This lecture will discuss the following topics:
- Definition of Embryology
- Significance of Embryology
- Old and New Frontiers
- Introduction to Molecular Regulation and Signaling
- Descriptive terms in Embryology
- Mitosis & Meiosis (quick review)

**Definition of Embryology**

Literally, *embryology* means the study of embryos; however, the term generally refers to prenatal development of embryos and fetuses.

**Developmental anatomy**

is the field of embryology concerned with the changes that cells, tissues, organs, and the body as a whole undergo from a germ cell of each parent to the resulting adult. Prenatal development is more rapid than postnatal development and results in more striking changes.

**SIGNIFICANCE OF EMBRYOLOGY**

- Bridges the gap between prenatal development and obstetrics, perinatal medicine, pediatrics, and clinical anatomy.
- Develops knowledge concerning the beginnings of human life and the changes occurring during prenatal development.
- Is of practical value in helping to understand the causes of variations in human structure.
- Illuminates gross anatomy and explains how normal and abnormal relations develop.

**HISTORY OF EMBRYOLOGY**

Scientific approaches to study embryology have progressed over hundreds of years.

- Anatomical approaches
- Experimental embryology
- Grafting experiments
- Molecular approaches

**Anatomical approaches** dominated early investigations

**Observations** became more sophisticated with advances in optical equipment and dissection techniques.

**Comparative and evolutionary studies**

- comparisons among species to understand the progression of developmental phenomena.
- investigated offspring with birth defects, and these were compared to organisms with normal developmental patterns.

**Experimental embryology**

trace cells during development to determine their cell lineages

- Observations
- vital dyes
- Radioactive labels and autoradiographic techniques
- Genetic markers

**Grafting experiments**
provided the first insights into signaling between tissues e.g. grafting the primitive node from its normal position on the body axis to another and showing that this structure could induce a second body axis.

**Molecular approaches**

Numerous means of identifying cells using
- reporter genes,
- fluorescent probes, and
- other marking techniques have improved our ability to map cell fates.
- other techniques were used to alter gene expression, such as knockout, knock-in, and antisense technologies has created new ways to produce abnormal development and allowed the study of a single gene’s function in specific tissues.

**Molecular biology**

Molecular biology has opened the doors to new ways to study embryology and to enhance our understanding of normal and abnormal development.

Each nucleosome consists of an octamer of histone proteins and approximately 140 base pairs of DNA.

Nucleosomes are joined into clusters by linker DNA and other histone proteins.

**Chromatin**

**Heterochromatin:**
In inactive state, chromatin appears as beads of nucleosomes on a string of DNA. Nucleosomes keep the DNA tightly coiled, such that it cannot be transcribed.

**Euchromatin:**
It is the uncoiled state. DNA must be uncoiled from the beads for transcription to occur.

**Induction and Organ Formation**

Organs are formed by interactions between cells and tissues. Most often, one group of cells or tissues causes another set of cells or tissues to change their fate, a process called induction.

In each such interaction, one cell type or tissue is the inducer that produces a signal, and one is the responder to that signal.

**Competence:** IS the capacity to respond to such a signal. It requires activation of the responding tissue by a competence factor.

**Induction- Epithelial mesenchymal interactions**

Epithelial cells are joined together in tubes or sheets, whereas mesenchymal cells are fibroblastic in appearance and dispersed in extracellular matrices.

Although an initial signal by the inducer to the responder initiates the inductive event, cross talk between the two tissues or cell types is essential for differentiation to continue (arrows in this figure ).

**Examples of epithelial -mesenchymal interactions include the following:**

- gut endoderm and surrounding mesenchyme to produce gut-derived organs, including the liver and pancreas;
- limb mesenchyme with overlying ectoderm (epithelium) to produce limb outgrowth and differentiation; and
- endoderm of the ureteric bud and mesenchyme from the metanephric blastema to produce nephrons in the kidney.
Inductive interactions can also occur between two epithelial tissues, such as induction of the lens by epithelium of the optic cup.

**Cell Signaling**

Cell-to-cell signaling is essential for induction, conference of competency to respond, cross-talk between inducing and responding cells.

1. **Paracrine interactions**, whereby proteins synthesized by one cell diffuse over short distances to interact with other cells. The diffusable proteins responsible for paracrine signaling are called paracrine factors or growth and differentiation factors (GDFs).

   Paracrine factors act by: signal transduction pathways either by activating a pathway directly or by blocking the activity of an inhibitor of a pathway (inhibiting an inhibitor),

2. **Juxtacrine interactions**, which do not involve diffusable proteins. Juxtacrine factors may include products of the extracellular matrix, ligands bound to a cell’s surface, and direct cell-to-cell communications.

**Mitosis**

Is the process whereby one cell divides giving rise to two daughter cells that are genetically identical to the parent cell. Each daughter cell receives the complete complement of 46 chromosomes.

Mitosis occurs in most somatic cells.

Interphase (replication phase): Before a cell enters mitosis, each chromosome replicates its deoxyribonucleic acid (DNA).

The chromosomes are extremely long, they are spread diffusely through the nucleus, and they cannot be recognized with the light microscope.

**Meiosis**

- Is the cell division that takes place in the germ cells to generate male and female gametes, sperm and egg cells, respectively.
- The number of chromosomes is halved to the haploid number and when fertilization takes place the diploid number is restored.
- Meiosis requires two cell divisions, meiosis I and meiosis II, to reduce the number of chromosomes to the haploid number of 23.
- Meiosis and meiosis resemble each other in many respects differing chiefly in the behavior of the chromosomes during early stages of cell divisions.

**Characteristic events during meiosis I**

**Synapsis**: homologous chromosomes align themselves in pairs (the pairing is exact and point for point except for the XY combination).

**Crossover**: interchange of chromatid segments between paired homologous chromosomes.

Points of interchange are temporarily united and form an X-line structure (a chiasma).

Approximately 1 or 2 crossovers per chromosome with each meiotic I division and most frequent between genes that are far apart on a chromosome.

At the end of meiosis I, two separate cells each with haploid (n) number of chromosomes.

Meiosis II similar to mitosis; the cross over and non cross chromatids separate randomly.
At the end of meiosis II, 4 daughter cells chromosome number remaining haploid, DNA is reduced to the haploid amount.

**Results of meiotic divisions**
1. Genetic variability is enhanced through Cross over which creates new chromosomes Random distribution of homologous chromosomes to daughter cells
2. each germ cell contains a haploid number of chromosomes so that at fertilization the diploid number of 46 is restored

**Clinical correlations**
1. chromosomal abnormalities
   A. numerical (nondisjunction, translocation)
   B. structural
2. gene mutations

**Meiotic nondisjunction**
During meiosis, homologous chromosomes normally pair and then separate. If separation fails (nondisjunction)

**Non disjunction may involve**
1. autosomes (trisomy 21, trisomy 13, trisomy 18)
2. sex chromosomes
   - Klinefelter syndrome (XXY) 47 chromosomes, XXXY 48 chromosomes
   - Turner syndrome (XO)

**Mitotic nondisjunction**
Nondisjunction may occur during mitosis in an embryonic cell during earliest cell divisions. Such conditions produce mosaicism. Some cells having an abnormal chromosome number and others being normal

**Translocation**
Sometimes, chromosomes break, and pieces of one chromosome attach to another
Balanced translocation: breakage and reunion occur between two chromosomes but no genetic material is lost and individuals are normal
Unbalanced translocation: part of one chromosome is lost and an altered phenotype is produced
Translocations are particularly common between chromosomes 13, 14, 15, 21, and 22 because they cluster during meiosis.

**Structural abnormalities**
Results from chromosomal breakage

**Partial deletion of a chromosome** e.g. partial deletion of the short arm of chromosome 5 (Cri-du-chat syndrome)

**Microdeletions**: spanning only a few contiguous genes may result in microdeletion syndrome or contiguous gene syndrome. E.g. microdeletion on the long arm of chromosome 15

**Gene Mutations**
8% of human malformations
A change in the structure or function of a single gene (single gene mutation)
* Dominant: Affection of one gene of an allelic pair
** Recessive: both allelic gene pairs must be mutant
Gene mutation cause congenital abnormalities, inborn errors of metabolism e.g. phenylketone uria, galactosemia with various degrees of mental retardation.
Thank you

Next lecture: Gametogenesis