Cell Biology- Final Exam Package

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Dr. Cavallo-Medved

SOS Tutors: Kaity Greco, Christina Basily & Vanessa Montemurri

greco114@uwindsor.ca basilyc@uwindsor.ca montemuv@uwindsor.ca

SOS Cell Biology FINAL EXAM

Chapter 10

10.1 Blending Theory of Inheritance(Pre-1900s) ○ Theory that suggested that hereditary traits blend evenly in offspring through the mixing of parent's blood. In other words, an offspring's trait is between the traits of the parents' traits. For example, if you have a tall dad and a short mom, the offspring will be medium height.
○ Theory does not explain why extremes do not gradually disappear over generations. For example, you have two short parents but the child is very tall.

10.1a Mendel and His Work

- Gregor Mendel (1860s) ○ Key founder of genetics
  - First to use scientific method to study Inheritance
  - Famous work with Peas
  - **Character** : Heritable characteristics such as flower color and seed shape
    - **Trait** : variation in character such as purple or white flowers
    - Mendel established that these characters are passed down through hereditary factors, which are now known as genes.
- Reasons Why Mendel Chose Pea Plant ○ Could be easily grown (in his garden) ○ Defined and distinct Characters ○ Variation in a character called Traits
- Normally , pea plants self- fertilize(self- pollinate) : IN THE SAME FLOWER, sperm (male gametes) nuclei in pollen produced by anthers fertilize egg cells(female gametes) produced in the carpel . What Mendel did was that he prevented this self-fertilization by cutting off the anthers of one flower. He gathered pollen from a *distinctly different* flower to fertilize the antherless flower= **CROSS-POLLINATION**
- Self- fertilized flowers are known to be **true-breeding/pure-breeding**. Traits passed on through generations remain unchanged (if there are no mutations)

10.1b Mendel's Way of Cross-Breeding

- Mendel first cross-breed a *true-breed* purple flower with a *true-breed* white flower.
  - First offspring were purple and showed no evidence of blending.
  - Second offspring produced by the self -breeding of the first offspring. Second offspring includes purple and white flowers respectively in a 3 to 1 ratio.
- **P generation** – parental or initial traits used in the cross
- **F_1 generation** – the first generation/offspring of the initial cross
- **F_2 generation** – offspring of the self-breeding of F_1 generation

10.1c Mendel's First Hypothesis

- **First Hypothesis**: Adult plants carry a pair of factors that govern the inheritance of each character. Mendel deduced that for each character, an organism inherits one factor from each parent.
- **Gene** (known as Mendel's factors) ▪ located on the chromosome.
    - **Alleles** – different version of a gene that produce different traits of a character.
    - For example, with 2 homologous chromosomes, a gene that encodes for eye color will be located on both chromosomes. Each chromosome will have an allele that encodes a different color such as blue or green . Therefore, each gene will have two alleles for a given character. *One allele is inherited from each parent.*
- **Diploid:** two copies of each gene ; the two alleles of a gene in a diploid individual may be identical or different.

10.1C Mendel's Second Hypothesis

- **Second Hypothesis**: If an individual's pair of genes consists of different alleles, one allele is dominant over the other, recessive, allele.
- **Dominant** allele is expressed (can be shown be as appearance or can be shown as symptoms)
- **Recessive** allele is *masked***.** It is not shown at all in neither appearance and symptoms. ○ A recessive allele is ONLY expressed if it is paired with the same recessive allele
- **Dominance:** term to describe the masking effect where an allele is "masked" or overtaken by a "stronger" allele.
- NOTE: When using any sort of crossing method, Dominant allele is represented as a capital case letter. Recessive allele is represented as a lower-case letter.

10.1C Mendel's Third Hypothesis

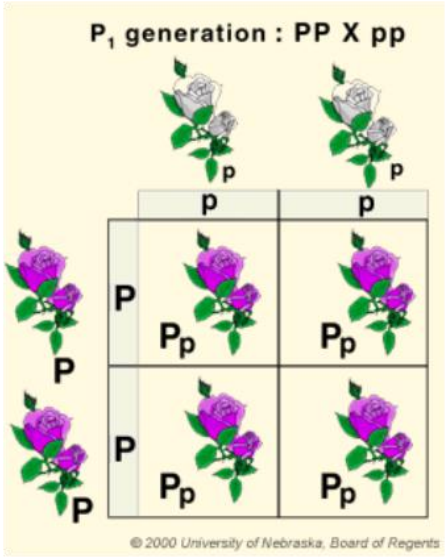
- **Principle of Segregation**: The pairs of alleles that control a character segregate(separate) as gametes are formed; half of the gametes(whether they be sperm or egg) carry one allele and the other half carry the other allele .
    - Note that both gametes only contain ONE copy of a gene for that specific trait. Therefore, gametes are considered **haploid** ○ During fertilization, the fusion of the two haploids/gametes will produce a zygote/diploid. This zygote will receive an allele encoding the same character from each gamete.

Recall: Dominant Allele – Upper case , Recessive –lower case
Let P represent purple and p represent white

- **Homozygote -** individual who has two of the same alleles ○ **Homozygous** – term to describe the same two alleles.
    - PP is dominant homozygous
    - pp is recessive homozygous ○ True-breeding purple(PP) and true-breeding white flowers(pp) are considered homozygotes.
- **Heterozygote** : individual who has one dominant allele and one recessive allele for a given gene.
    - Pp is considered **heterozygous**
        - P is dominant and p is recessive. Therefore, the color Purple will be only shown .

10.1c Monohybrid Cross

- **Monohybrid** – A F_1 heterozygote produced from a cross that involves a single character.
    - (mono= one , hybrid= offspring of *P generation* with *different traits*)
- In general , a **Monohybrid Cross** involves the crossing between two individual heterozygotes(Pp x Pp) for the same pair alleles .
    - **Punnet Square** – a diagram/method used to predict the outcome of a cross. It is a great way to determine the genotypes and phenotypes of the offspring and their expected proportions (ratios)



    - **Genotype-** genetic constitution of an organism
    - **Phenotype** – outward appearance
    - Pp and PP are genetically different based on the different alleles (genotype) , but both will produce an purple color as its outward appearance due to the dominant P allele (phenotype) .

10.1d Probability

- Probability – the possibility that an outcome will occur if it is a matter of chance on a scale of 0 to 1.
- **Product Rule (MULTIPLICATION !) KEY WORD : AND**
    - Two events are independent (Ex. A 2 appearing on one dice will not affect the outcome of rolling a 3 on another dice)
    - The probability that two or more independent events will both occur (doesn't have to happen at the same time just in the end they both have to occur) .
        - To get the probability of this outcome, you multiply both the individual probabilities together
        - Example : Probability of getting a number 4 on a dice and number 6 on the other will be ?
- The probability of getting a number 4 out of the 6 possible choices is 1/6 . This goes the same for getting a 6. Therefore, the outcome of these two events to both occur : 1/6 x 1/6 = 1/36.
- **Sum Rule (ADDITION) KEY WORD : OR**
    - When several different events all give the same outcome.
        - For example, rolling a 7 with two dices. There are 6 possible ways to get the same outcome(rolling a 7)
    - The probability that either event A or event B or event C will occur. ▪ Sum of the individual probabilities of each event.

10.1e Testcross

- **Testcross** – a cross between an individual with the dominant phenotype and a homozygous recessive individual. The genotype of the dominant phenotype is UNKNOWN.
    - Testcrossing the unknown genotype with the known homozygous recessive individual (pp) determines whether the unknown genotype is homozygous or heterozygous.

10.1f Mendel's Fourth Hypothesis

- **Principle of Independent of Assortment** : the alleles of the genes that govern the two characters segregate independently during formation of gametes. This hypothesis/assumption addresses the inheritance trait for more than one character.
    - The allele for seed shape that the gamete receives (R or r) has no influence on which allele for seed color it receives.
    - In other words, you are no more likely to get a green round pea than a green wrinkled pea.
- **Dihybrid Cross** : a cross between two individuals that are heterozygous (shape and color of the flower)
    - RRYY x rryy

- Offspring is all RrYy
- All round yellow phenotype

○ RrYy x RrYy

- This cross produces a genotype ratio of 9:3:3:1

- 9/16 = round yellow
- 3/16= wrinkled yellow
- 3/16 = round green
- 1/16 =wrinkled green

10.1h Walter Sutton's Chromosome Theory of Inheritance

- Student Walter Sutton discovered similarities between the inheritance of genes and the behavior of chromosomes during meiosis(gamete production)
- **Chromosome theory of Inheritance –** genes and their alleles are carried on the chromosomes. Sutton drew conclusions based on the parallels between genes and chromosomes:
  - Chromosomes and alleles occur in pairs in sexually reproducing diploid organisms. (Usually termed homologous chromosomes)
  - In gamete reproduction, chromosomes and alleles of each pair split and are delivered singly to gametes.
  - The separation of any pair of chromosomes in meiosis and gamete formation is independent of the separation of the other pairs just like the independently assortment of the alleles of different genes in the dihybrid cross.
  - One chromosome/allele from the male parent paired up with another chromosome from the female parent.
- **Locus** – the particular site on a chromosome at which a gene is located ○ A particular DNA sequence that encodes a protein or RNA product responsible for the phenotype controlled by the gene.

10.2a Non-Mendelian Pattern : Incomplete Dominance

- **Incomplete Dominance** : the effects of recessive alleles can be detected in a heterozygote individual. Good way to describe this effect is that the appearance is a mixing between the two colors of the parents
- Good example would be flower color of Snapdragons ○ True breeding dominant red-flowered snapdragon(C^RC^R) mates with recessive true-breeding white-flowered(C^WC^W) will result in all pink snapdragons (C^RC^W)
- Human Traits involved with Incomplete Dominance ○ **Sickle Cell Disease –** alteration of hemoglobin molecule changes the binding site's shape of a red blood cell.
  - Homologous recessive – encodes a defective form of one of the polypeptides
  - Heterozygous recessive – milder form of the disease. Individual is able to still produce the normal polypeptide from normal allele.
  - ○ **Familial Hypercholesterolemia**
    - Gene involved encodes Low-density lipoprotein(LDL) receptor. Receptor is responsible for removing excess cholesterol from blood.

- Homozygous for severe form of disease- results in 6 times the normal level of cholesterol in the blood = prone to heart attacks
- Heterozygous – mild form of disease. Individuals have half the number of receptors, and twice the normal blood cholesterol level. ○ **Tay-Sachs Disease**
- Homozygous recessive- Individuals affected do not have function enzyme that breaks down gangliosides in the brain = brain impairment and eventually death
- Heterozygote – Indivudals affected have no symptoms but small traces of breakdown of gangliosides can be detected at a biochemical level.

10.2b Non-Mendelian Pattern: Codominance

- **Codominance –** alleles approximately have equal effects, making the two alleles equally detectable in heterozygotes.
- Best example is Blood type M, MN and N (DIFFERENT FROM ABO blood group as they are different glycoproteins than A and B) ○ L^ML^M : M form of the glycoprotein present → Blood Type M ○ L^NL^N : N form of the glycoprotein present → Blood Type N
  - ○ L^ML^N: Both M and N form of the glycoprotein present → Blood type MN

10.2c Multiple Alleles

- Multiple Alleles- when there are more than two different alleles for a gene ○ Although an individual can have only have two alleles for a gene, in a given total population, more than two different alleles can be found for that same particular gene.
  - ○ Each multiple allele of a gene contains the smallest difference in DNA sequence.
- Still follows Mendel's principles
- **Human ABO Blood Group**
  - ○ Exhibits both dominance and codominance
  - ○ **Antigen**- glycoproteins attached to the surface of red blood cells. Antigens are considered foreign particles if the immune system does not recognize them as normal particles.
    - **I^A allele** - produces A antigen (*dominant*)
    - **I^B allele** – produces B antigen (*dominant)*
    - **i allele** – does not produce neither A nor B (*recessive)* ○ Blood Type
    - **Blood Type A**: I^AI^A and I^Ai
    - **Blood Type B**: I^BI^B and I^Bi
    - **Blood Type O**: ii (universal donor)
    - **Blood Type AB** : I^AI^B (universal recipient) ○ **Antibodies** - protein produced by the immune system in response to an antigen.
    - Blood Type A will produce antibodies against antigen B (anti-B)
    - Blood Type B will produce antibodies against antigen A (anti-A)

- Blood Type AB will produce NO antibodies as they produce both antigens A and B (NONE)
- Blood Type O will produce antibodies for both antigen A and B since the *i* allele does produce neither of the two antigens. (anti-A, anti-B)
- FOR EXAMPLE : If you are in need of blood and you are Blood Type A . If you get blood from someone who is Blood Type B, then your blood will start to coagulate when you make antibodies for Antigen B. You MUST receive the same blood type from someone else.

10.2d Epistasis

- **Epistasis:** genes interact, with one or more alleles of a gene at one locus inhibiting or masking the effects of one or more alleles of a gene at a different locus. Therefore, expected phenotypes may not appear among offspring.
- Labrador Retrievers' fur can be either black, brown ,or yellow.
    - A gene that encodes an enzyme that produces a certain amount of melanin = **Melanin pigment gene**.
        - Melanin is a brownish black pigment. Variations of melanin determines the color shown on the Labrador's fur coat.
        - B allele- produces black fur color (dominant) (BB or Bb)
        - b allele- produces brown fur color (recessive) (bb) ○ Another gene at a different locus determines whether the black or chocolate color appear. = **Pigment Deposition gene**
        - E allele- allow the alleles that determines the color of fur to be expressed. (Dominant)(EE or Ee) = allows the amount of melanin pigment to be produced.
        - e allele- allow the alleles that determines the color of the fur to be NOT expressed (recessive) (ee)= Labrador lacks melanin and has yellow color.
    - *E gene is epistatic to the B gene.*
    - Phenotypes
        - Black Fur : BB EE , BB Ee , Bb EE, BbEe
- Dominant E allows the expression of B allele be shown as black fur
- Brown Fur : bb EE, bb Ee
- Domiannt allows the expression of b allele be shown as brown fur ▪ Yellow Fur : BB ee ,Bb ee, bb ee
- Despite having a dominant B or recessive b allele, having homozygous recessive ee determines the lack of melanin in fur
- 9 black : 3 brown : 4 yellow
    - This ratio is produced because BB ee and bb ee causes the yellow phenotype due to the homologous recessive ee genotype. Instead of

two phenotype outcomes like we see in Mendelian dihydrid crosses, we have three.

10.2e Polygenic Inheritance

- **Polygenic Inheritance** : Inheritance in which several genes at different loci contribute to the same character.
    - Continuous distribution is formed , meaning there are different types of the same character instead having a concrete outcome.
- **Quantitative traits :** traits ,such as body weight in humans, skin color, length in corn , seed color , and color spotting in mice , that have their measurements to be continuous instead in discrete units.
- Phenotypic distribution **:** Bell shaped Curve . → Good indication that the trait is quantitative.
- Continuous distribution of these quantitative traits can be caused by **environment effects**. Body size is a good example. If you receive less nutrition, you are more likely to be short. The lack of nutrition can prevent the actual height determined by the genes involved from being reached.

10.2f Pleiotropy

- **Pleiotropy** – single gene affecting more than one character/effect of an organism.
- Sickle- Cell Disease ○ Caused by recessive allele of a single gene that affects hemoglobin structure and function
    - Can lead to Block vessel damage
    - Damages to many tissues and organism in the body and thus affects many body functions
    - Symptoms : fatigue, abdominal pain , heart failure, paralysis

CHAPTER 11

11.1 a Gene Linkage

- Mendel's study of the specific certain 7 characters all assorted independently. HOWEVER, not all genes assort independently due to linkage. There are more genes than chromosomes, so there is a higher chance that two different genes are on the same chromosome. Therefore , the two genes will be inherited together instead of being separated during meiosis.
- **Linkage** : the phenomenon where **linked genes** are on the same chromosome.
    - Way to break the linkage : RECOMBINATION (ex. Crossing over during Prophase I of Meiosis I)
- **Drosophila Melanogaster** ○ Model research organism for animals to investigate Mendel's principle ○ Used to test linkage and recombination based on a genetic map that shows the relative distance between genes.
    - The more far apart of two genes are on a chromosome, the more likely they would be separated.
- Gene Symbolism ○ Normal alleles (Wildtype)
    - Most common allele
    - "+" symbol
    - Usually Dominant ▪ In fruit fly :
- pr+ = red eyes
- vg+ = normal wings
    - Mutant alleles- any change from the wildtype ▪ NO "+" symbol
        - In fruit fly :
            - pr= purple
            - vg= vestigial wing
            - EXPERIMENT: *pr+pr+ vg+ vg+* X *prpr vg vg* ○ Expected if Assorted Independently (Mendelian's dihybrid cross) : All dihybrid pr+prvg+vg - offspring will have normal red eyes and normal wings (1:1:1:1)

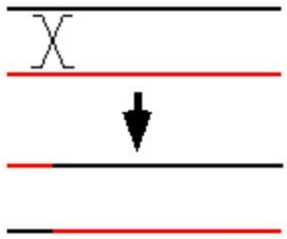
- Observed In experiment: More Wildtype and Purple Flies with Vestigial wings than the other two phenotypes = No independent assortment

- Recombination frequency is a function of the distance between linked genes.
- The greater the distance, the greater the recombination frequency (or percentage) = greater chance of crossover between genes = greater chance to be separated
- Max 50% recombination frequency = Independently assortment ○ 50% recombination frequency *reflect* on 50% of the offspring to be recombinant. ○ Why only 50%?
    - Supposed you have 100 cells going through meiosis. Each cell has two homologous pairs (4 chromatids). If each cell have two genes separated between do 2 chromatids, then there will be 200 offspring with the recombinant allele out of 400 total offspring.

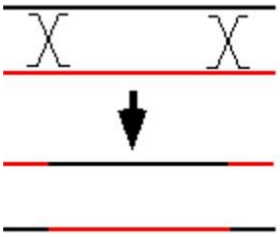
- Recombination Frequency = ## !!"" !!"!#$"#$%&' !"#$%&'()(*+ x 100

11.1b Linkage Maps

- Linkage of a chromosome showing the relative locations of genes.
- Centrimorgan/ Map unit (mu) = 1%
- Single Cross Over – one location on the chromosome where recombination happens



- Double Cross Over – Two locations on the chromosome where recombination happens



11.2 a-b Sex-Linked Genes

- **Sex Chromosomes** or **Sex-linked genes** – determine gender / inherited differently in males and females. Two different pairngs of X and Y chromosomes will determine the gender

- **XX –** Female ○ A female can only have gametes carrying the X-linked allele
  XY – Male ○ A male have half of the gametes carrying the X-linked allele and half of the gametes carrying Y-linked allele
- Other chromosomes are called **autosomes** ○ In humans, chromosome 1 to 22 are autosomes
-

Human X Chromosome	Human Y Chromosome
• Large (~2350 genes) • Many X-Linked genes are nonsexual traits such as colour perception, blood cloting and DNa replication	• Small(few genes) • Little Homology with X chromosome • Contains **SRY gene**

- **SRY gene**- regulation of direct development toward maleness at an early point in embryonic development.

11.2c <u>Sex-linkage</u>

- X chromosome is considered the sex-linked gene as they have way more genes than the Y chromosome. In other words, majority of the disorders caused by sex-linked genes will be mainly on the X chromosome.
- Males have only one X chromosome. Therefore, if he receives a recessive X chromosome, he will express that recessive trait as he has no other dominant X chromosome.
- Females have two X chromosomes. Therefore, if the recessive X chromosome is present, the only way it can be expressed is if the females has another recessive X chromosome. Otherwise, the recessive X chromosome is masked by the dominant X chromosome and the female will be considered as a carrier
- To Determine That the X Chromosome is the main chromosome involved in sex-linked disorders we can look at Morgan's Work on flies :
  - Normal Wild-Type : Red eye color
    - Dominant
    - "X^{w+}" ○ Mutant: White eye Color
    - "X^{w}" ○ Note :
  - First he mated a white-eyed male($X^{w}Y$) with a true-breeding female with red eyes. ($X^{w+}X^{w+}$)
    - Result: F_1 offspring were all red eyes . Offspring males had the genotype $X^{w+}Y$. Offspring females had the genotype $X^{w+}X^{w}$. Morgan concluded white-eye trait was recessive
  - HOWEVER, he mated the F_1 offspring with each other (Red eyed Male X Red-Eye Female)
    - Result: All F_2 females had eye red eyes ($X^{w+}X^{w}$). Half of the F_2 males had red eyes($X^{w+}Y$) and half had white eyes($X^{w}Y$).

- Reciprocal Cross
  - To make sure the white-eye gene trait is inherited through the X-linked gene.
  - Phenotypes switched between the original parents: White-eyed females (X^wX^w) crossed with a red-eyed male ($X^{w+}Y$)
    - Result: All male offspring had white eyes as it can only get one of the two X^w from the female. All offspring female were heterozygous $X^{w+}X^w$.
  - Comparing the reciprocal cross results to the results above , we can see that they are not the same . Therefore, the X-linked inheritance shows non-Mendelian patterns.

11.2d Sex-Linked Genes in Humans are Inherited as They Are in Drosophila

- Human X-Linked(Sex-linked) Disorders:
  - **Red-green color blindness** – caused by recessive allele
  - **Hemophilia** : Defective blood clotting protein – caused by recessive allele
  - NOTE: X-linked recessive traits are more common in MALES because they do not have the extra X chromosome like females that can dominant the recessive allele. For a female, they must receive two recessive alleles Therefore, the disorders above are more common in men than in women.
- **Pedigree –** chart show genotypes and phenotypes in a family's past generation

11.2e One X Chromosome Inactivation

- Females have twice as many X chromosomes as males. They do not require twice as much as the product of genes.
- In females mammals, inactivation of one X chromosome makes the dosage of X-liked genes the same as males. In other words, the activity of most genes carried on the X chromosome is the same in males and females= **Dosage Compensation**
- Inactivation occurs by Condensation of X Chromosomes Folds and packs the chromatin of one of the two chromosomes into a tightly coiled state
  - The inactive, condensed X chromosome seen attached to the side of the nucleus in cells of females as dense mass of chromatin called **Barr Body**.
- Random inactivation of either X chromosome
- The chosen X chromosome to be inactivated will stay inactivated in all descendants of the cell. In other words, when the cell goes through mitosis, the Barr Body will always replicate inactive daughter Barr bodies.
- When a female has two X chromosomes carrying different alleles of a gene, one allele (dominant) will be only active in one cell line, while the other allele (recessive) will be only active in another different cell line. In this situation the dominant allele will be more dominant/active to produce their phenotype.
- Example : Calico Cats This example shows that an inactivation of either of the two different alleles can still show both the allele's phenotype .

- Heterozygote Female Calico cats will always have orange and black patches of fur.
- Very rare in male calico cats as they can only get one of the two X-linked alleles from the mother. Usually they are either black or orange.

11.3a Chromosomal Alterations That Affect Inheritance

- **Deletion** : a broken segment is lost from a chromosome ○ May cause severe problem if the lost broken segment contains important genes for essential for cellular functions
  - **Example**: Cri-du-chat
    - deletion from human chromosome causes mental retardation and a malformed larynx (causes the person to shout more like a cat)
- **Duplication** : a segment is broken from one chromosome and inserted into its homologue.
  - vary from harmful to beneficial
- **Translocation** : broken segment is attached to a different, nonhomologous chromosome ○ Vary from harmful to beneficial
- Inversion : a broken segment reattaches to the same chromosome from which it was lost , but in reversed orientation. Order of genes is reversed ○ Vary from harmful to beneficial
- Mutations on autosomes will not be inherited while mutations on sex chromosomes will.

11.3b The Number of Entire Chromosomes May Also Change

- **Nondisjunction** : the failure of homologous pairs to separate during the first meiotic division(Meiosis I) ○ Frequency of nondisjunction increases with age
- **Misdivision** : the separation of chromatid (Meiosis II)
- **Euploids** : individuals with normal number of chromosomes
- **Aneuploids:** individuals with extra or missing chromosomes ○ Abnormalities usually prevent embryo development
  - **Down Syndrome :** condition produced by extra chromosome 21 (*trisomy 21*)
    - Short shature, some degree of mental retardation
- **Polyploids :** Individuals with *one or more extra copies* of the entire *haploid* complement of chromosomes (Triploids, tetraploids) ○ Originates from failure of the spindle to function normally during mitosis in cell lines leading to germ-line cells
  - Common in plants. Polyploidy plants have a greater chance of surviving than diploid plants
  - Uncommon in animals . Polyploidy in animals is considered lethal during embryonic development.
- NOTE: It is suggested to review the sex chromosome disorders on page 248 on the bottom right!

11.4 a-c Human Genetics and Genetic Counselling

We are observing how mutant alleles infect individuals based on the types of inheritance

- **Autosomal Recessive Inheritance** ○ Males or females carry a recessive alleles on an autosomes(not the sex chromosomes)
    - **Examples** : Cystic fibrosis albinism , sickle cell ○ *Homozygote Dominant* will show no symptoms.
    - Heterozygotes are considered the carrier of this mutant allele and will show no symptoms. In other words, your recessive allele can be inherited in your offspring
    - *Homozygote recessive* will show symptoms of traits
- **Autosomal Dominant Inheritance** ○ Dominant gene is carried on an autosome
    - *Homozygote dominant* and *heterozygote* will show symptoms of the trait ○ *Homozygote recessive* will be normal as the recessive allele is not mutated ○ **Example**: Achondroplasia – type of dwarfism

- **X-Linked Recessive Inheritance** ○ Recessive allele carried on the X chromosome ○ Males
        - Recessive allele on X chromosome
        - Show symptoms
        - Dominant allele on X chromosome will normal symptoms ○ Females
        - Heterozygote carrier will show NO symptoms
        - Homozygous recessive will show symptoms ○ **Examples**: Colour blindness and hemophilia

11.4d Genetic Counselling Techniques

- Genetic counselling allows prospective parents to assess the possibility that they might have an affected child.
    - Begins with the identification of parental genotypes through family pedigrees ○ Information based on the pedigree and other direct testing allow parents to decide whether or not they should have a child.
- **Prenatal Diagnosis** : cell derived from a developing embryo or its surrounding tissues or fluids are tested for presence of mutant alleles or chromosomal alterations ○ **Amniocentesis :** cells are obtained from the amniotic fluid surrounding the embryo
    - **Chorionic villus sampling:** cells are obtained from portions of the placenta that develop from tissues of the embryo
- **Postnatal Genetic Screening** ○ Inherited disorders are identified by biochemical or molecular tests for disorders are routinely applied to children and adults and even newborn infants

11.5a-b Nontraditional Patterns of Inheritance

- **Cytoplasmic Inheritance** "follows the pattern of inheritance of mitochondria or chloroplast ○ Gene located in the mitochondria and chloroplast are subjected to mutation as well.
    - Follows the Maternal line/MATERNAL INHERITANCE – Maternal genotype is passed onto offspring. In other words, the genome of the mitochondria and chloroplast is only past through the mother line whether you are female or male. ○ Reason why Maternal line :A female gamete is much larger than a male gamete. Therefore, most of the zygote will get its mothers organelles including the mitochondria.
- **Genetic Inheritance :** the expression of an allele of a particular nuclear gene is based on whether an individual organism inherits the allele from the male or female parent.
    - Silent allele (one that is not expressed) is called the imprinted allele
        - Not inactivated by mutation but rather by chemical modification(methylation)
    - **Loss of Imprinting** : when imprinting mechanism on a gene that is supposed to be silent does that work. This can lead to disorders.

Chapter 12: DNA Structure, Replication and Organization

Key Contributors:

- Watson and Crick (1953)

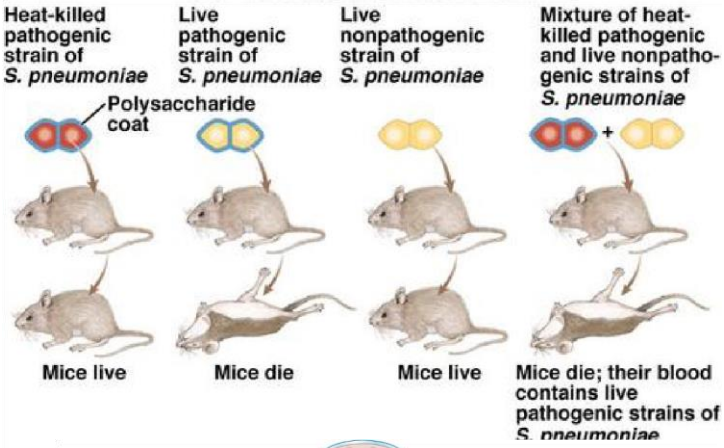
- constructed **3D model** of DNA using chemical and physical information
- model showed two polynucleotide chains in double helix

- Rosalind Franklin (early 1950s)

- used **x-ray diffraction analysis** to see arrangement of atoms in DNA
- supporting proof for Watson and Crick's model

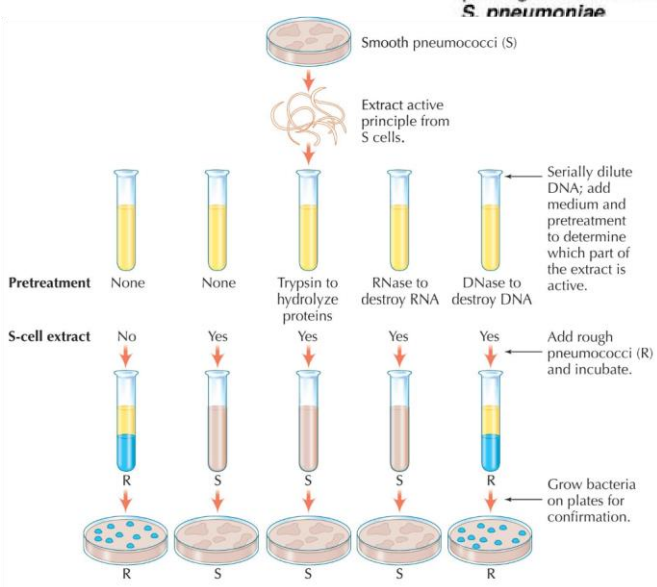
- **Frederick Griffith (1928)**

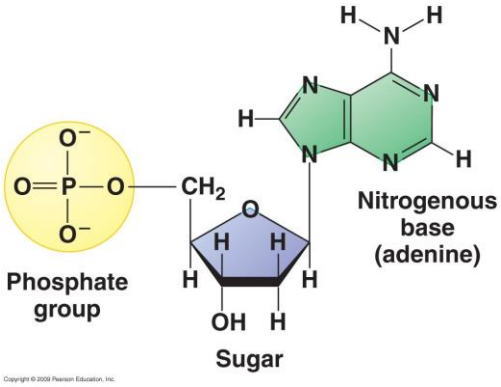
- *Streptococcus pneumoniae*
- S strain with polysaccharide capsule(virulent) and R strain (non-virulent)
- if heat treated, S does not kill
- heat treated S + live R= kills mouse
- rough transformed permanently to have infectious trait (ability to make capsule)



- **Avery and MacLeod (1940s)**

- wanted to conclude what was responsible for transforming R strain *S. pneumoniae* to S in Griffith's experiment
- when RNA or protein destroyed, still had transformation
- when DNA destroyed, no transformation (**therefore DNA was the molecule responsibl**e)





Hershey and Chase (1952)

- studied T2 phage that infects *E. coli*
- Radioactively labelled protein with ^{35}S isotope and DNA with ^{32}P isotope in virus phages; let them infect bacterial cells
- radioactivity only detected in E. coli cells infected by DNA labelled phages

<u>DNA Structure</u>

- composed of repeated subunits called **nucleotides** that have three components:
  - **phosphate group**
  - **deoxyribose sugar (5 carbon ring)**
  - **Nitrogenous base** (Adenine, Guanine, Cytosine, Thymine)
- **Pyrimidines**= single carbon ring (T and C) **way to remember is "CUT the pyramid"**
- **Purines**= double carbon ring (A and G)

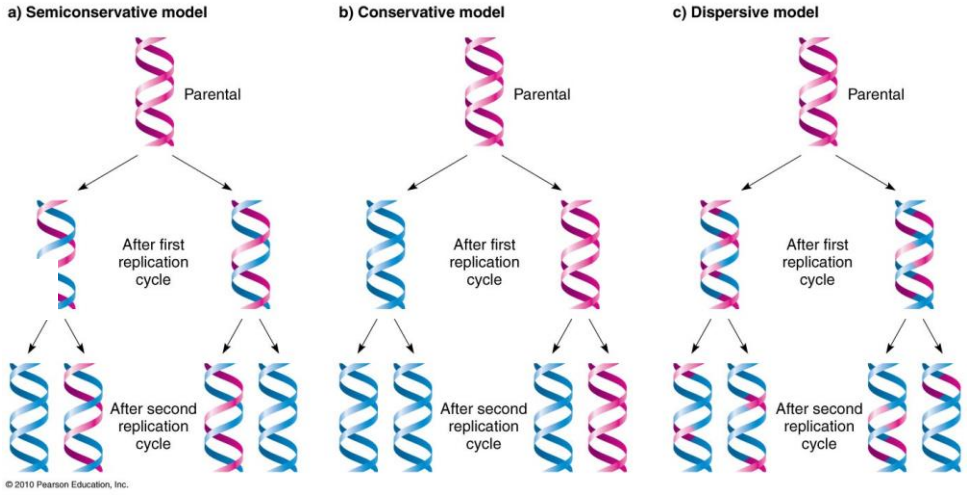
- N bases pair with **H bonds** (T double bonded to A, G triple bonded to C)
- **Chargoff's Rule**= number of purines is equal to the number of pyrimidines in complementary strands ; also amount of A=T and amount of G=C
- **sugar-phosphate backbone** (bridge between the 3' C of one sugar to the 5' C of the next sugar; phosphodiester bonds)

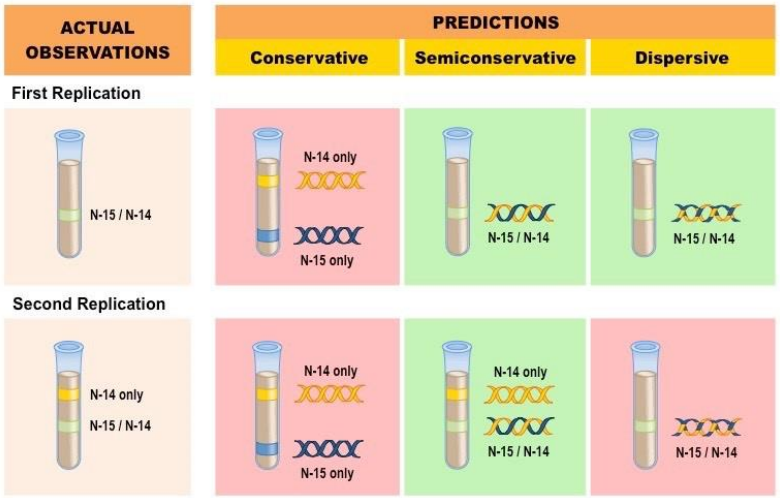
-polaritydirectionality of double helix (phosphate at 5', hydroxyl at 3')
strands run **antiparallel**

DNA Replication: 3 Models

I. **Conservative**

- two strands of original serve as template for new
- after two complementary copies separate from templates, original wind together





II. **Dispersive**

- neither parental molecule remains intact; both chains contain old and new strands

III. **Semi-conservative** (Watson and Crick)

- accepted model with one strand of each present **- Meselson and Stahl: Proof**
- used nonradioactive heavy N to tag parental DNA (15N incorporated into nitrogenous bases)
- transferred to bacteria to culture
- mixed with CsCl and centrifuged

DNA Replication:

Polymerases

- **read 3'—>5'**
- **assemble 5'—>3' (**-OH always exposed at the newest end)

Helicase – unwinds DNA
Primase- synthesizes RNA primer (OH group needed to start new DNA)
DNA polymerase I- removes RNA primers
DNA polymerase III- extends primers to build strand, uses 3' end to build in 5' to 3' direction
Ligase- closes remaining gaps, makes covalent bond between 3' end of one DNA segment and 5' end of another
dNTPs- used as building blocks of new chain; four types are dATP, dTTP, dNTP, dGTP
Sliding DNA clamp- binds to rear strand after DNA polymerase, makes binding more efficient
Single stranded binding proteins (SSBs)- coat exposed single stranded DNA, turns in opposite direction to reduce tension then rejoins strands

Telomeres

- highly **repetitive**, noncoding DNA near ends of chromosomes
- with each replication, a portion is lost due to RNA primers at 5' end, no -OH group at end of this strand for polymerase to recognize and elongate
- **telomerase** enzyme adds extra noncoding repetitive DNA
- very active in embryo, germ line and **cancer** cells

Levels of Organization of Chromosome:

- DNA wrapped around 8 **histone proteins** (2 H2A, 2 H2B, 2 H3, 2 H4) to form a **nucleosome**, histone protein H1 binds to this to hold

DNA in place and cause further folding into a **solenoid.** Solenoids coil tightly together to form DNA double helix shape

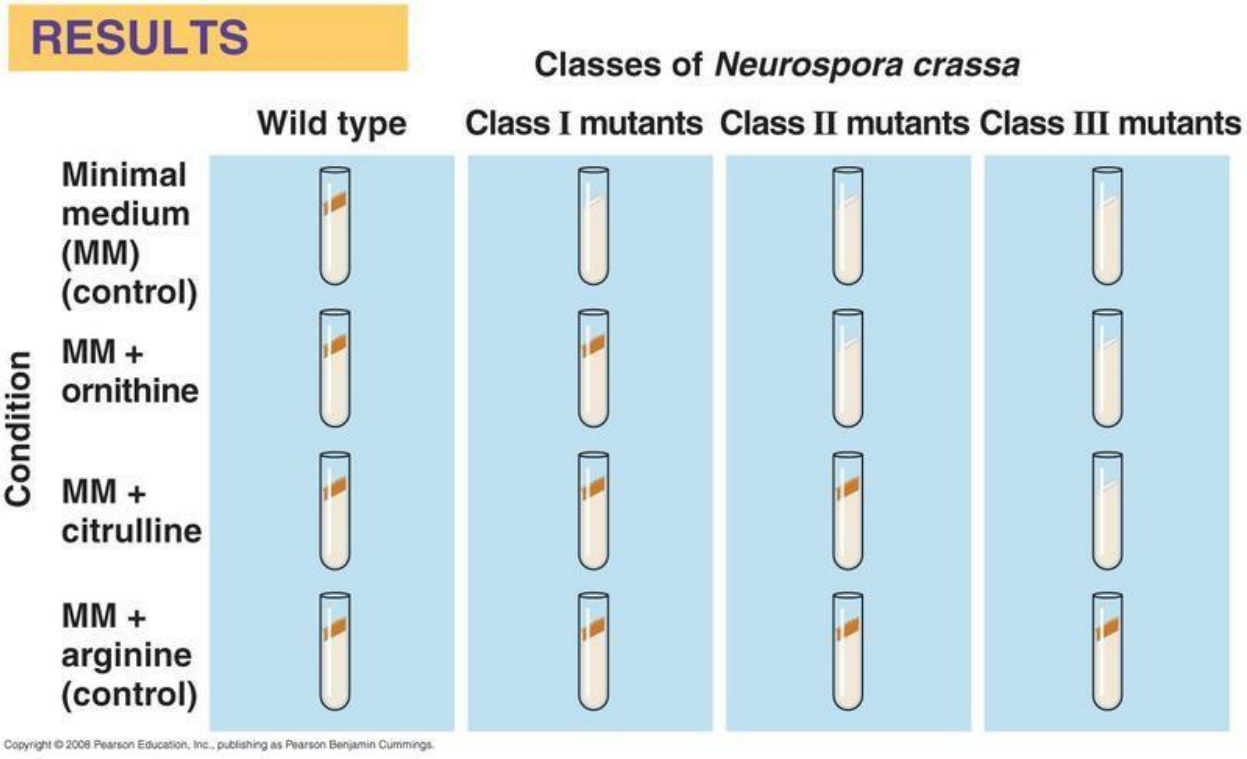
Euchromatin= loosely packed DNA+ proteins, allow for access to genes and active transcription
Heterochromatin= densely packed DNA+proteins, no gene access so inactive transcription ex/ Barr bodies

Chapter 13: Gene Structure and Expression

Do genes specify enzymes?

- **Beadle and Tatum**

- *Neurospora crassa* grown on minimal media
- exposed to x-rays to create auxotrophs (by inducing mutations)
- Arginine (arg) synthesis pathway requires 4 different enzymes
- **one gene-one enzyme hypothesis**



- later restated as **one gene-one polypeptide hypothesis**

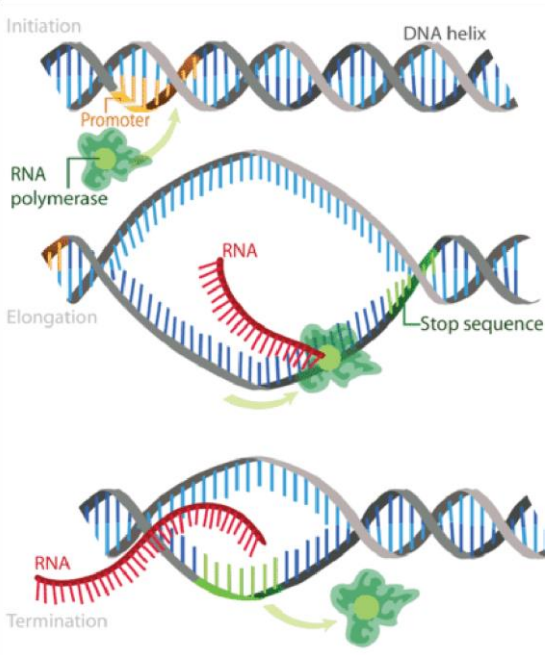
Central Dogma= DNA—>RNA—>protein

Key Features of the Genetic Code

- code for the 20 amino acids
- read in codons (3 bases at a time)
- U replaces T in RNA
- start/initiator codon= **AUG**
- stop/nonsense/termination= **UAA, UAG, UGA**
- **degeneracy** means multiple codons code for same amino acid

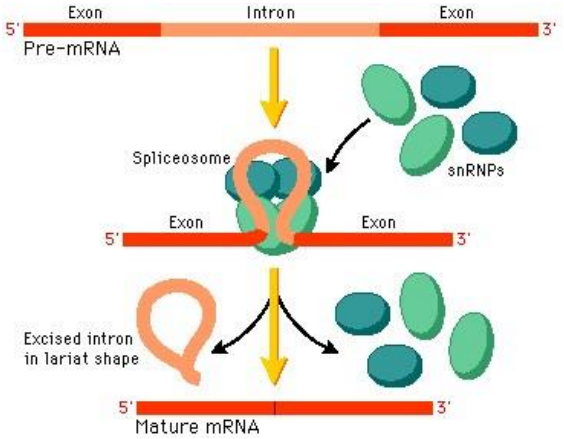
Transcription

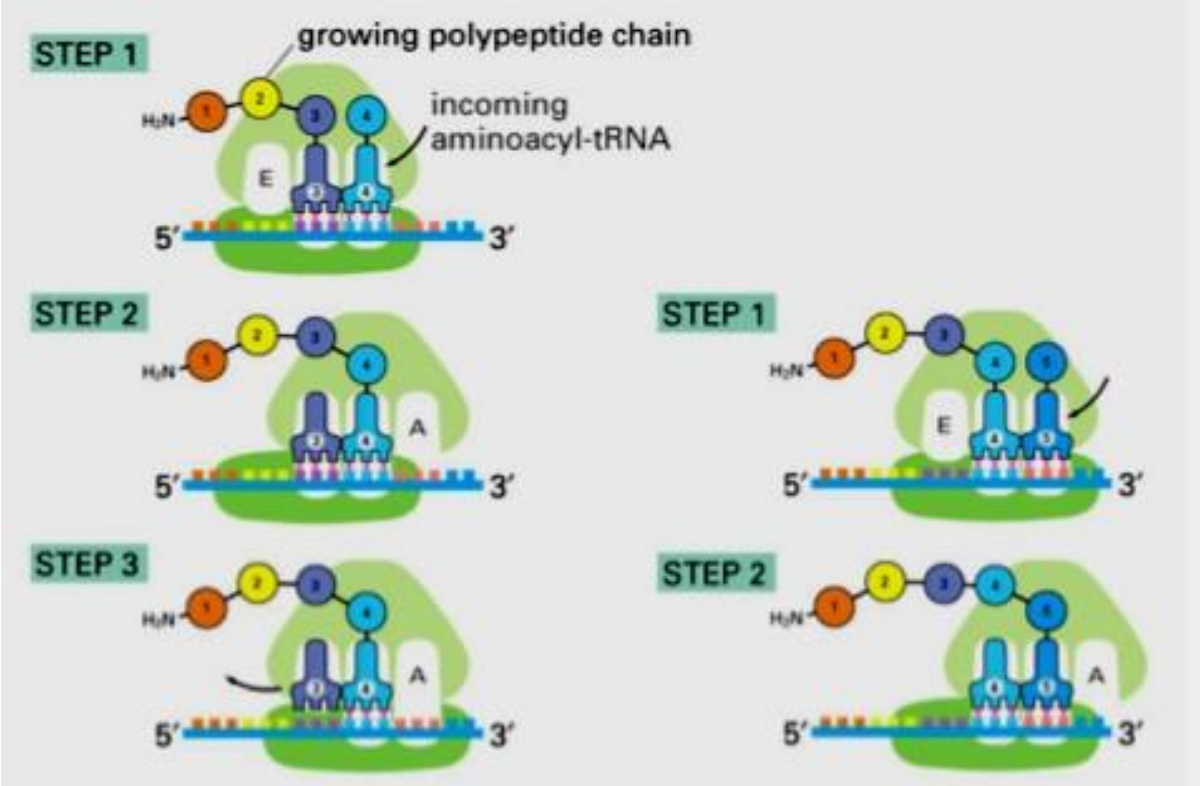
- **single** stranded **mRNA** transcribed from DNA template strand
- **RNA polymerases** used
- U instead of T
- TATA box of promoter region determines where transcription initiates
- **3 steps:**
  - **Initiation**
    - **Elongation**
  - **Termination**



Processing mRNA

- **poly A tai**l added to pre-mRNA on the 3' end (protects from digesting enzymes)
- guanine cap present on 5' (helps ribosome to attach to mRNA during translation)
- mRNA **splicing** (removing introns)
  - **alternative splicing** (getting different proteins from the same mRNA by including only specific parts)→**exon shuffling** (rearrangements that cause new protein strands)

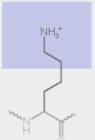
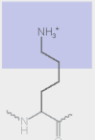
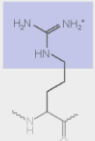
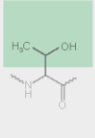




Translation

- assembly of amino acids into polypeptide chains on ribosome
- occurs in the cytoplasm
- **tRNA** brings associated amino acids to ribosome
- **aminoacylation=** adding amino acid to tRNA done by aminoacyl-tRNA synthetase enzyme
- mRNA read in codons in 5' to 3' direction, tRNA possesses the anticodons to the mRNA codons
- ribosome has 3 sites:
  - **A site**= where first aminoacyl-tRNA enters and binds to codon
  - **P site**= peptidyl-tRNA binding site where new amino acid is added to growing polypeptide chain
  - **E site**= exit binding site where tRNA unbound to amino acid leaves the ribosome

Mutation Types:

	No mutation	Point mutations			
		Silent	Nonsense	Missense	
				conservative	non-conservative
DNA level	TTC	TTT	ATC	TCC	TGC
mRNA level	AAG	AAA	UAG	AGG	ACG
protein level	Lys	Lys	STOP	Arg	Thr
					

basic

Chapter 14

Control of Gene Expression

WHY IT MATTERS

- A human egg cell is almost completely inactive metabolically when it is released from the ovary
- It remains quiescent as it travels down a fallopian tube leading from the ovary to the uterus, carried along by movements of cilia lining the walls of the tube
- Subsequent divisions produce specialized cells that differentiate into the distinct types tailored for me myriad specific functions in the body, from muscle cells to cells of the lend of the eye|
- One type of RNA product, mRNA, further directs the synthesis of protein products by translation
- When a gene is turned on- it means a it is transcribed actively

14.1 REGULATION OF GENE EXPRESSION IN PROKARYOTIC CELLS

- Prokaryotic cells tend to be single celled and relatively simple, with generation times measured in minutes

14.1a The operon is a unit of transcription

- Several genes are involved in a typical metabolic process
- For example three genes encode for the proteins for the metabolism of lactose by E.coli
- Francois Jacob and Jacques Monod proposed the Operon Model for the control of the expression of genes for lactose metabolism in E.coli
- **Operon**: is a cluster of prokaryotic genes and the DNA sequences involved in their regulation
- Another regulatory DNA sequence in the operon is the **operator**: a short segment that is a binding sequence for a **regulatory protein**: a gene that is separate from the operon encodes the regulatory protein termed a **repressor**, which, when bound to the DNA, reduces the likelihood that genes will be transcribed. Other operons are controlled by a regulatory protein termed an **activator**: which when bound to the DNA, increases the likelihood that genes will be transcribed.
- **Transcription Unit:** the cluster of genes transcribed into a single mRMA
- A ribosome translated the entire mRNA from one end to the other, sequentially making each protein encoded in the mRNA

14.1b The lac operon for lactose metabolism is transcribed when an inducer inactivates a repressor

- Three adjacent genes, Z-Y-A
- Genes are transcribed starting with **lacZgene;** the promoter for the transcription unit with it's upstream of **lacZ:** which encodes the enzyme beta- galactosadase, which catalyzes the conversion of the disaccharide sugar, lactose, into the monosaccharide sugars, glucose and galactose.
- The lacY gene encodes a permease enzyme that transports lactose actively into the cell, and the lac A gene encodes a transacetylase into the cell, the function of which is more relevant to metabolism of compounds other than lactose
- Allolactose is an inducer for the lac operon- it binds to the Lac repressor, altering its shape so that the repressor can no longer bind to the operator DNA
- Because an inducer molecule increases its expression, the lac operon is called an **inducible operon**

14. 1d Transcription of the trp operon genes for tryptophan biosynthesis is repressed when tryptophan activates a repressor

- Tryptophan is an essential amino acid used in the synthesis of proteins
- If tryptophan is absent from the medium, E.coli must manufacture it
- The five genes in this operon, **trpA to trpE:** encode the enzymes for the steps in the tryptophan biosynthesis pathway
- For the trp operon then, the presence of tryptophan represses the expression of the tryptophan biosynthesis genes; hence this operon is a **repressible operon**
- Tryptophan acts as a **corepressor**: a regulatory molecule that combines with a repressor to activate it and thus shut off die operon

1. In the lac operon, the repressor Is made in an active form. When the inducer (allolactose) is present, it binds to the repressor and inactive it The operon b then transcribed
2. In the trp operon, the repressor is made in an inactive form. When the co-repressor (tryptophan) is present its binds and activates it

Organization of a Eukaryotic Protein-Coding Gene. Promoters with TATA boxes have other sequence elements that play a similar role. RNA polymerase II itself cannot recognize the promoter sequence, instead, proteins called **transcription factors** recognize and bind to the TATA box and then recruit the polymerase. Adjacent to the promoter, is the **promoter proximal region**: which contains regulatory sequences called **promoter proximal elements**. Regulatory proteins that bind to promoter proximal elements may stimulate or inhibit die rate of transcription initiation. More distant from the gene is the **enhancer**. Regulatory proteins binding to| regulatory sequences within an enhancer also stimulate or inhibit the rate of transcription initiation.

Activation of Transcription. To initiate transcription, proteins called **general transcription factors (or basal transcription factors**) bind to the promoter in the area of the TATA boxes. The combination of general transcription factors with RNA polymerase II is the **transcription**

initiation complex. **Activators**: are regulatory proteins that play a role in a positive regulatory system that controls the expression of one or more genes.

14.2c Methylation of DNA can control Gene Transcription

- In DNA **methylation**: enzymes add a methyl group (CH3) to cytosine bases in the DNA. Methylated cytosine in promoter regions can regulate transcription through a process called **silencing**: in which transcription of genes controlled by those promoters is greatly reduced

14.2d Chromatin structure plays an important role in whether a gene is active or inactive

- **Chromatin Remodeling:** the process of changing chromatin structure
- Eukaryote DNA is organized into chromatin by combination with historic proteins
- The negative charge of DNA and the positive charges of the histone proteins naturally attract each other in nucleosomes and contribute to the structure's stability.

14.3 POSTTRANSCRIPTIONAL, TRANSLATIONAL, & POSTTRANSLATIONAL REGULATION

Variations in Pre-mRNA Processing. Can regulate which proteins are made in cells. Can be processed by alternative splicing: produces different mRNA from the same pre-mRNA by removing different combinations of exons along with the introns. It uses regulatory control.

Regulation of Gene Expression by Small RNAs. RNA interference (RNAI) was made by Andrew Fire and studied gene regulation. Two major groups of small regulatory RNAs are involved in RNAi: microRNAs. The miRNA, in a protein complex called the miRNA induced silencing complex (miRISC), binds to the sequences in the 3' UTR of a target mRNAs. The other major type of small regulatory RNAs is the small interfering RNA (siRNA). The siRNA with the protein complex is the siRNA-induced silencing complex (siRISC).

14.4a Cancers are genetic diseases

- **Cancers are genetic diseases:**

1. Cancers can have high incidence in some human families. **Familial (hereditary) cancers:** cancers that run high in families. **Sporadic (nonhereditary) cancers**: cancers that do not appear to be inherited.
2. Descendants of cancer cells are all cancer cells.
3. The incident of cancers increases upon exposure to mutagens, agents that causes mutation sin DNA.
4. Particular chromosomal mutations are associated with specific forms of cancers. Affecting the expression of genes
5. Some viruses can induce cancers as they carry cancer genes

Proto-oncogenes. **Proto-oncogenes (onkos= balk or mass):** are genes in normal cells that encode various kinds of proteins that stimulate cells that encode various kinds of proteins that

stimulate cell division. **Oncogenes**: genes that stimulate the cell to progress to the cancerous state of the unregulated cell cycle.

Tumour Suppressor Genes. These are genes in normal cells encoding proteins that inhibit cell division. The best known tumor suppressor is TP53, so called because its encoded protein, p53 has a molecular weight of 53,000 Daltons, Normal p53 stops cell division by combining with and inhibiting cyclin-dependent protein kinases that trigger the cell's transition from the G_1 phase to the S phase of the cell cycle. TP53 genes are found is at least 50% of all cancers. Cancer rarely develops by alteration of a single proto-oncogene to an oncogene, or inactivation of a single tumor suppressor gene. This is called the **multistep progression of cancer:** successive alterations in several too many genes are gradually accumulated to transform normal cells to cancer cells.

Unit 15

DNA Technologies and Genomics

WHY IT MATTERS

- Darwin took the DNA and isolate it and broke it into fragments and then sequenced them by industrial sequencing robots
- **DNA Technologies:** the techniques used to isolate, purify, analyze and manipulate DNA sequences for such purposes
- **Genetic Engineering:** the use of DNA technologies to alter genes for practical purposes

15.1 DNA CLONING

- **Clone:** is a line of genetically identical cells or individuals derived from a single ancestor
- **DNA cloning:** is a method for producing many copies of a piece of DNA; the piece of DNA is referred to as a gene of interest- a gene to study or manipulate
- **Recombinant DNA:** is DNA from two or more different sources that are joined together

15.1a Bacterial enzymes called restriction endonucleases from the basis of DNA cloning

- The key to DNA cloning is the specific joining of two DNA molecules from different sources, such as a genomic DNA fragment and a bacterial plasmid
- **Restriction Endonuclease (or restriction enzymes)**
- The restriction in the name of the enzymes refers to their normal role inside bacteria, in which the enzymes defend against viral attack by breaking down the DNA molecules of infecting viruses
- The restriction enzymes used in cloning-such as EcoRI-cleave the sugar-phosphate backbones of DNA to make DNA fragments with single-stranded ends.
- These ends are called **sticky ends:** because the short, single-stranded regions can form hydrogen bonds with complementary sticky ends on any other DNA molecules cut with the same enzyme

15.1b Bacterial plasmids illustrate the use of restriction enzymes in cloning

- These bacterial plasmids used for cloning are **cloning vectors:** DNA molecules into which a DNA fragment can be inserted to form a recombinant DNA molecule for cloning

Identifying the Clone Containing the Gene of Interest. DNA hybridization: the gene of interest is identified in the set of clones when it base-pairs with a short, single-stranded complementary

DNA or RNA molecule called a nucleic acid probe. This probe is usually labeled with a radioactive or a nonradioactive tag.

15.1c DNA libraries contain collections of closed DNA fragments

- **Genomic Library:** a collection of clones that contains a copy of every DNA sequence in a genome
- **After using DNA polymerase you make the second strand or die complementary DNA (cDNA)**
- The entire collection of cloned cDNAs made from the mRNA isolated from a cell is a cDNA library

15.1d The polymerase chain reaction amplifies DNA in vitro

- **Polymerase Chain Reaction (PCR):** produces an extremely large number of copies of a specific DNA sequence from a DNA mixture without having to clone the sequence in a host organism
- **The process is called amplification because it increases the amount of DNA to the point where it can be analyzed or manipulated easily.**

1. Primers are made of DNA, not RNA as in natural DNA replication
2. The left primer binds to one strand while the right primer binds to the opposite strand of the original DNA
3. Of all the DNA sequences put into the PCR reaction tube, only the target sequence, the sequence between the primers, is amplified
4. Although the diagram shows DNA being made left to right on the bottom strand and right to left on the top, the DNA polymerase is reading the template 3' to 5' in both cases.
5. A successful outcome of PCR is shown by analyzing a sample of the amplified DNA using **agarose gel electrophoresis**: a technique by which DNA, RNA or protein molecules are separated in a gel subjected to an electric field.

15.2 APPLICATIONS OF DNA TECHNOLOGIES

- The ability to clone DNA revolutionized DNA technology
- Restriction Fragment Length Polymorphisms (RFLPs "riff lips"): restriction enzymegenerated DNA fragments of different length from the same region of the genome
- Usually analyzed by **Southern blot analysis** (named after Edward Southern): in this technique, the genomic DNA is digested with a restriction enzyme, and the DNA fragments are separated using agarose gel electrophoresis.
- **DNA fingerprinting:** is a technique used to distinguish between individuals of the same species using DNA samples

DNA Fingerprinting Principles. Several loci in noncoding regions of the genome are used for analysis. Each locus is an example of a short tandem repeat (STR) sequence: meaning that it has a short sequence of DNA repeated in series with each repeat about 3 to 5bp

DNA Fingerprinting in Testing Paternity and Establishing Ancestry. Also used to share in the paternity testing for kids without lathers. A comparison of DNA for a number of loci can prove almost infallibly whether a child has been fathered or mothered by a given person.

Genetic Engineering Methods for Animals. The genes may be introduced into germ-line cells: which develop into sperm or eggs and thus enable the introduced gene to be passed from generation to generation. Or the gene may be introduced into somatic (body) cells, differentiated cells that are not part of lines producing sperm or eggs, in which case the gene is not transmitted from generation to generation. **Germ line cells:** are embryos are often used as targets for introducing genes, particularly in mammals. A related technique involves introducing desired genes into stem cells: which are cells capable of undergoing many divisions in an unspecialized undifferentiated state, but which can also differentiated into specialized cell types. Adult stem cells: function to replace specialized cells in various tissues and organs.

15.2d DNA technologies and genetic engineering are a subject of public concern

- **Genetically Modified Organisms (GMOs):** is a transgenic organism; the majority of GMOs are crop plants. **Cartagena Protocol on Biosafety:** promotes biosafety by establishing practical rules and procedures for the safe transfer (between countries), handling and use of GMOs.

15.3 GENOME ANALYSIS

- Genes are only part of a genome
- The complete sequencing of approximately 3 billion base pair human genome –the Human Genome Project (HGP) began in 1990

153b Genome sequence determination and annotation involves obtaining and analyzing the sequences of complete genomes

- **Bioinformatics:** which fuses biology with mathematics and computer science, apply sophisticated computer algorithms in this endeavor.
- **Open Reading frames (ORFs):** that is a start codon (ATG at the DNA level) separated by a multiple of three nucleotides from one of the stop codons (TAG, TAA, or TGA at the DNA level)
- **Most of these genes make up to 25-50% of the total genomic DNA in different eukaryotic species, have no determined function at this time**
- **All the protein coding sequences occupy less than 2% of the human genome**
- **Introns:** the noncoding spacers in genes occupy another 24% of the genome

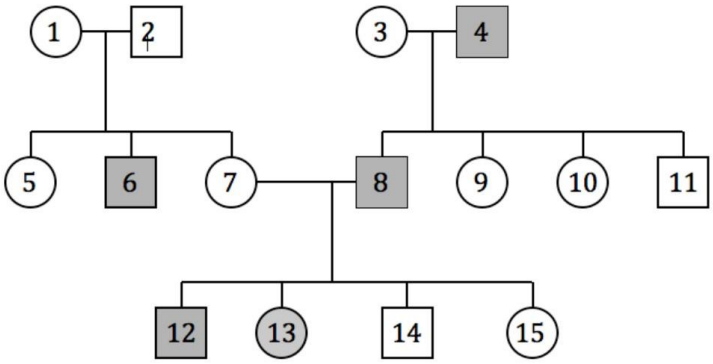
15.3e Studying the array of expressed proteins is the next level of study of biological systems

- Proteome: refers to the complete set of proteins that can be expressed by an organism's genome
- Cellular Proteome: is a subset of those proteins, the collection of proteins found in a particular cell type under a set of environmental conditions
- Proteomics: is the study of the proteome

- **Proteomics follow two major goals:** 1) to determine the number and structure proteome and 2) to determine the functional interactions between the proteins
- **Protein Micoarrays (protein chips):** which are similar in concept to DNA microarrays

QUESTIONS :

1. Below is a pedigree for colorblindness. Those that are affected by colorblindness are shaded in grey. What is best possible choice for the genotypes of 1 and 2 based on their offspring.



   a) 1: ee 2: EE
   b) 1: EE 2:Ee
   c) 1: Ee 2:Ee
   d) 1: EE 2:EE

2. Based on the pedigree above, if Parent 3 and Parent 4 were to have another child, what are the chances that their child is affected by colorblindness a) 25%
   b) 50%
   c) 75%
   d) 95%

3. Which of the following not paired right?
   a) Trisomy 21 – Extra chromosome
   b) Cri-du-chat- deletion
   c) Turner Syndrome – One X chromosome
   d) Klinefelter Syndrome- Feminine Male
   e) None of the above

4. Albinism is the mutation of the TYR gene. Such mutation on this gene results the altered production of melanin. Melanin is used in skin, hair ,eye, etc. Therefore, an albino will result in the lack of pigment in their eyes, hair, skin, and anywhere that uses melanin. What is the term to describe this phenomenon.
   a) Polygonic
   b) Polygamy
   c) Epistasis

d) Codominance
e) Pleiotropy

5. A cluster of prokaryotic genes and the DNA sequences involved in their regulation a. Operon
   b. Chromosome
   c. Regulator
   d. Genes

6. Other operons are controlled by a regulatory protein termed a_____.
   a. Repressor
   b. Regulatory protein
   c. Activator
   d. Inhibitor

7. The Souther Blot Analysis was discovered by what individual
   a. Edward West
   b. Mendel
   c. Edward Southern
   d. Edward South

8. The best description of Genetically Modified Organisms (GMOs) is:
   a. a transgenic organism
   b. a mutation in an organism
   c. found in plants
   d. can be expressed via other genes found on an organism expressed as mutants
9. Genes that stimulate the cell to progress to the cancerous state of the unregulated cell cycle best describes what?
   a. Proto-oncogenes
   b. Oncogenes
   c. Beta genes
   d. Activator genes

10. Single stranded mRNA found within the transcription processes uses DNA polymerase to transcribe it? True or False
    a. True
    b. False

11. The poly A-tail is added to which end of the newly synthesized RNA strand? a. 5’ end
    b. OH group on the 5’ end
    c. OH group on the 4^{th} carbon

d. 3’ end

12. UAG, UAA, UGA are all examples of?
    a. Non-sense codons
    b. Stop codons
    c. Halt codons
    d. Bye-bye-bye
13. DNA from two or more different sources that are joined together
    a. Recombinated
    b. Recombinated DNA
    c. Recombinant DNA
    d. Hello From The Other side DNA

14. Telomeres are best described as?
    a. Highly repetitive, noncoding DNA near ends of chromosomes
    b. DNA genes found at the end of chromosomes
    c. Junk DNA that codes for absolutely nothing, whatsoever→ useless
    d. Junk or garbage that means nothing to us

15. Cystic fibrosis albinism & sickle cell are considered to be?
    a. Homozygous dominant
    b. Autosomal recessive
    c. Both A & B
    d. X-linked

ANSWERS:

1. C
2. B
3. E
4. E
5. A
6. C
7. C
8. A
9. B
10. B
11. D
12. B
13. C
14. A
15. C

GOOD LUCK WITH YOUR FINAL EXAM!!

If you have any questions please do not hesitate to contact your Cell Biology SOS tutors (**Anthony Pisciuneri**) at: pisciunl@uwindsor.ca, (**Olivia King**) at: king11d@uwindsor.ca, and (**Theresa Ho**) at: ho11i@uwindsor.ca