Structural organization and functions of lampbrush chromsome

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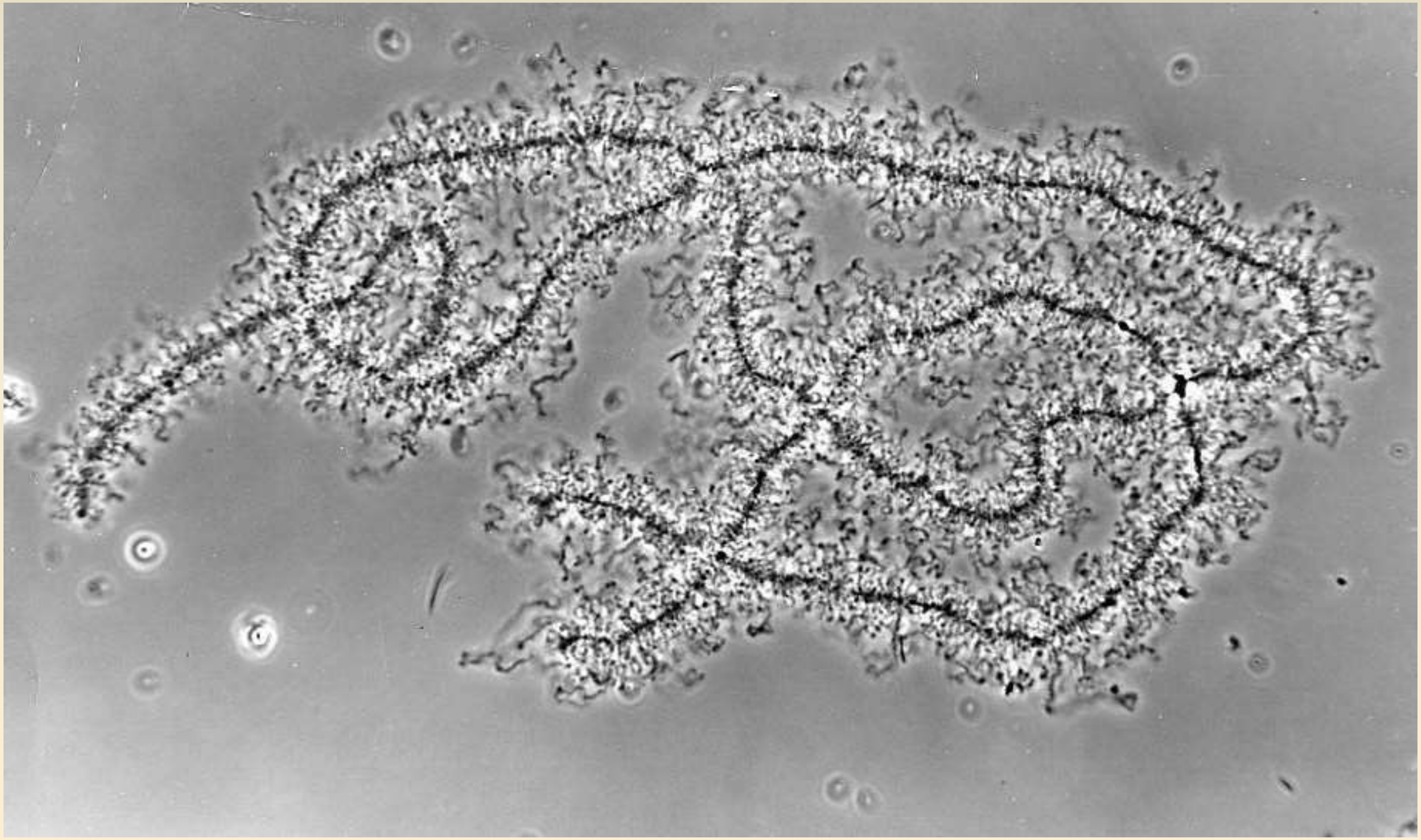
Introduction

- Lamprush chromosome is a greatly enlarged chromosome that has apparently filamentous granular loops extending from the chromomeres.
- It is a largest chromosome found ever and is a characteristic of vertebrate oocytes.
- It was first reported by Flemming in 1882 in Salamander (*Amblystoma maxicanum,* an amphibian) eggs. However, the name lampbrush was given by Ruckert in 1982.
- The lampbrush name is given because of its similarities in appearance to the brushes used to clean lamp chimneys at that time.
- It is found in oocytes of birds, lower vertebrata and invertebrates during the prolonged prophase of the first meiotic division. It is also found in plants.
- It is found in diplotene stage of prophase I and is meiotic bivalents, each consisting of two pairs of sister chromatids.

Morphology of lampbrush chromosome



Morphology of lampbrush chromosome

- In the early prophase, lampbrush chromosome (LBC) is a bivalent that consists of two pairs of conjugating homologues, forming a tetrad.
- Each chromatid is composed of alternatively positioned regions of condensed inactive chromatin (visible as dark irregular structures) and side loops of decondensed chromatin.
- In the homologous sections of the bivalent, chromatin is condensed (spirally twisted) or decondensed in the form of side loops – two per each chromosome and four at the level of the bivalent.
- The loops of a paired chromosome form mirror-image structure.
- The loop constitutes a part of the chromosome axis. It is extensible as well as contractible.
- This stage can last several months to several years.
- It is 400 ± 800μm long as opposed to as the most 15 ± 20 μm during later stages of meiosis.
- Thus the lampbrush chromosomes (LBCs) are ~30 times less tightly packed.
- The total length of the entire chromosome is 5 to 6mm and is organized into ~5000 chromomeres (thickenening on the chromosome axis).

Morphology of lampbrush chromosome

- They are composed of a main axis having two chromatids. Main axis has a row of granules known as chromomeres, which are held together by the axial fibres.
- The lateral loops in pairs project from the chromomeres and are transcriptionally active.

Lampbrush chromosomes are analogous structure to the lampbrush; here a – telomeric loop, b – side loops, c – a chromatid without loops.

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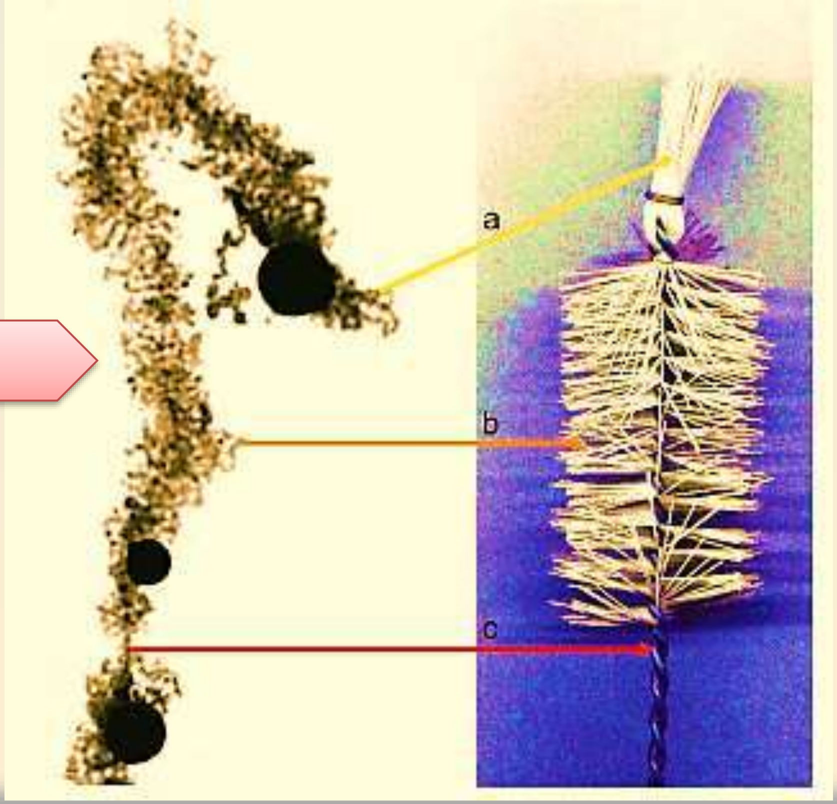
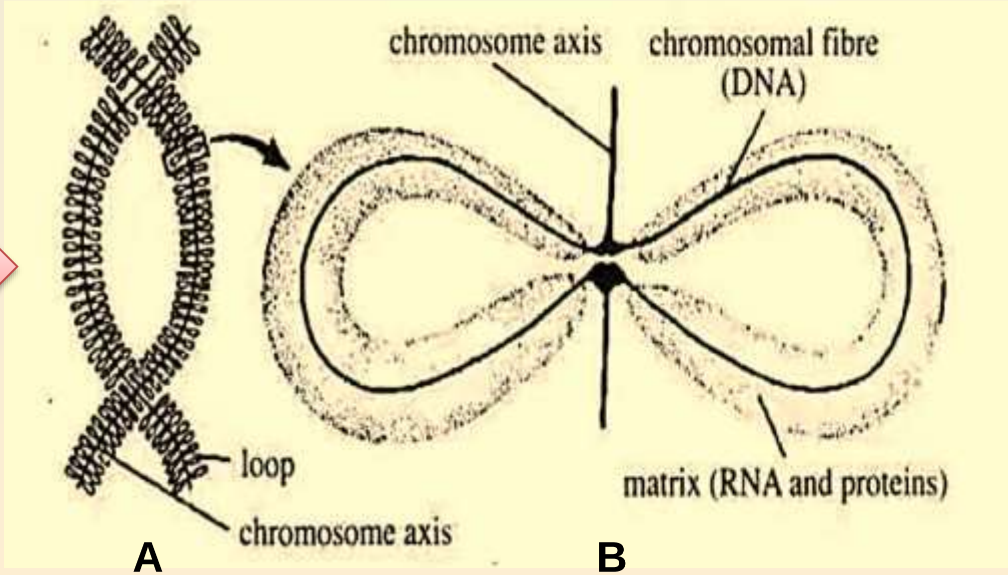


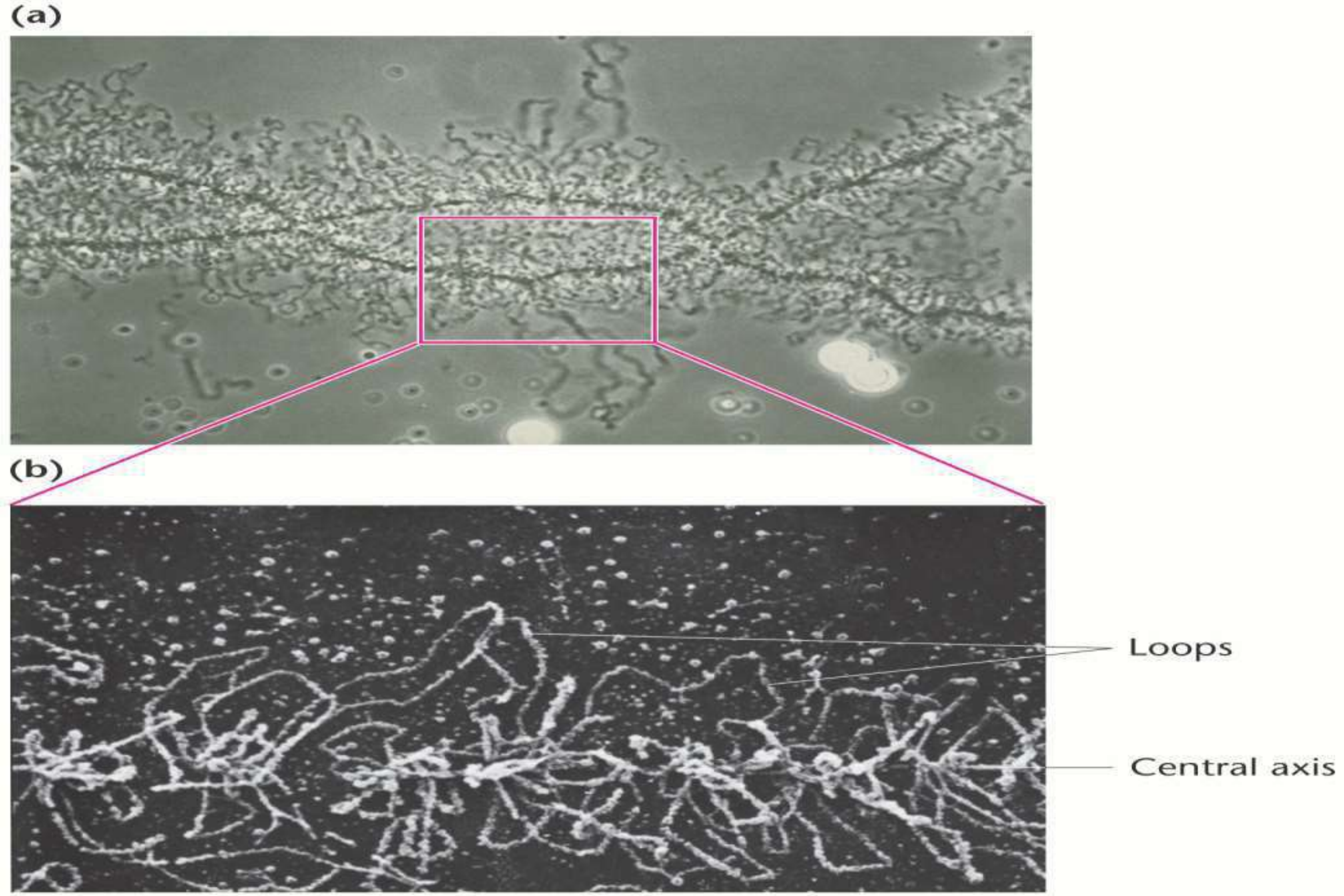
Morphology of lampbrush chromosome

- The contractibility of the loop results in the contraction and dilation of the chromomere.
- Each chromosome of a pair has several chromomeres distributed over its length; from each of a majority of the chromomeres generally a pair of lateral loops extends in the opposite directions perpendicular to the main axis of the chromosome.
- In some cases, more than one pair, even up to 9 pairs of loops may emerge from a single chromomere. About 1 to 9 loops of variable size may arise from a single chromomere.

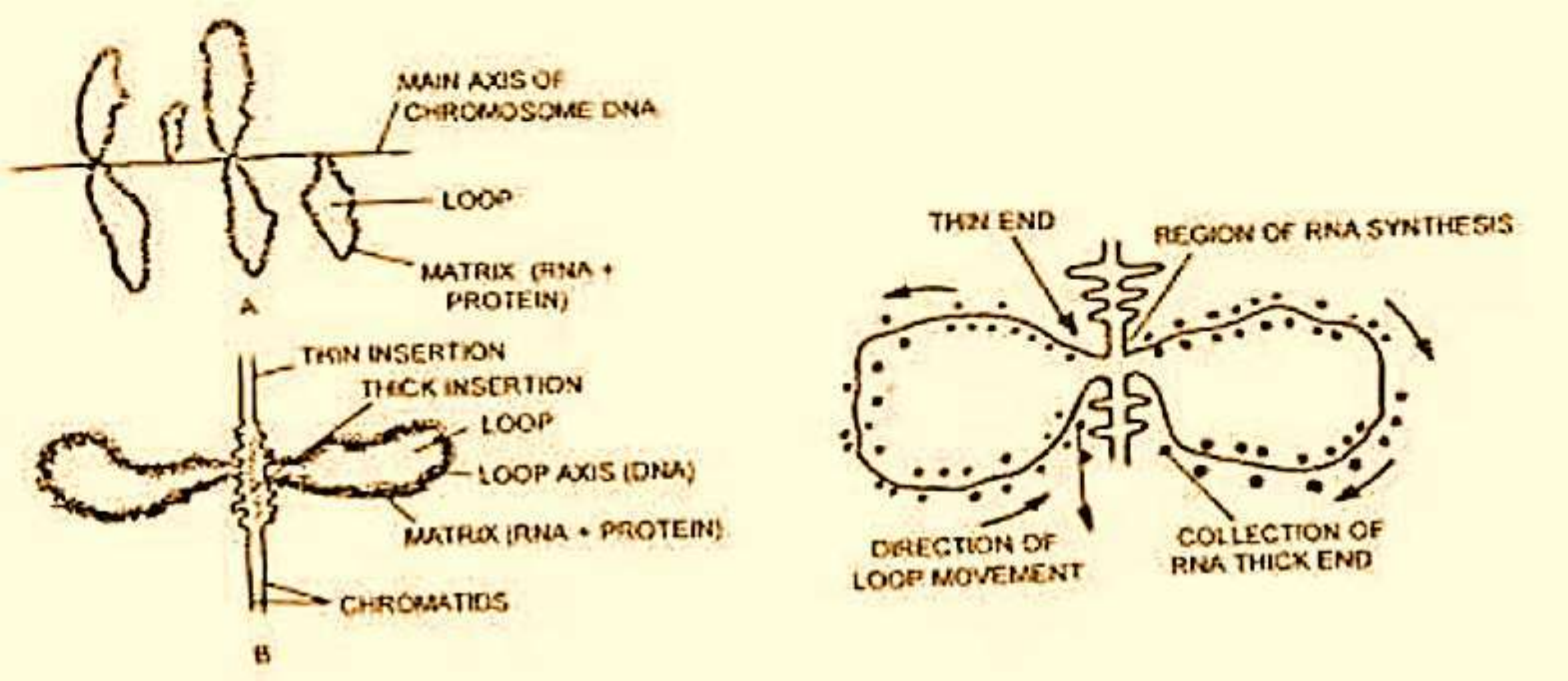
Lampbrush chromosome (LBC). A. At low magnification; B. Loop magnified



Morphology of lampbrush chromosome



Loops of lampbrush chromosome

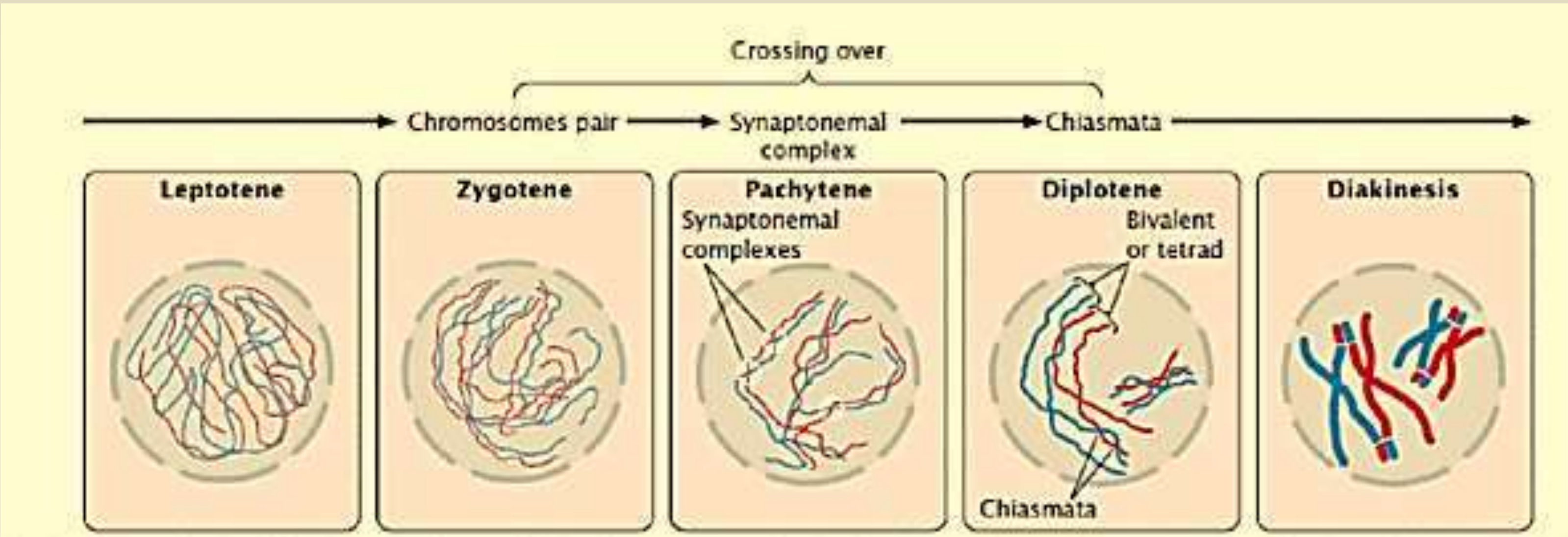


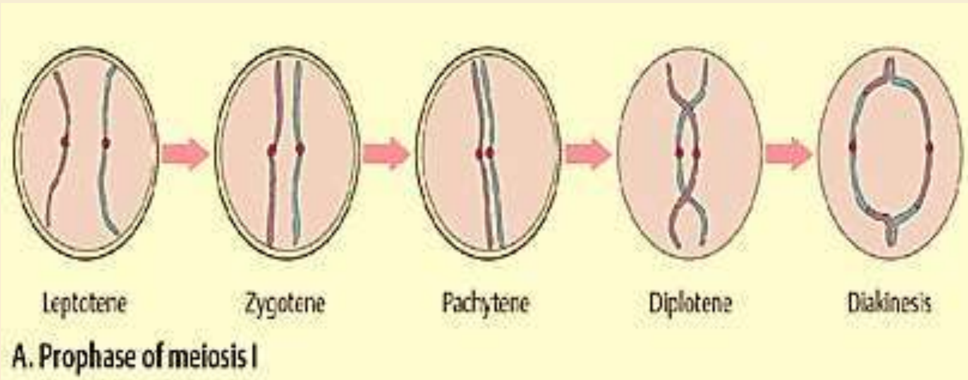
Lampbrush chromosome (LBC). A. Cross structure; B. Enlarged view; C. Synthesis of RNA in a side loop of lampbrush chromosome.

Loops of lampbrush chromosome

- The pairs of loops are produced due to uncoiling of the two chromatin fibers present in a highly coiled state. The loops are always asymmetrical.
- The centromere of the chromosomes have no loops.
- About 10,000 loops per chromsome set or haploid set are found.
- The size of loops varies with an average of 4 -5μm in interchromomeric fibres.
- About 5 -10% of DNA exists in the lateral loops, the rest being tightly condensate in the chromomeres which are transcriptionally inactive.
- The loop's size increases with the size of genome.
- Each loops has an axis made uo pf single DNA molecule that is unfolded from the chromsome during RNA synthesis.
- Uncoiling or formation of loops makes the DNA exposed and available for transcription of gene.
- The number of pairs of loops gradually increases in meiosis till it reaches maximum in diplotene.
- As meiosis proceeds further, number of loops gradually decreases and the loops ultimately disappear.
- Disappearance of loops is due to reabsorption back into the chromomere.
- Actin filaments are seen involved in extending the loop away from the chromomeric axis.

Genesis of Lampbrush chromosome (LBC)





Genesis of Lampbrush chromosome (LBC)

- It is formed during the diplotene stage of meiosis in yolk rich oocytes nuclei during the active synthesis of mRNA molecules for the future use by the egg.
- It is considered as an primitive and adaptive feature that has evolved to pre-programme the egg for rapid early development (not in mammal).
- It is formed to meet the demand during cleavage when no synthesis of mRNA molecule is possible due to active involvement of chromosomes in the mitotic cell division.
- It is 400 ± 800μm long as opposed to as the most 15 ± 20 μm during later stages of meiosis.
- Thus the lampbrush chromosomes (LBCs) are ~30 times less tightly packed.

Transcription in loops

- The loop is seen as differentiated into thin end from where transcription starts and a thick end from where transcribed RNA is collected.
- There is no RNA synthesis at the thick end of the loop.
- Chromatin fibers are seen progressively uncoiling towards the thin end of the loop which later associated with RNA and protein to become thicker.
- The DNA at the thick end of a loop is progressively withdrawn and reassembled into the chromomere.
- The loops can be categorized by size, thickness and other morphological characteristics.
- Polymerase II transcribes largest loops , while the smallest loops are transcribed by polymerase III.
- They contain 5S RNA coding units, tRNA or short replication sequences.
- Since, 5S RNA sequences are short and divided by noncoding elements, transcription being basically limited to coding sequences,
- The transcripts of these sequences are also short and, consequently, do not have the distinctive matrix made up of RNP filaments.
- That is why they are so well visible in the microscopic phase contrast.
- LBCs can be divided into those with one transcriptional unit and those with two or more.
- Over the length of 1μm, one transcriptional unit is transcribed by a densely compacted package of around 13-20 polymerase molecules.
- Changes in transcriptional activity greatly affects the morphology of chromosome.

Function of Lampbrush chromsomes

- It is involved in the synthesis of mRNA and therefore proteins that are needed for heavy demand of embryonic development.
- It is also involved in the production of “masked” mRNA for early development.
- Each loop is believed to represent one long Operon consisting of repititive citrons to meet high rate of synthesis.
- Each locus codes for RNA.
- It also helps in the formation of yolk material in the egg.
- Much about function of lampbrush chromosome is not known since most of the studies has been focused on its structural detail.
- It has been shown that disintegrating loop ceases the formation of lampbrush chromosome (LBC).

Significance in biological research

- Loops are used in chromosome mapping, especially each loop appears at a constant point in the chromosome.
- It is extremely useful to visualize gene expression in its natural state and enables to observe changes that are associated with transcription.
- It provides evidence for eukaryotic gene amplification which is required during the growth phase of oocytes.
- It is fit model for experiments related to hybridization analysis.

Further reading

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