis: The process of cell division in sexually reproducing organisms that reduces the number of chromosomes in reproductive cells from diploid to haploid, leading to the production of gametes in animals and spores in plants.

21. Haploid: An organism or cell having only one complete set of chromosomes.

22. Diploid: An organism or cell having two sets of chromosomes or twice the haploid number.

23. Tetraploid: Having four times the haploid number of chromosomes in the cell nucleus.

24. Homologous chromosomes: Corresponding chromosomes; one from each parent.

25. Recombination: The natural formation in offspring of genetic combinations not present in parents, by the processes of crossing over or independent assortment.

Question Bank:

1. What causes Down Syndrome?

    Answer: Increase in number of 21 chromosomes (Trisomy 21)

2. Approximately what percentage of children with down syndrome die before birth?

    Answer: 85%

3. In humans, gene expression from the X chromosome is equaized between the sexes by what method?

    Answer: X inactivation in females

4. This inactive X chromosome or _____ is a crumpled, inactive state of chromatin with most or all of the genes turned _____.

    Answer: Barr body ; off

5. What corrects the imbalance in X chromosome products in the nematode? How is this accomplished?

Answer: Dosage Compensation ; Each hermaphroditic X chromosome is repressed (reduced) by half (instead of the entire X chromosome being inactivated).

6. What happens to the hermaphrodite if dosage compensation fails?

Answer: The nematode will die.

7. What gene was found in the nematode that controls dosage compensation? What gene controls BOTH dosage compensation and sex determination?

Answer: DPY ; SDC

8. Fill in the following genetic pathways where indicated:

XX (normal) SDC (____) ? Sex Determination & Dosage Compensation (Normal) ? Hermaphrodite

Answer: SDC is ON

XX (mutant) SDC (off) ? Sex Determination & Dosage Compensation (_____) ? Dead Male

Answer: S.D. & D.C. is Blocked

XX (mutant) SDC (on) ? Sex Determination & Dosage Compensation (Blocked) (Normal) ? _____

Answer: Male

XX (mutant) SDC (on) ? Sex Determination & Dosage Compensation (On) (Blocked) ? _____

Answer: Dead Hermaphrodite

9. Dosage Compensation genes are activated when bound to the _____ thus decreasing transcription.

Answer: X chromosome

10. What proteins bring (recruit) the dosage compensation proteins to the X Chromosome?

Answer: SDC proteins

11. What prevents dosage compensation proteins from binding to a Y chromosome?

Answer: XOL-1 (XOL-1 directs male development & turns dosage compensation off).

12. What does XOL-1 stand for?
Answer: XO lethal

13. What gene does XOL-1 repress?
Answer: SDC

14. XX XOL-1 SDC ? dosage compensation & transcription ? _____
(normal) (off) (___) (normal) (repressed)

Answer: SDC is On ; leads to a hermaphrodite

15. It has been discovered that proteins involved in dosage compensation evolved from proteins involved in the condensing and decondensing of _____.
Answer: Mitotic Chromosomes

16. What are the dual roles played by the MIX-1 protein?
Answer: (1) localize to X chromosome for dosage compensation ; (2) mitosis

17. How does MIX-1 carry out these dual roles without getting confused?
Answer: It has different protein partners. When bound with DPY-27 it carries out dosage compensation. When bound to SMC-4 it carries out mitotic chromosomal condensing.

18. What happens if there is a mutation in the SMC-4 protein?
Answer: The chromosomes do NOT separate

19. Name the dual roles that DPY-28 plays.
Answer: Dosage compensation and meiosis

20. In meiosis what does DPY-28 regulate?
Answer: The number of crossing-overs.

21. If there is a mutation in the DPY-28 gene what occurs?
Answer: Multiple recombinations

Lecture IV: Sexual Evolution: From X to Y

Chapters:

1. Start of Lecture IV
2. Introduction by HHMI Program Director Dr. Dennis Liu
3. Introductory interview with Dr. David Page
4. Description of study measuring testosterone levels of participating students
5. Testosterone study: Student predictions
6. Testosterone Study: Interpretations
7. What does the Y chromosome do?
8. Cartoon map of Y-Chromosome genes
9. Real map of the Y chromosome: Nonrecombining region is passed down clonally
10. Map of the Y chromosome with its three classes of genes
11. Overview of 300 million years of Y chromosome evolution
12. Synopsis of the animation on Y chromosome evolution
13. Animation: SRY gene evolves and an autosome becomes a Y chromosome
14. Animation: Y chromosome degrades over time
15. Animation: Y chromosome also gains new genes
16. Student Question: Why doesn't inversion occur on other chromosomes?
17. Student Question: How does temperature determine the sex of a reptile?
18. Student Question: Why doesn't the X chromosome undergo inversions?
19. Deletions on the Y chromosome are a leading cause of male infertility
20. Video: Sperm motility in normal-and low-sperm count samples
21. Some men with low sperm counts are missing part of the Y chromosome
22. Review of spermatogenesis
23. Seminiferous tubules of men without the DAZ gene
24. Intracytoplasmic sperm injection (ICSI) as a remedy for low sperm count
25. Video: ICSI procedure
26 Problems with ICSI and male babies
27. Ethical issues with ICSI
28. Student Question: Does ICSI always work?
29. Student Question: Does my dog have more genes on its Y chromosome than my brother has?
30. Student Question: In ICSI, how is the embryo returned to the uterus?
31. Student Question: Will evolution lead to the complete destruction of the Y chromosome?
32. Student Question: Will Y chromosome deletions always be transmitted?
33. Student Question: Could we program the sex of a would-be child?
34. Student Question: What is considered a normal sperm count?
35. Student Question: Why do flies have the Y chromosome but reptiles don't?
36. Student Question: Could we reinsert DAZ genes in sperm with DAZ deletions?
37. Closing remarks by HHMI President Dr. Thomas Cech

Possible Areas of Use for Lecture IV within the classroom:

1. Male reproductive system
2. Meiosis
3. Ethical debate (genetic engineering)

Vocabulary:
1. Testosterone
2. Sex Chromosomes
3. Gene
4. Recombination
5. Meiosis
6. Gonad
7. Testis
8. Gamete
9. Homologous Chromosomes
10. Autosomes
11. Mutation
12. Inversion
13. Deletion
14. Infertility
15. Sperm
16. Spermatogenesis
17. Vas Deferens
18. Epididymis
19. Seminiferous Tubule
20. Egg
21. Embryo
22. Uterus
23. Clone

Lecture IV: Vocabulary Definitions

1. Testosterone: A steroid hormone, $C_{19}H_{28}O_2$, produced primarily in the testes and responsible for the development and maintenance of male secondary characteristics.

2. Sex Chromosome: Either of a pair of chromosomes, usually designated X or Y, in the germ cells of most animals and some plants, that combine to determine the sex and sex-linked characteristics of an individual, with XX resulting in a female and XY in a male in mammals.

3. Gene: A hereditary unit consisting of a sequence of DNA that occupies a specific location on a chromosome and determines a particular characteristic in an organism.

4. Recombination: The natural formation in offspring of genetic combinations not present in parents, by the processes of crossing over or independent assortment.

5. Meiosis: The process of cell division in sexually reproducing organisms that reduces the number of chromosomes in reproductive cells from diploid to haploid, leading to the production of gametes in animals and spores in plants.

6. Gonad: An organ in animals that produce gametes, especially a testis or ovary.

7. Testis: The reproductive gland in a male vertebrate, the source of spermatozoa and the androgens, normally occurring paired in an external scrotum in humans and certain other mammals.

8. Gamete: A reproductive cell having the haploid number of chromosomes, especially a mature sperm or egg capable of fusing with a gamete of the opposite sex to produce the fertilized egg.

9. Homologous Chromosomes: Corresponding chromosomes; one from each parent.

10. Mutation: A change of the DNA sequence within a gene or chromosome of an organism resulting in the creation of a new character or trait not found in the parental type.

11. Autosome: A chromosome that is not a sex chromosome.

12. Inversion: A chromsomal defect in which a segment of the chromosome breaks off and reattaches in the reverse direction.

13. Deletion: The loss, as through mutation, of one or more nucleotides from a chromosome.

14. Infertility: The inability of a couple to conceive after one year of unprotected intercourse.

15. Sperm: A male gamete or reproductive cell; a spermatozoon.

16. Spermatogenesis: Development of spermatozoa.

17. Vas Deferens: The main duct through which semen is carried from the epididymis to the ejaculatory duct.

18. Epididymis: A convoluted tubule in each testis; carries sperm to vas deferens.

19. Seminiferous tubule: One of two or three twisted, curved tubules in each lobule of the testis in which spermatozoa develop.

20. Egg: A female gamete; an ovum.

21. Embryo: An organism in its early stages of development, especially before it has reached a distinctively recognizable form. In humans, the prefetal product of conception from implantation through the eight week of development.

22. Uterus: A hollow muscular organ located in the pelvic cavity of female mammals in which fertilized egg implants and develops.

23. Clone: A group of genetically identical cells or organisms derived from a single cell or individual by some kind of asexual reproduction.

Question Bank:

1. According to the results of the testosterone study conducted where were the highest levels of testosterone found (within which age group)?
Answer: 15 to 20

2. What does NRY stand for? How does NRY differ from other chromosomes?
Answer: Non-recombining region ; Only specific to males and there is NO recombination during meiosis.

3. Where can recombination occur on the Y chromosome?
Answer: Only at the ends.

4. Within the NRY there are three classes of genes list them and their purpose.
Answer: (1) SRY – development of gonad into testes
(2) RPS4Y – cell housekeeping

(3) DAZ – sperm production

5. How many genes or gene families are found on the Y Chromosome? How does this compare to the X chromosome?

Answer: Y has approximately 26 genes/gene families while the X has approximately 1000 genes.

6. How did the male determining gene arise?

Answer: Through mutation of pre-existing chromosomes

7. Where there sex chromosomes 300 million years ago?

Answer: No – there were only autosomes

8. The cell housekeeping genes found on the Y chromosome are like _____, they are rare survivors.

Answer: living fossils

9. Recombination can only occur at the ends of the Y chromosome, how did this get that way?

Answer: The Y underwent inversions therefore can not swap genes anymore.

10. The following is a list of modern male genes, fill in the spaces with their previous names.

_____ ? SRY

_____ ? RPS4Y

_____ ? DAZ

11. Why do genes on the X chromosome remain healthy?

Answer: Recombination can still occur

12. Deletions on the Y chromosome are a leading cause of?

Answer: Male infertility

13. These deletions cause males to produce too little what? What gene is missing that causes this?

Answer: Sperm ; DAZ

14. Approximately how long does it take for males to produce mature sperm?

Answer: 2 months

15. What process is now being conducted to help infertile couples produce a baby?

Answer: Intracytoplasmic Sperm Injection (ICSI)

16. What is the problem with ICSI?

Answer: If the embryo turns out to be a male baby then he will also be missing the DAZ genes.

17. Write a brief paragraph with your comments on the following ethical issues discussed in the video.

1. When or should these boys be told about their infertility?
2. What if a couple with low sperm count knows BEFORE – should they – (a) adopt, (b) go ahead with ICSI, (c) use donor sperm, (d) use only female embryos?

DVD Extras:

Animations:

Meiosis and recombination
MIX-1 and dosage compensation
Evolution of the Y chromosome

Video Clips:

C. elegans mating
Amoeboid sperm of C. elegans
From fertilization to egg laying in C. elegans
Embryonic cell division in C. elegans
Sperm motility
Intracytoplasmic Sperm Injection (ICSI)

Lecture Demonstrations:

Clonal vs. Sexual reproduction using fruits and vegetables
Balance of X signal elements and autosomal proteins regulates sex determination in C. elegans
C. elegans branched pathway for dosage compensation and sex determination

Lecture Biographies:

David C. Page, M.D.
Barbara J. Meyer, PH.D.

HHMI Mailing Address:

HHMI
Holiday Lectures on Science
4000 Jones Bridge Road
Chevy Chase, MD. 20815-6789

Web-Sites:

www.holidaylectures.org
www.visembryo.com (visible embryo)
www.biointeractive.org

Computer Lab for classroom:

Interactive Feature on Gender Testing