ASSIGNMENT 2

INNOVATIVE TECHNOLOGY & BIO-SCIENCE

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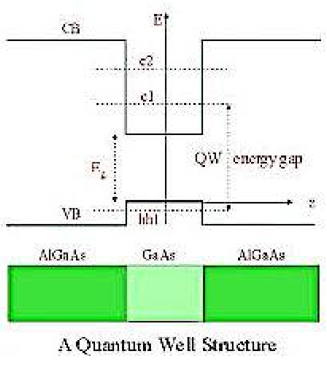
1. Explain quantum well, quantum wire and quantum dot nano-materials with the help of examples.

1. Quantum wells

Quantum wells are **heterostructures** in which a thin layer (sufficiently thin such that quantum interference effects begin to appear prominently in the motion of the electrons) of one semiconductor is **sandwiched** between two layers of a different semiconductor material, thereby forming a ***heterojunction***. Materials are chosen so that electrons available for conduction in the middle layer have lower energy than those in the outer layers, creating an energy dip (or well) that confines the electrons in the middle layer. This is possible since differences in the energy gap permit **spatial confinement of electrons and holes** injected into the middle layer. The electron wavefunctions in such a well consist of a **series of standing waves.**



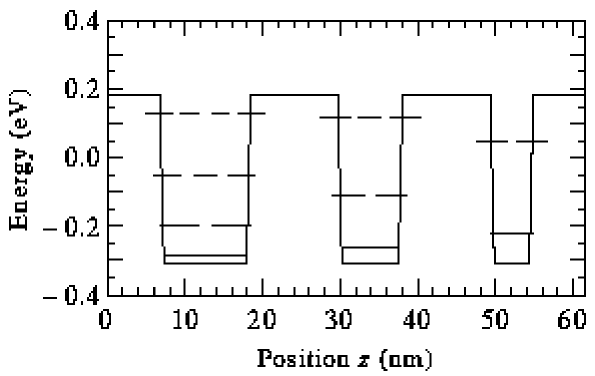


Fig : Energy-band profile of a structure containing three quantum wells, showing the confined states in each well. The structure consists of GaAs wells of thickness 11, 8, and 5 nm in $Al_{0.4}Ga_{0.6}As$ barrier layers. The gaps in the lines indicating the confined state energies show the locations of nodes of the corresponding wavefunctions.

Quantum well devices are often **fabricated using molecular beam epitaxy**. The most intensively studied and thoroughly documented semiconductor materials for heterostructures are **GaAs and $Al_xGa_{1-x}As$**, but several other III-V (InGaAs, GaN, and AlN) and IV-VI (PbS, PbTe, and GeTe) systems are also used.

2. Quantum Wire

A **quantum wire** is an electrically conducting wire in which quantum effects influence the transport properties. Usually such effects appear in the dimension of nanometers, so they are also referred to as **nanowires**. In these narrow structures electron transport is possible only in a very few transverse modes (with energies less than the Fermi energy).

Quantum wires can be used as electron **waveguides**. Semiconductor quantum wires have been used to make switchable high-speed lasers.

Quantum wires can be **fabricated** by an appropriate arrangement of metallic gates on top of a 2D electron gas. The electron gas beneath a negative gate voltage is depleted, **slicing the quantum well into two**.

Carbon nanotube is an example of quantum wire. I have explained it in the carbonaceous nanomaterials section in my previous ITBS assignment in good detail.

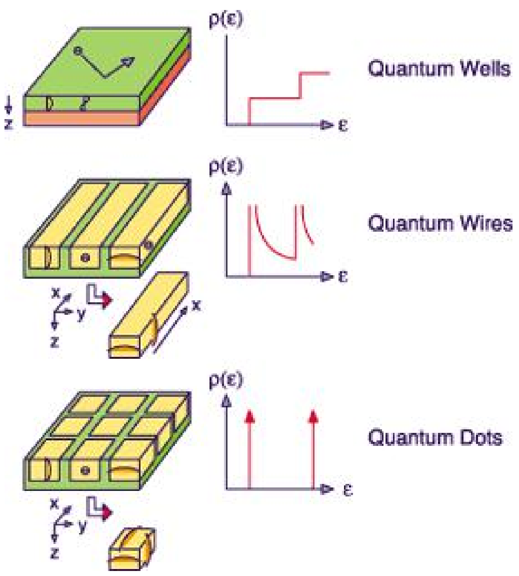


Fig : Energy position curves of Quantum well, wire and dot.

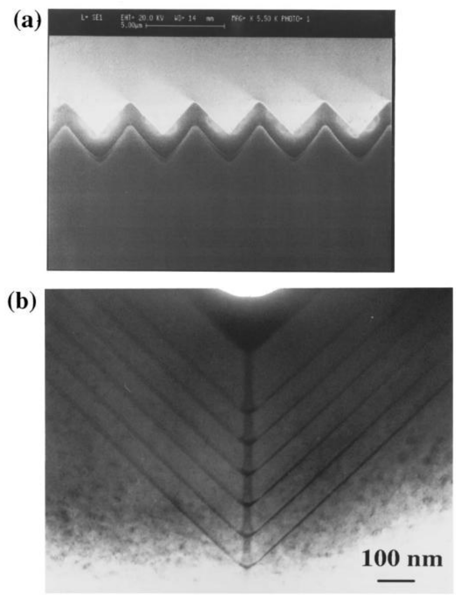


Fig : Scanning Electron microscope images Of quantum wires.

3. Quantum Dot

Quantum dots (**QDs**) are tiny semiconductor particles a few nanometres in size, having optical and electronic properties that differ from larger particles due to quantum mechanics. nanoscale semiconductor materials tightly confine either electrons or electron holes. Quantum dots are sometimes referred to as **artificial atoms**, emphasizing their singularity, having bound, discrete electronic states, like naturally occurring atoms or molecules. It was shown that the electronic wave functions in quantum dots resembles the ones in real atoms. By coupling two or more such quantum dots an **artificial molecule** can be made, exhibiting hybridization even in room temperature. Quantum dots have properties intermediate between bulk semiconductors and discrete atoms or molecules. Their optoelectronic properties change as a function of both size and shape. Larger QDs of 5–6 nm diameter emit longer wavelengths, with colors such as orange or red. Smaller QDs (2–3 nm) emit shorter wavelengths, yielding colors like blue and green. However, the specific colors vary depending on the exact composition of the QD. Potential applications of quantum dots include single-electron transistors, solar cells, LEDs, lasers, single-photon sources, quantum computing, and medical imaging.

2. Differentiate between eukaryotic cell and prokaryotic cell.

Feature	Prokaryotic	Eukaryotic
Cell Membrane	Complex cell membrane + cell wall+ glycocalyx(slime/capsule)	Cell membrane(animals) Cell membrane + cell wall(plants) Microfilaments.
Nuclear membrane	Naked genetic material	Nuclear membrane enclosing genetic material
Genetic Material	Genomic DNA(single chromosome) + some bacteria contain plasmid (EXTRA circular DNA containing non essential genes, responsible for antibiotic action). DNA communicates directly with cytoplasm. Supercoiled DNA	Genomic DNA(multiple chromosomes) DNA communicates indirectly via Nuclear pores and ER. Histone coiled DNA
Organalles	None except non membranous ribosomes.	Various specialised membrane bound organelles like mitochondria, endoplasmic reticulum etc.
Spl.	Characteristic Mesosomes : extensions of plasma membrane	None
Storage	Inclusion Bodies	Membranous Vacuoles
Size	Smaller in size Bacteria 1-2 micrometers PPLO 0.3 Mycoplasma 0.1 Blue green Algae	Larger in size RBC 7 micrometers WBC 10-20
Reproduction	Gen. Binary fission, fast	Mitosis, slow
Shape	Extensions of cell wall Flagella, fimbrae, pilli. Bacillus (rod like) Coccus (spherical)	RBC (round, biconcave) WBC(Amoeboid) Nerve cell(branched, long) Tracheid (elongated) Mesophyll (round, Oval)

	Vibrio (comma) Spirillum(spiral)	

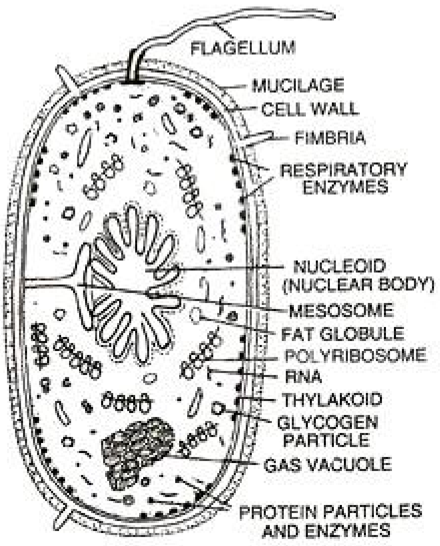


Fig. 8.6. Ultrastructure of a bacterial cell.

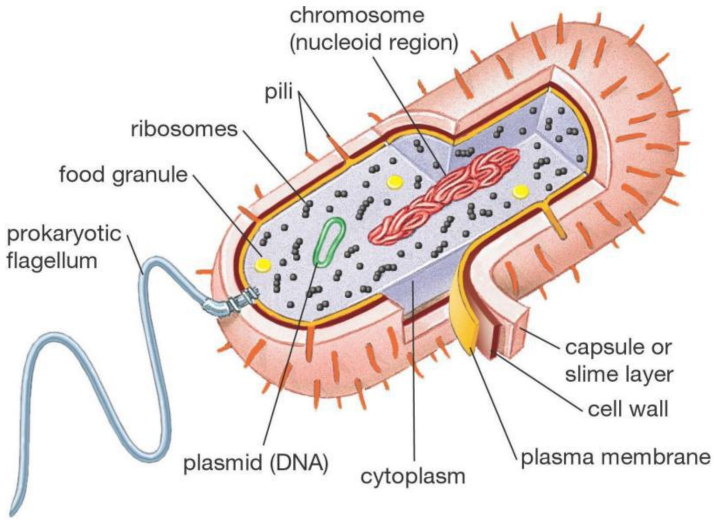
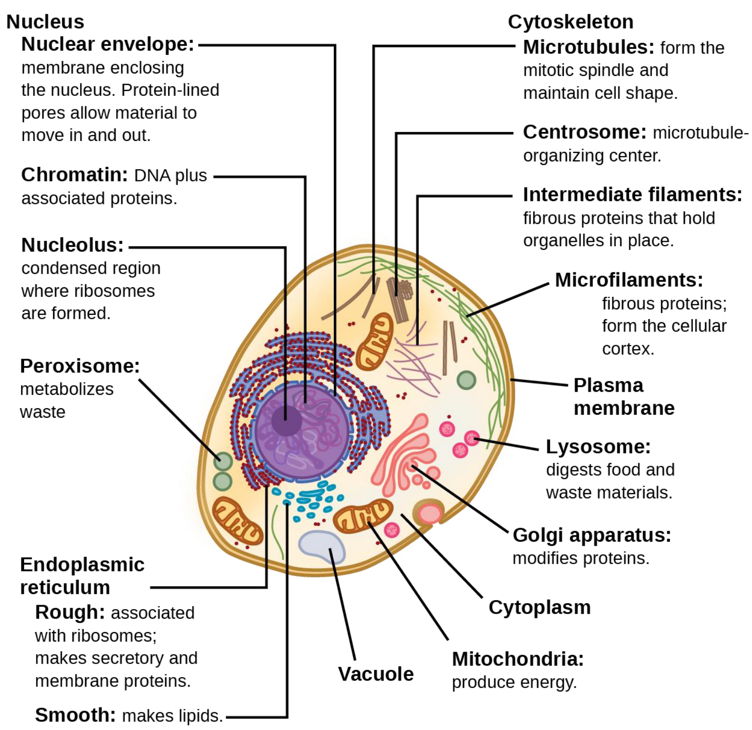


Fig : Typical Bacterial Cell (prokaryotic)



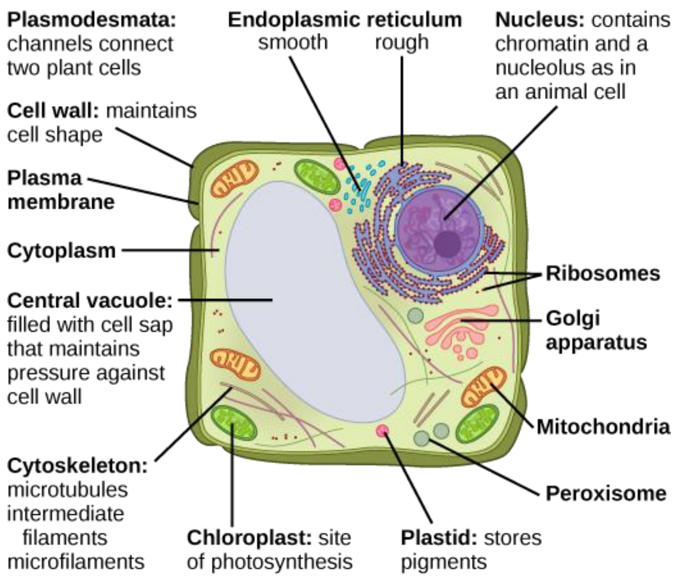


Fig : Typical Plant Cell (Eukaryotic)

Fig : Typical Animal Cell (Eukaryotic)

3.Describe the different stages of meiosis I.

3.1 Prophase I

Prophase of the first meiotic division is typically longer and more complex when compared to prophase of mitosis. It has been further subdivided into the following five phases based on chromosomal behaviour, i.e., **Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis**.

3.1.1 Leptotene

During this stage the chromosomes become gradually visible under the light microscope. The compaction of chromosomes continues throughout leptotene.

3.1.2 Zygotene

During this stage chromosomes start pairing together and this process of association is called **synapsis**. Such paired chromosomes are called homologous chromosomes. Electron micrographs of this stage indicate that chromosome synapsis is accompanied by the formation of complex structure called **synaptonemal complex.** The complex formed by a pair of synapsed homologous chromosomes is called a **bivalent** or a tetrad. However, these are more clearly visible at the next stage. The first two stages of prophase I are relatively short-lived compared to the next stage.

3.1.3 Pachytene

During this stage bivalent chromosomes now clearly appears as tetrads. This stage is characterised by the appearance of recombination nodules, the sites at which crossing over occurs between non-sister chromatids of the homologous chromosomes. Crossing over is the exchange of genetic material between two homologous chromosomes. Crossing over is also an enzyme-mediated process and the enzyme involved is called recombinase. Crossing over leads to recombination of genetic material on the two chromosomes. Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over.

3.1.4Diplotene

The beginning of diplotene is recognised by the dissolution of the synaptonemal complex and the tendency of the recombined homologous chromosomes of the bivalents to separate from each other except at the sites of crossovers. These X-shaped structures, are called **chiasmata.** In oocytes of some vertebrates, diplotene can last for months or years.

3.1.5 Dikinesis

This is marked by terminalisation of chiasmata. During this phase the chromosomes are fully condensed and the meiotic spindle is assembled to prepare the homologous chromosomes for separation. By the end of diakinesis, the nucleolus disappears and the nuclear envelope also breaks down. Diakinesis represents transition to metaphase.

Metaphase I

The bivalent chromosomes align on the equatorial plate

Anaphase I

The homologous chromosomes separate, while sister chromatids remain associated at their centromeres.

Telophase I

The nuclear membrane and nucleolus reappear, cytokinesis follows and this is called as diad of cells (Figure 10.3). Although in many cases the chromosomes do undergo some dispersion, they do not reach the extremely extended state of the interphase nucleus. The stage between the two meiotic divisions is called interkinesis and is generally short lived. Interkinesis is followed by prophase II, a much simpler prophase than prophase I. The microtubules from the opposite poles of the spindle attach to the pair of homologous chromosomes.

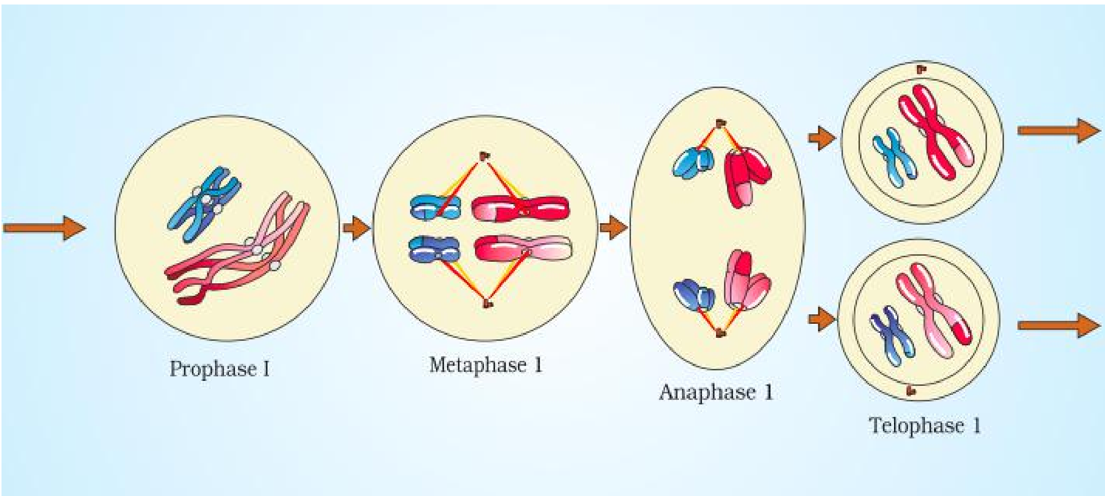
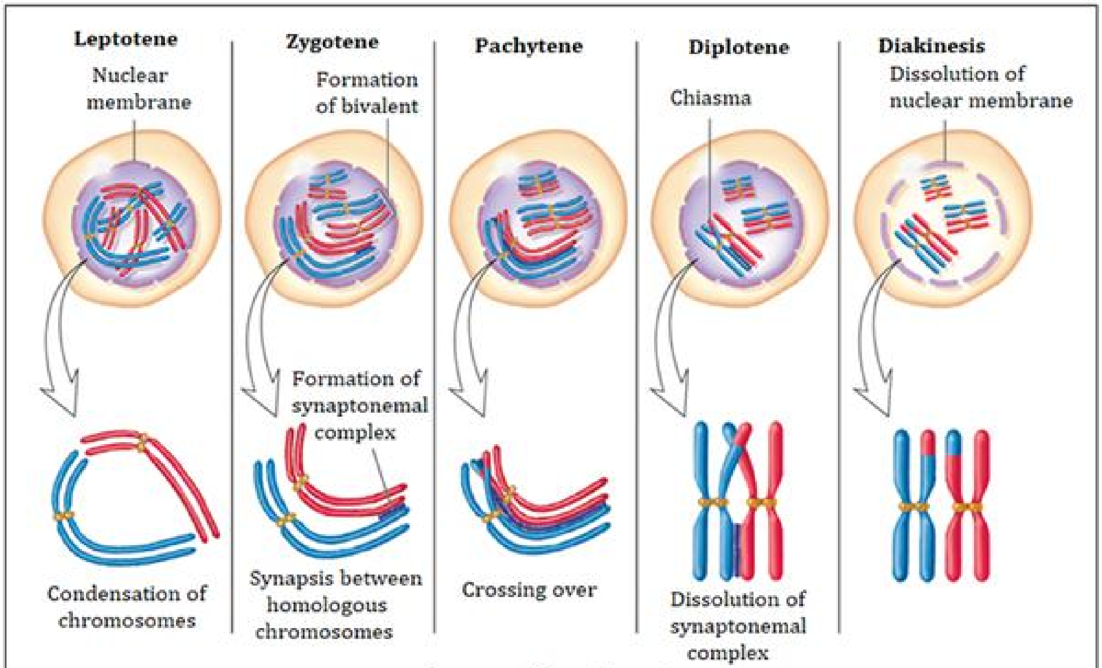


Fig : MEIOSIS I STAGES



Stages of Prophase I

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Sources of study :

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ISBN 978-87-7681-418-2

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