NUCLEUS

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Unit - II

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General Organizational Features:

Nucleus is the largest and visually most prominent cell organelle of eukaryotic cells that can be observed during interphase and the early stages of cell division. It is the repository of the genetic information of the cell as well as the cell's control centre. Nuclear matrix is called the nucleoplasm or karyolymph. Chromatin can be seen as a dense fibrous material within the nucleoplasm of suitably stained nucleus. Chromatin is dispersed in the interphase nucleus and condenses into chromosomes during cell division.

Shape, Size and Number:

(i) Shape of the nucleus is sometimes related to that of the cell, but it may be completely irregular.

- In spheroidal, cuboidal or polyhedral cells, nucleus is usually spheroid.
- In cylindrical, prismatic or fusiform cells, it tends to be ellipsoid.

(ii) Each somatic nucleus has a specific size that depends partly on its DNA content and mainly on its protein content.

- Size of the nucleus is also related to the functional activity of non-dividing cells in permanent tissues and organs.
- Average diameter:
  - About 2 µm in yeast cells
  - About 8 µm in higher plant cells

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(iii) Every cell has at least one nucleus. But many eukaryotic cells may be multi-nucleated

— Skeletal and cardiac muscle cells, osteoclasts, tapetal cells in plants, slime molds and Plasmodium have multinucleate condition as a regular feature.

— Binucleate cells are most commonly found in cancer cells.

Interphase Nucleus:

(a) Nuclear Membrane

(i) Nuclear membrane (nuclear envelope) is a special perinuclear cisterna of the cell's endomembrane system.

(ii) Visible under electron microscope; light microscope provides little information about the nuclear envelope.

(iii) Nuclear envelope comprises two unit membranes, each of 8 nm thickness, and separated by a perinuclear space of about 15 nm width.

(iv) Nuclear membrane has perforations (= Nuclear pores) of 30-100 nm diameter.

— These nuclear pores tend to be octagonal in shape.

— Inner and outer membranes of the nuclear envelope fuse together at the nuclear pores.

(v) Each membrane of the nuclear envelope has a typical lipoproteinous composition characteristic of biomembranes.

(b) Nuclear Pores

(i) Diameter : 30-100 nm

(ii) At their nuclear side the pores are generally aligned with channels of nucleoplasm situated between more condensed

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lumps of chromatin, which attach to a fibrous lamina of proteins 50 to 80 nm thick that is attached to the inner membrane, but not to the nuclear pores.

(iii) In mammals, nuclear pores account for 5-15% of the surface area of the nuclear membrane.

— In certain plant cells, and protozoa pores may occupy 20-35% of the surface area of the nuclear membrane.

(iv) Nuclear pores, however, are not wide-open channels, and they are occluded by an electron dense material.

(v) The pores are enclosed by circular structures called *annuli*.

(vi) The pores and annuli are together designated as the *pore complex*.

(vii) *Pore complexes* have an eight-fold symmetry.

— They consist of two "*rings*" (or *annuli*) with an inside diameter of 80 nm, *large particles* which form a central plug, and eight radial "*spokes*" that extend from the plug to the rings.

— Sometimes particles may be seen attached to the cytoplasmic side of the ring that are also octagonally arranged. These particles might be inactive ribosomes attached to the periphery of the pore complex.

(viii) Number of pores in the nuclear membrane seems to correlate with the *transcriptional activity* of the cell.

In *Xenopus laevis* (a frog), oocytes (very active in transcription) have 60 pores/μm^2 (and up to 30 million pore complexes per nucleus) while mature erythrocytes (inactive in transcription) have only 3 pores/μm^2 (150-300 pores per nucleus).

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(ix) Two proteins have been found associated with the annulus of the nuclear pores.

- One is an <u>integral membrane protein</u> (a glycoprotein) which may anchor the annuli to the lipid bilayers.

- The second 63,000 dalton protein is located on the cytoplasmic side of the electron-dense material which occludes the nuclear pores.

(x) Isolation of nuclear pore proteins has been difficult.

(xi) <u>Annulate lamellae</u> may be found in the cytoplasm which are usually associated with rapidly proliferating cells and can be considered as a storage form of pre-assembled pore complexes.

(xii) Nuclear pore complexes remain attached to each other by a mesh-like <u>fibrous lamina</u> containing specialized proteins called <u>lamins</u>, which may play a crucial role in the assembly of interphase nuclei.

(xiii) Nuclear pores are a selective diffusion barrier between the nucleus and cytoplasm.

(c) <u>Nucleolus</u>

(i) Cells contain in their nucleus one or more prominent bodies called <u>nucleoli</u>.

(ii) Size of the nucleolus has a relationship with the synthetic activity of the cell.

(iii) Nucleoli disperse during cell division (late prophase) and are reformed at telophase at specific chromosomal locations called '<u>nucleolar organizers</u>'.

- Nucleolar organizers contains the gene for 18S, 5.8S and 28S rRNA.

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(iv) Nucleolus contains high concentrations of RNA.

(v) Electron microscopy of the nucleolus shows a <u>fibrillar</u> and a <u>granular zone</u>.

- Fibrillar zone consists of fine fibres of 5-10 nm diameter and is located in a more central region of the nucleolus.

This suggests a relationship: Nucleolar DNA ⟶ Fibrillar zone ⟶ Granular zone.

(vi) Fibrillar area contains rRNA genes while the granular area represents ribosome precursor particles at various stages of assembly and processing.

- Once the ribosomal subunits are mature, they are released from the nucleolus and exit into the cytoplasm through nuclear pores.

(vii) During mitosis nucleoli undergo cyclic changes. Nucleoli are formed around the DNA loop that extends from the nucleolar organizer.

(viii) There may be several nucleoli per cell, but frequently they tend to fuse into one or a few nucleoli at this stage.

(ix) Nucleolar organizer region is one of the last to undergo condensation, thus producing a <u>secondary constriction</u> on the chromosome.

- The fibrillar and granular components are gradually dispersed into the nucleoplasm.

(x) After the cell divides, during telophase, the nucleolar organizer DNA uncoils and the nucleolus is reassembled.

(xi) RNA polymerase I remains bound to the nucleolar organizer during mitosis.

(xii) Ribosomal RNAs undergo complex processing in the nucleolus. All these

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processing steps take place on RNA-protein complexes, and not on the naked RNA.

(xiii) Nucleolus is the cellular site at which all the ribosomal components are assembled together into ribosomal sub-units.

(d) Chromatin

(i) Cell nuclei contain a constant amount of DNA complexed with proteins in a structure called chromatin.

(ii) Each species has a characteristic content of DNA, which is constant in all the individuals of a particular species. This is called c-value.

(iii) Chromatin appears as a viscous, gelatinous substance which contains DNA, RNA, basic proteins called histones and more acidic non-histone proteins.

(iv) DNA and histone are always present in a fixed ratio of about 1:1.

- Non-histone proteins are very heterogeneous; they include RNA and DNA polymerases, and putative regulatory proteins.

(v) Histones are small proteins which are basic due to high contents of the basic amino acids arginine and lysine.

- They bind tightly to DNA, as the latter is acidic.

- The four main histones, H_2A, H_2B, H_3 and H_4 are very similar in different species.

- H_1 is not conserved between species and has tissue-specific forms. It is present only one per 200 base pairs of DNA. It is rather loosely associated with chromatin.

(vi) Nucleosome is a repeating unit

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of chromatin which comprises an octamer of four histones (H_2A, H_2B, H_3 and H_4) complexed with 200 base pairs of DNA.

(vii) Bacterial chromosomes are not complexed with histones.

(viii) At the time of cell division, chromatin becomes condensed into the chromosomes.

— Chromosomal shape is determined by the position of the centromere.

— Karyotype represents the whole group of characteristics of a particular chromosomal set, i.e., the number of chromosomes, relative size, position of centromere, length of arms, secondary constrictions and satellites.

(ix) Some regions of the chromosome remain condensed during interphase and are stained differentially by basic dyes. They are late replicating and genetically inert, and are called heterochromatin.

— Rest of the chromosome is in a non-condensed state and genetically active. This is called euchromatin.

(Fig. below)

—x—

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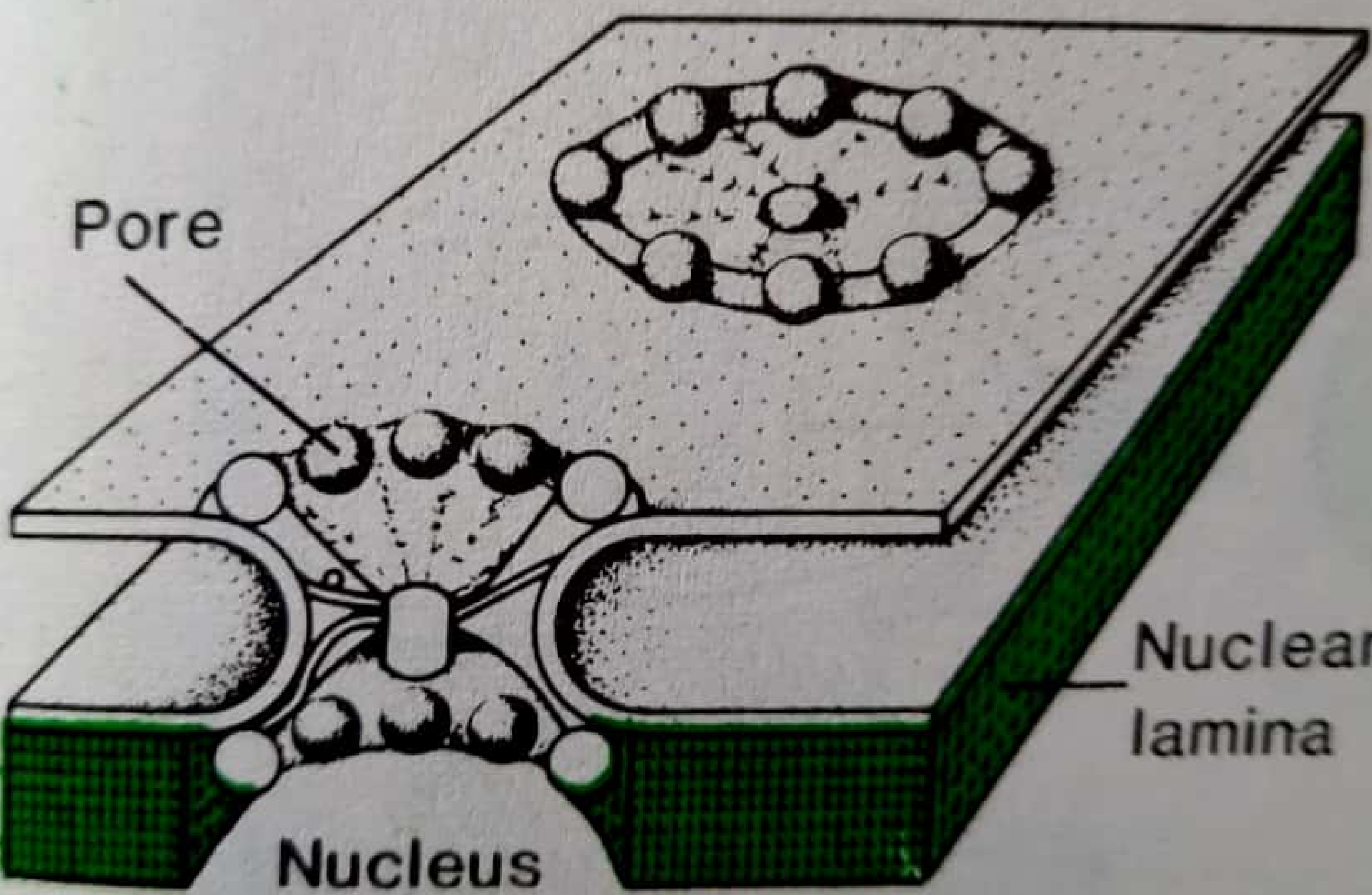

Fig. 13–3. Diagram of the nuclear envelope, which consists of two lipid bilayers with 80 nm pores occupied by pore complexes of octagonal radial symmetry. On the inner side, a nuclear *lamina* 50 to 80 nm thick covers the membrane, except at the nuclear pores. The lamina proteins bind chromatin, which thus becomes attached to the nuclear envelope. (Modified from Franke, W.W., et al.: J. Cell Biol., 91:39, 1981.)

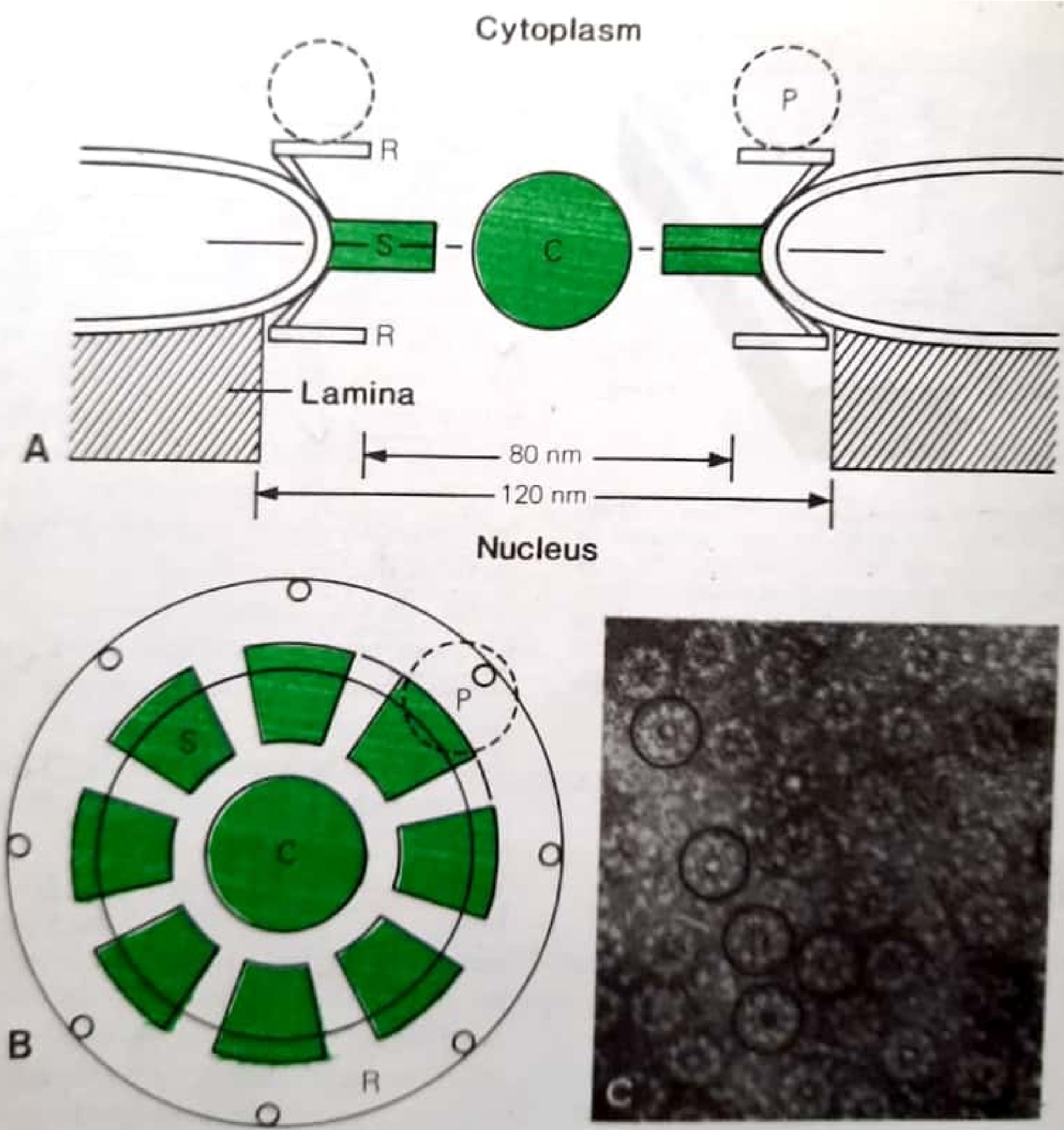

Fig. 13–4. Diagram of the pore complexes as visualized by computerized image reconstruction techniques. *A*, cross section; *B*, top view; *c*, nuclear envelope from *Xenopus* oocytes, which was negatively stained with gold thioglucose, manually isolated, and spread on an EM specimen holder. The data for the diagram was derived from the electron micrograph. Note the two peripheral rings *(R)*, the central spokes *(S)*, the central plug *(C)*, and the nuclear lamina. The cytoplasmic particles *(P)* sometimes found attached to the cytoplasmic ring are the same size as ribosomes. (Redrawn from Unwin, P.T.N., and Mulligan, R.A.: J. Cell Biol., 93:63, 1982.)