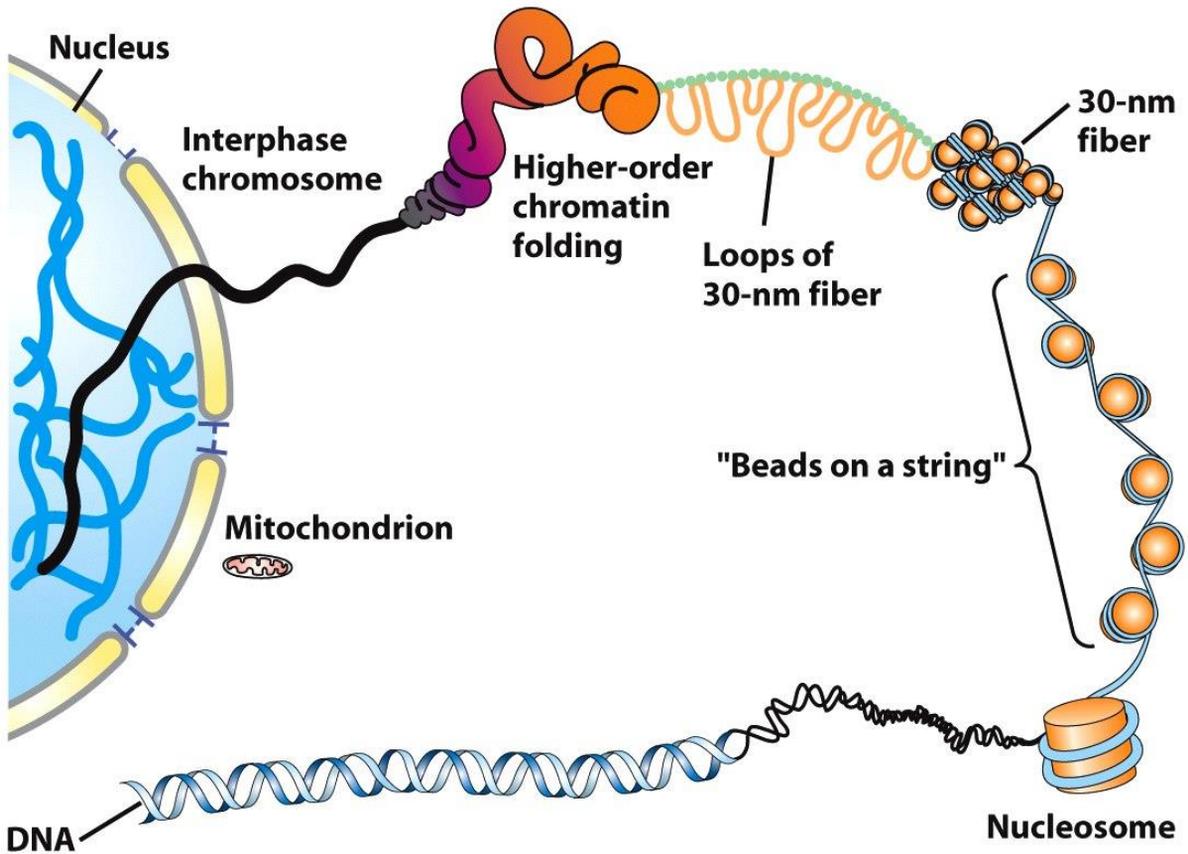


# **Gene Expression**

## **Chapter 6: Genes, Genomics, and Chromosomes**

# Overview of the structure of genes and chromosomes



## Major Types of DNA Sequence

Single-copy genes  
Gene families  
Tandemly repeated genes  
Introns

Simple-sequence DNA  
Transposable DNA elements  
Spacer DNA

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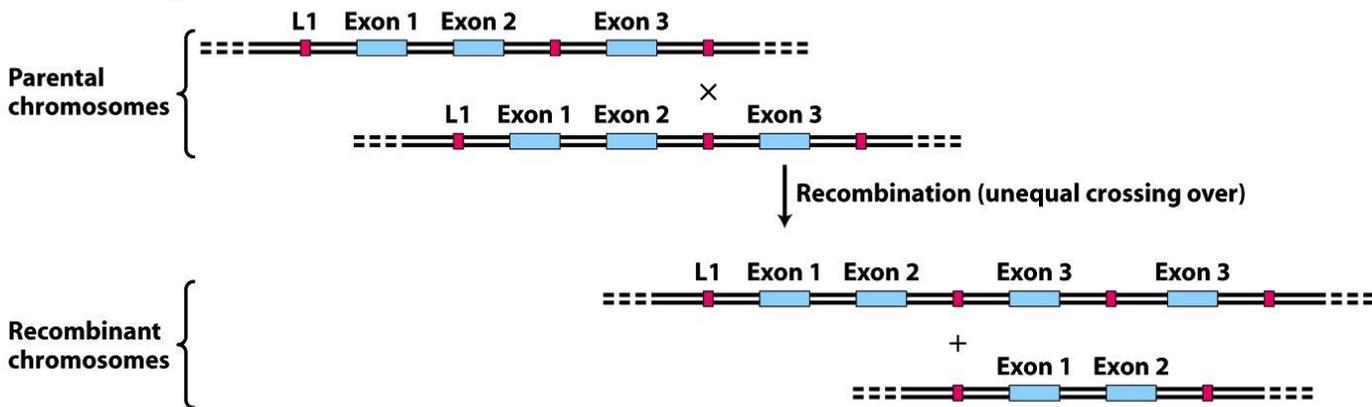
# Eukaryotic gene structure

**Gene:** is a unit of DNA that contains the information to specify the synthesis of a single polypeptide chain or functional RNA (tRNA)

• Most eukaryotic genes contain introns and produce mRNAs encoding single proteins

## Exon and Gene duplication

### (a) Exon duplication



### (b) Gene duplication

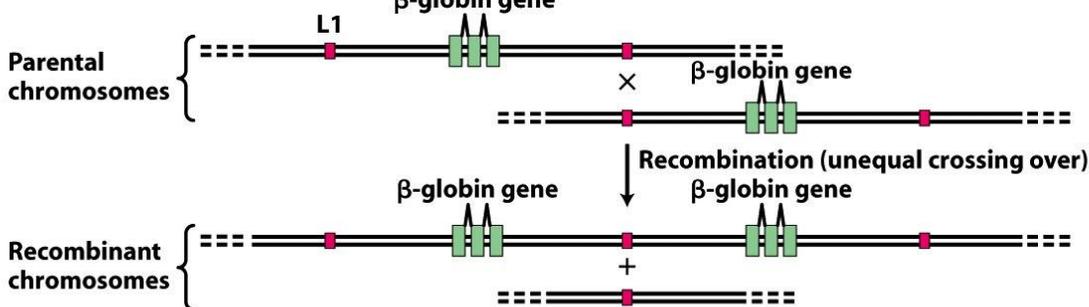


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- Simple and complex transcription units are found in eukaryotic genomes

**Simple transcription unit:** the transcription unit that produces a primary transcript which is processed to yield a single type of mRNA, encoding a single protein

### Simple transcription unit

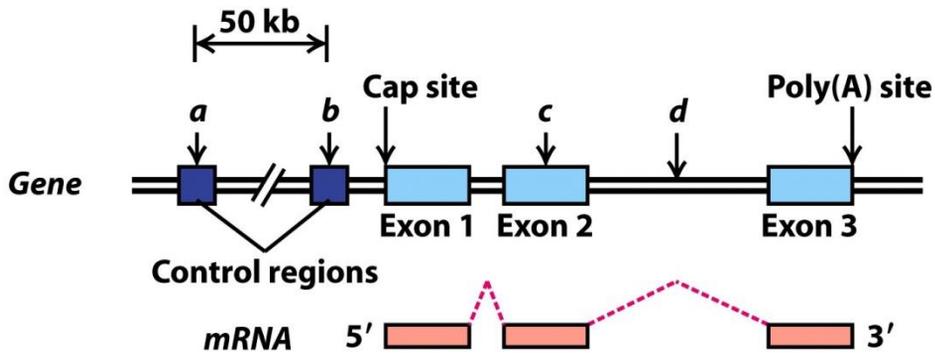


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- Simple and complex transcription units are found in eukaryotic genomes

**Complex transcription unit:** the transcription unit that produce a primary transcript which can be processed in more than one way, leading to the formation of mRNAs containing different exons

**Isoforms:** the various proteins encoded by the alternatively processed mRNAs expressed from one gene

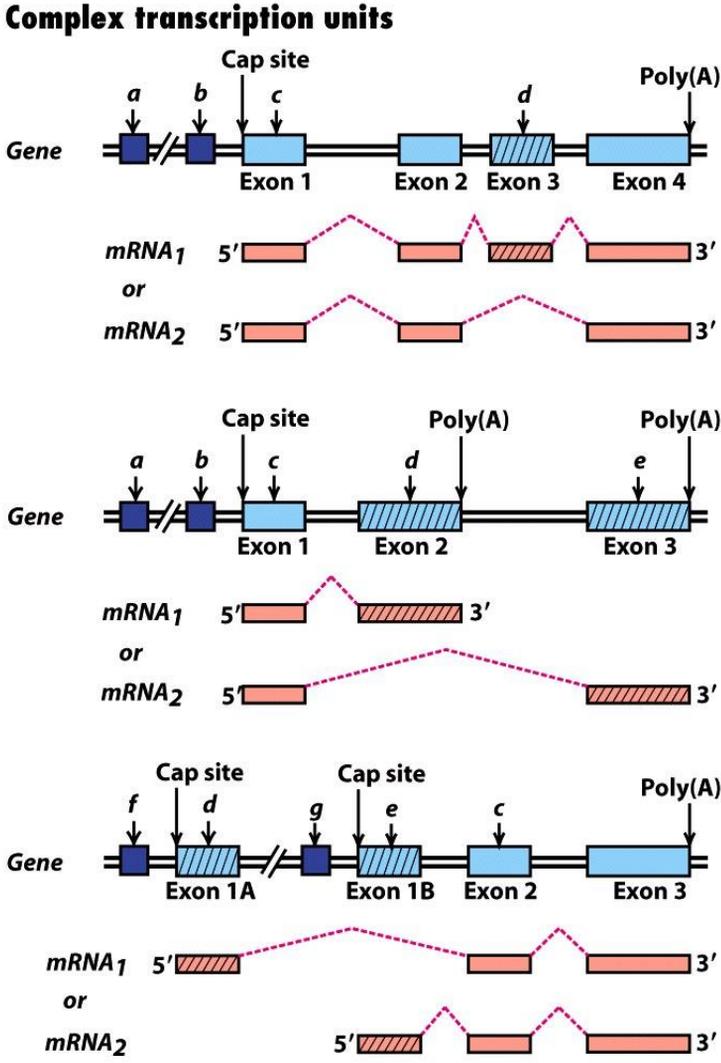


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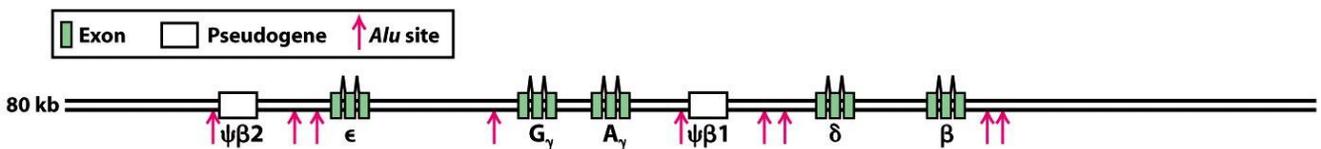
•Protein-coding genes may be solitary or belong to a gene family

**Solitary genes:** are protein coding genes that are represented only once in the haploid genome

**gene family (gene cluster):** set of genes that arose by duplication of a common ancestral gene and subsequent divergence due to small changes in the nucleotide sequences

**Protein family:** set of homologous proteins encoded by a gene family

(a) Human  $\beta$ -globin gene cluster (chromosome 11)



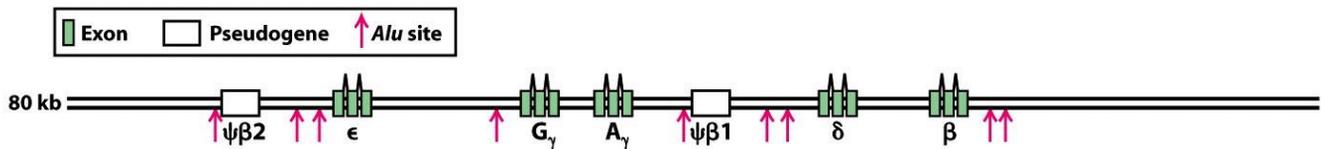
**Pseudogene:** DNA sequence that is similar to that of a functional gene but does not encode a functional protein, probably arose by sequence drift of duplicated genes

**Alu:** is a non coding repeating sequences (~ 300 bp) that is abundant in the human genome

# Chromosomal organization of genes and noncoding DNA

- Genomes of many organisms contain much nonfunctional DNA
- Nonprotein-coding genes encode functional RNAs

## (a) Human $\beta$ -globin gene cluster (chromosome 11)



## (b) *S. cerevisiae* (chromosome III)



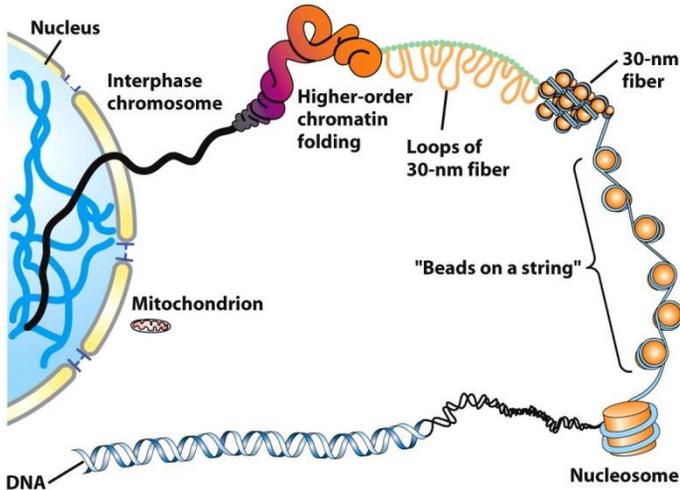
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# Structural organization of eukaryotic chromosomes

- Chromatin exists in extended and condensed forms

Structure of nucleosome

Structure of 30 nm fiber



### Major Types of DNA Sequence

|                         |                           |
|-------------------------|---------------------------|
| Single-copy genes       | Simple-sequence DNA       |
| Gene families           | Transposable DNA elements |
| Tandemly repeated genes | Spacer DNA                |
| Introns                 |                           |

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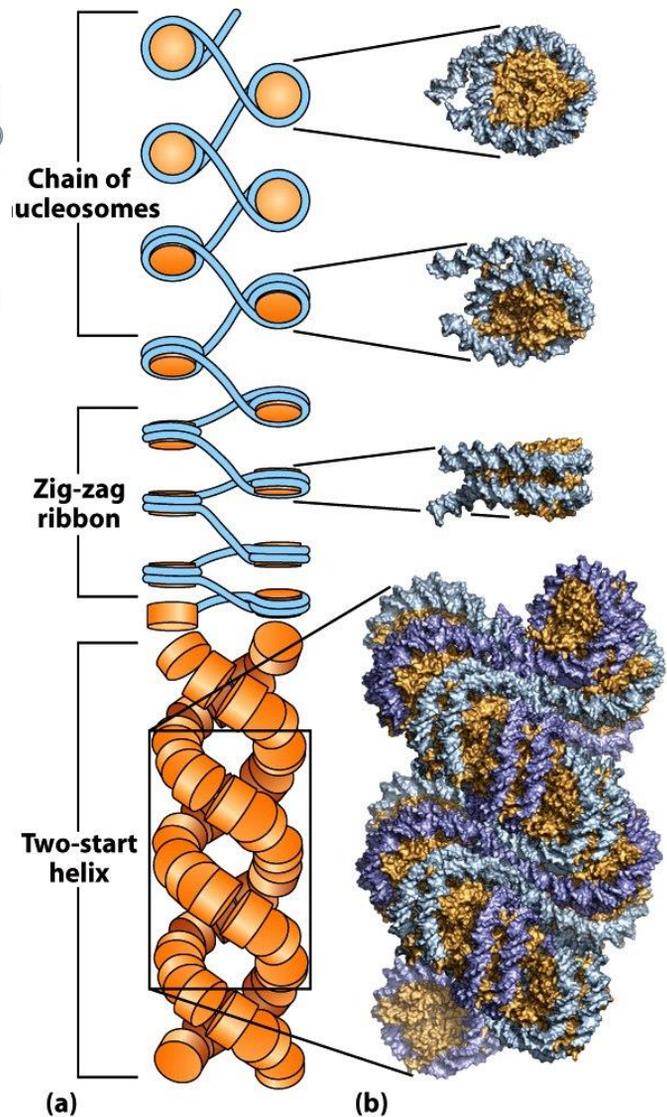


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• Modifications of histone tails control chromatin condensation and function

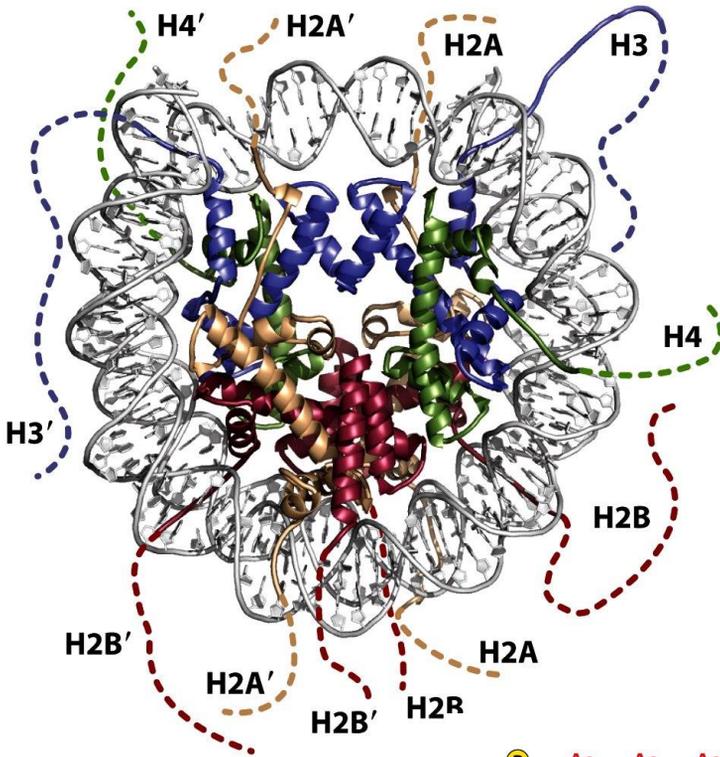


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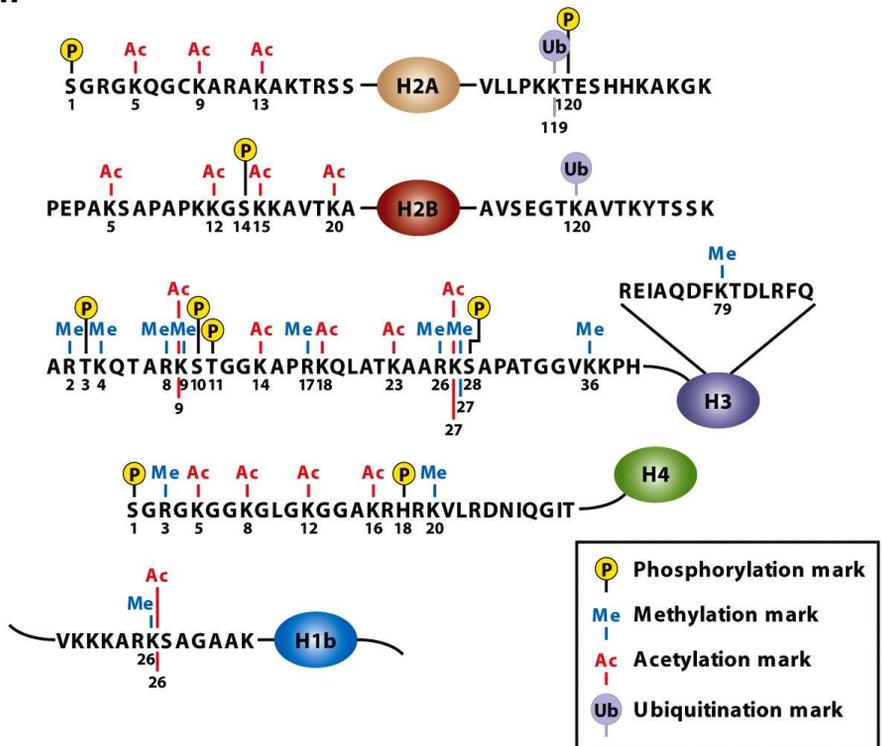


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# Histone acetylation

Lys 16 in N-terminus of H4 can be either acetylated or deacetylated

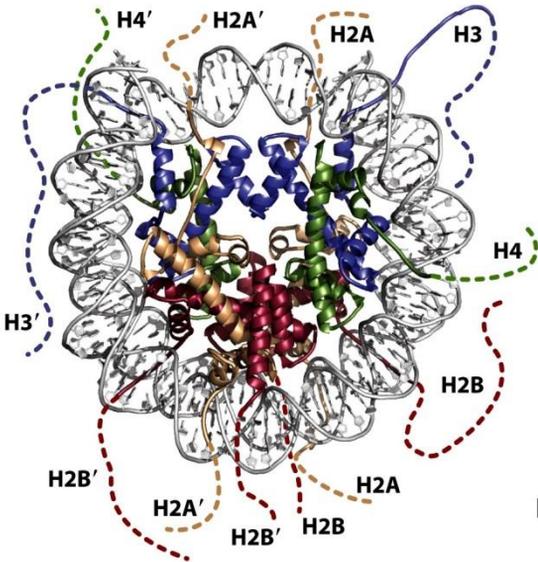


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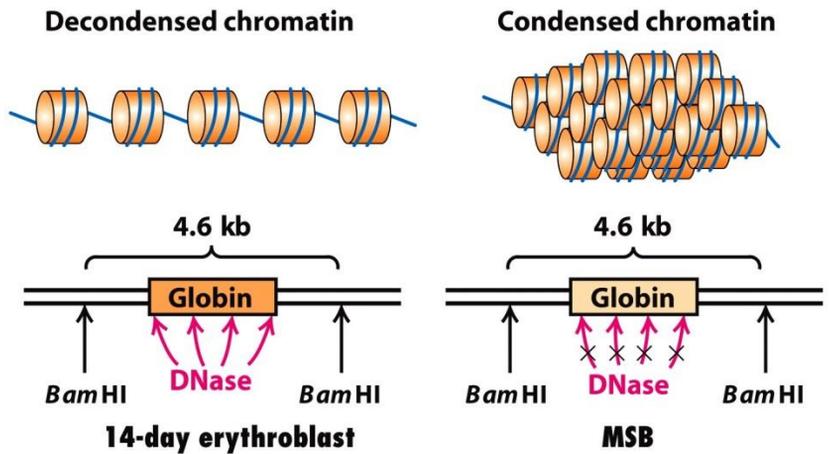


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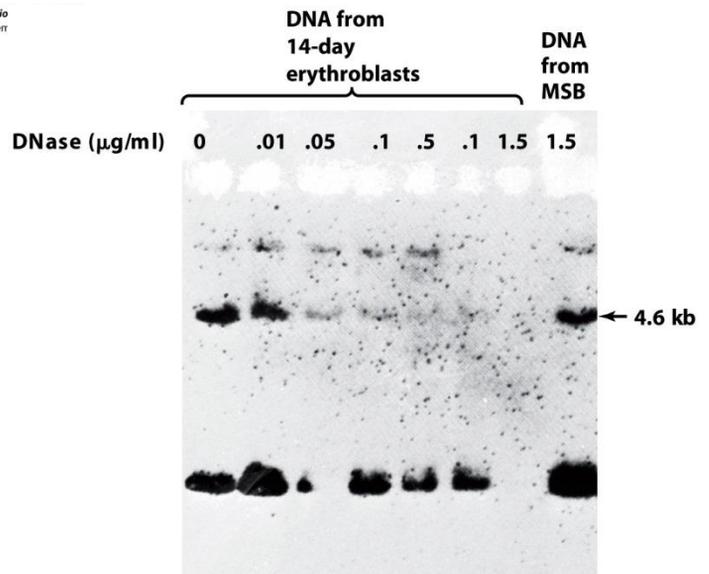


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## **Other histone modifications:**

- Lys  $\epsilon$  amino group can be methylated
- Arg side chains can be methylated
- Ser & Thr side chains can be phosphorylated
- Lys in the C-terminal tails of H2A & H2B can be ubiquitinated

# Heterochromatin versus euchromatin

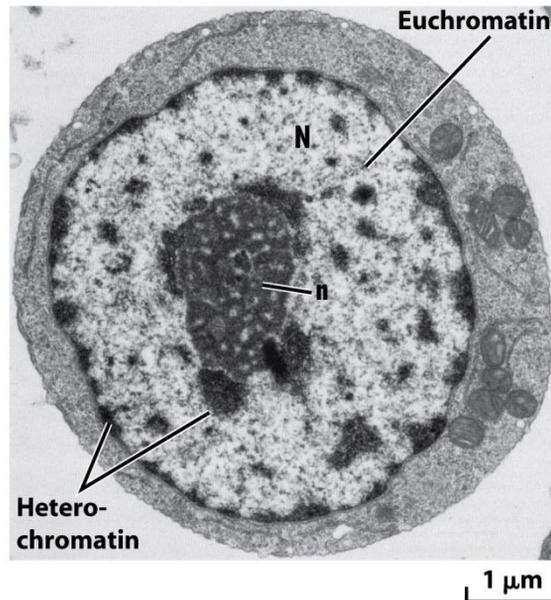


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## Heterochromatin (inactive/condensed)



## Euchromatin (active/open)



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## Reading the histone code

**Reading the histone code:** means that the histone code is “read” by proteins that bind to the modified histones tails & in turn promote condensation or decondensation of chromatin, forming “closed” or “opened” chromatin structures

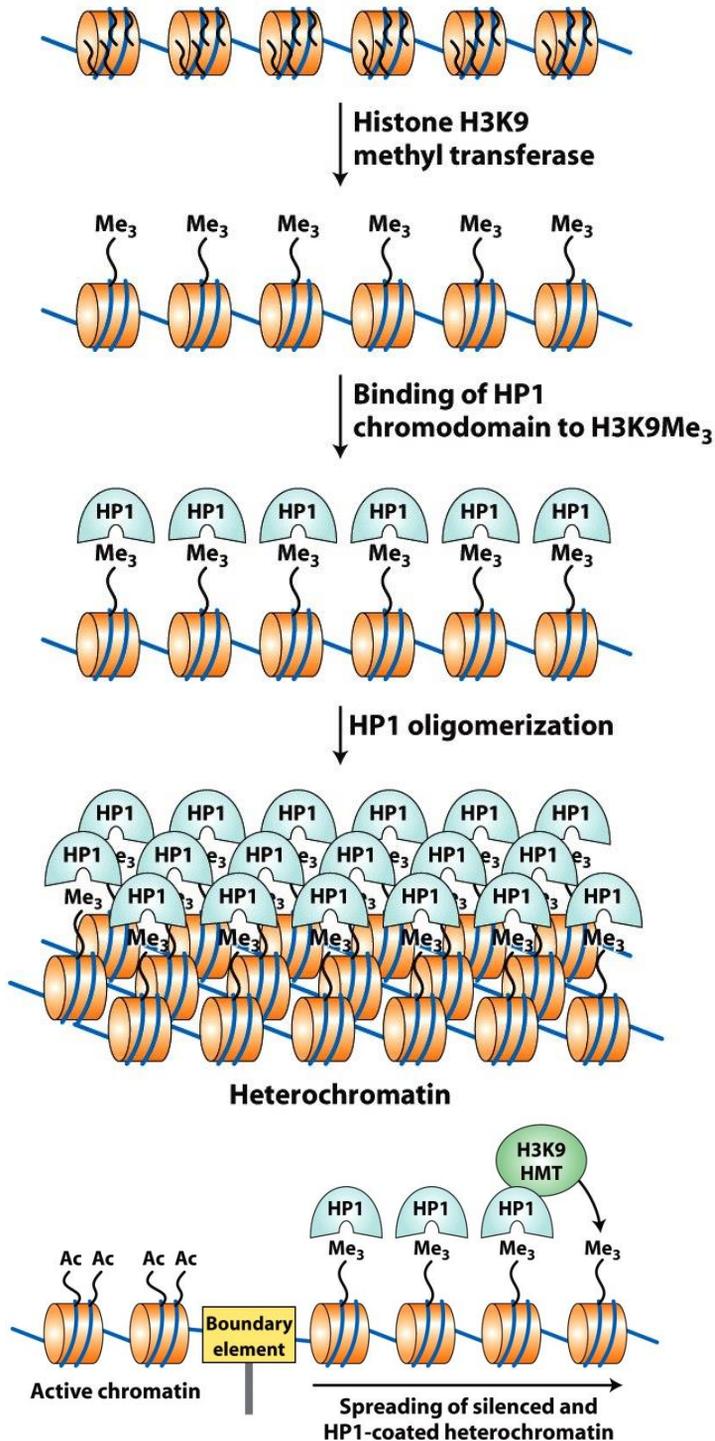
➤ In higher eukaryotes some proteins contain a chromodomain

**Chromodomain:** a protein domain that binds to histone tails when they are methylated at specific lysines

➤ One example of the chromodomain containing proteins is **Heterochromatin Protein I (HP1)**, that also contains another domain called **chromoshadow** domain

# Model for the formation of heterochromatin

**Boundary proteins:** are regions in chromatin where several non-histone proteins bind to DNA, possibly blocking histone methylation on the other side of the boundary



# X-chromosome inactivation in mammalian females

**Dosage compensation:** is a process that inactivate one of the X chromosomes in females. This will generate equal expression of genes on the sex chromosomes in males & females

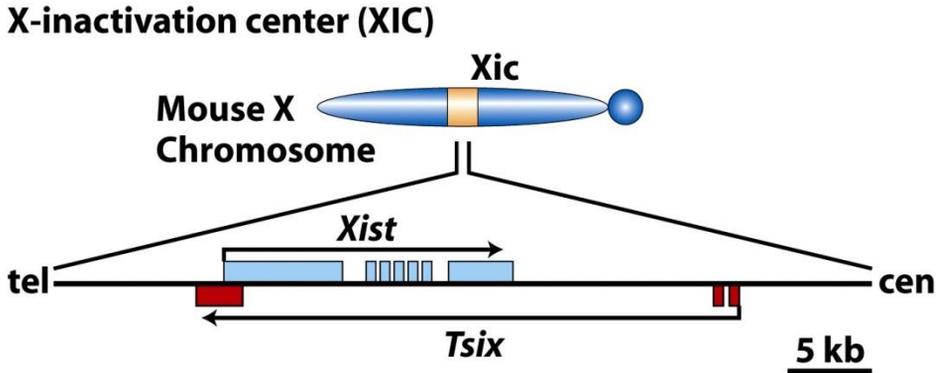
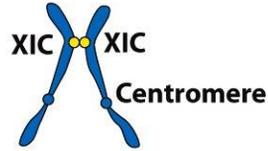


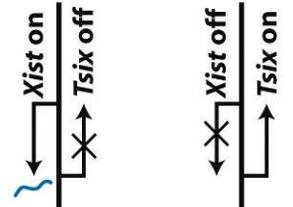
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## Mechanism of dosage compensation in females (2X)

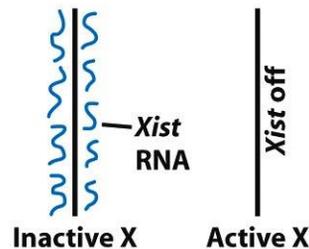
**1** XICs on two X chromosomes sense each other and pair.



**2** *Xist* is transcribed on one X chromosome; *Tsix* on the other.



**3** *Xist* RNA coats the chromosome from which it is transcribed.



**4** Changes in chromatin in *Xist*-coated X chromosome inactivate most transcription from the chromosome.



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# How inactivation of the Xist – coated X chromosome occurs?

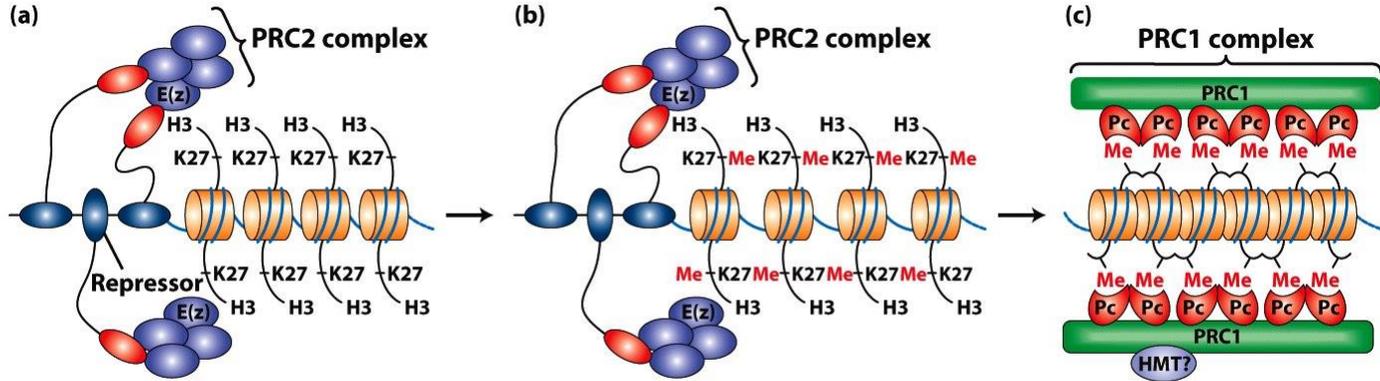


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The women are genetic mosaics since half of their cells have an active  $X_m$  and the other half have an active  $X_p$

**Epigenetic process:** is a process that affects the expression of specific genes & is inherited by daughter cells, but is not the result of a change in DNA sequence

- Nonhistone proteins provides a structural scaffold for long chromatin loops

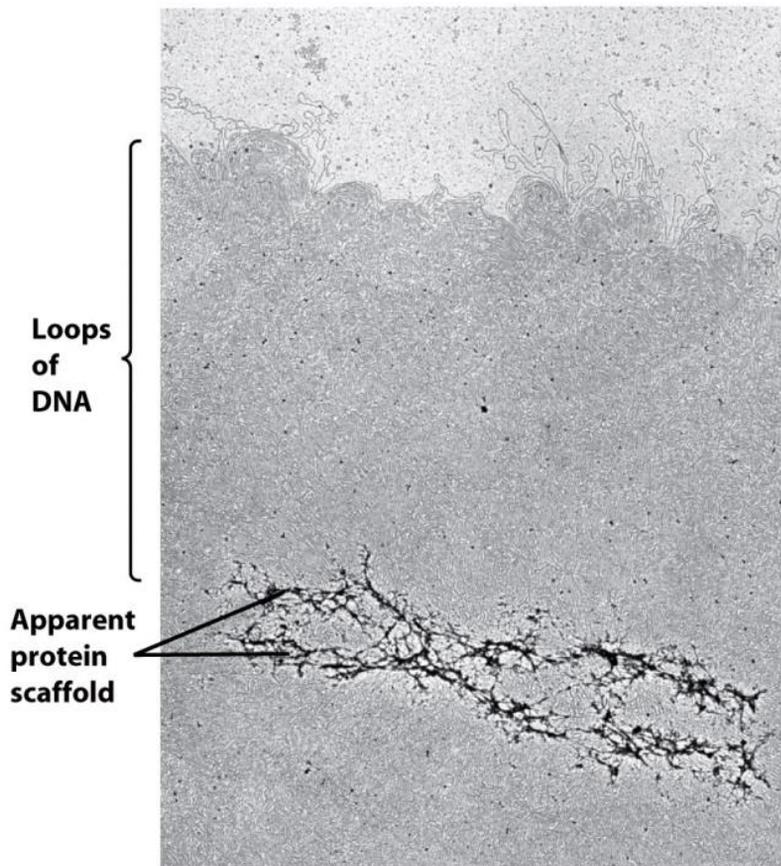


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**SARs:** Scaffold - associated regions

**MARs:** Matrix – attachment regions

**Insulators:** DNA sequences of tens to hundreds of base pairs that insulate transcription units from each other

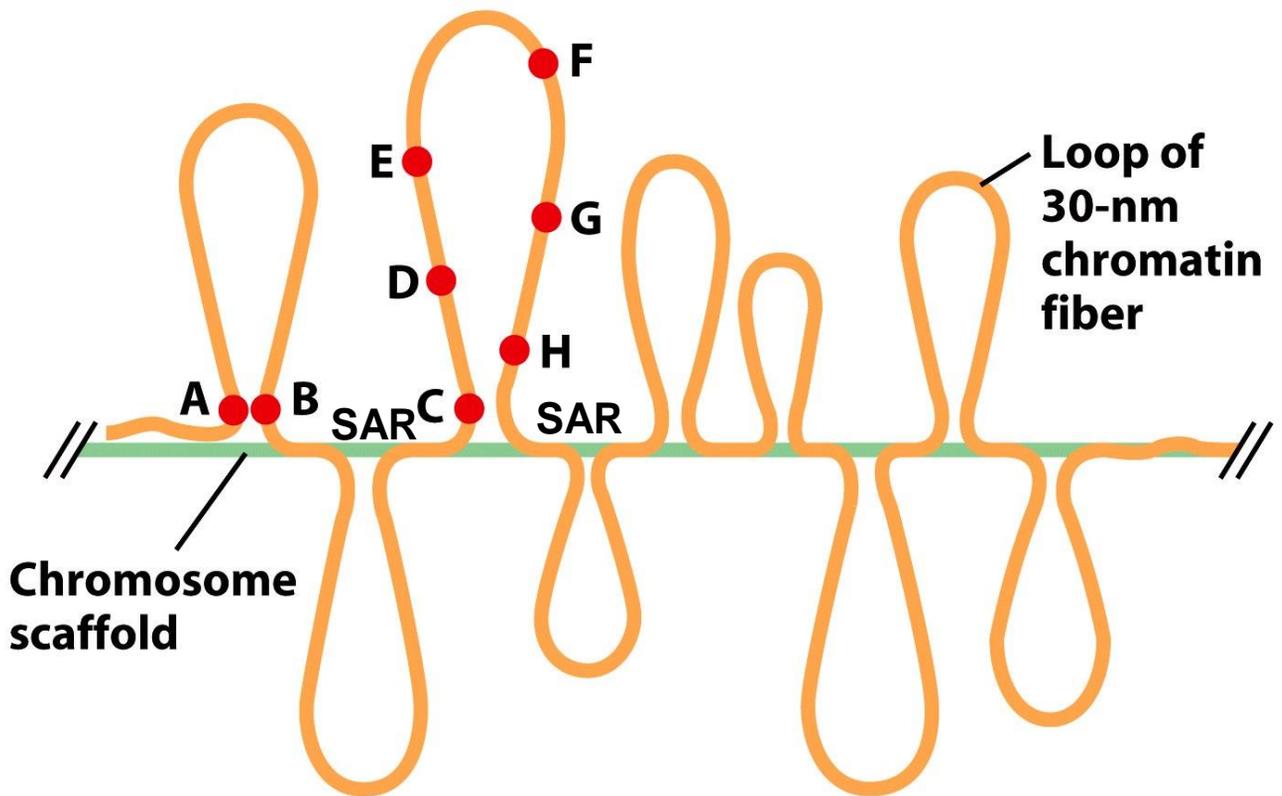


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# Ringlike structure of SMC protein complexes

**SMC protein:** Structural maintenance of chromosome protein

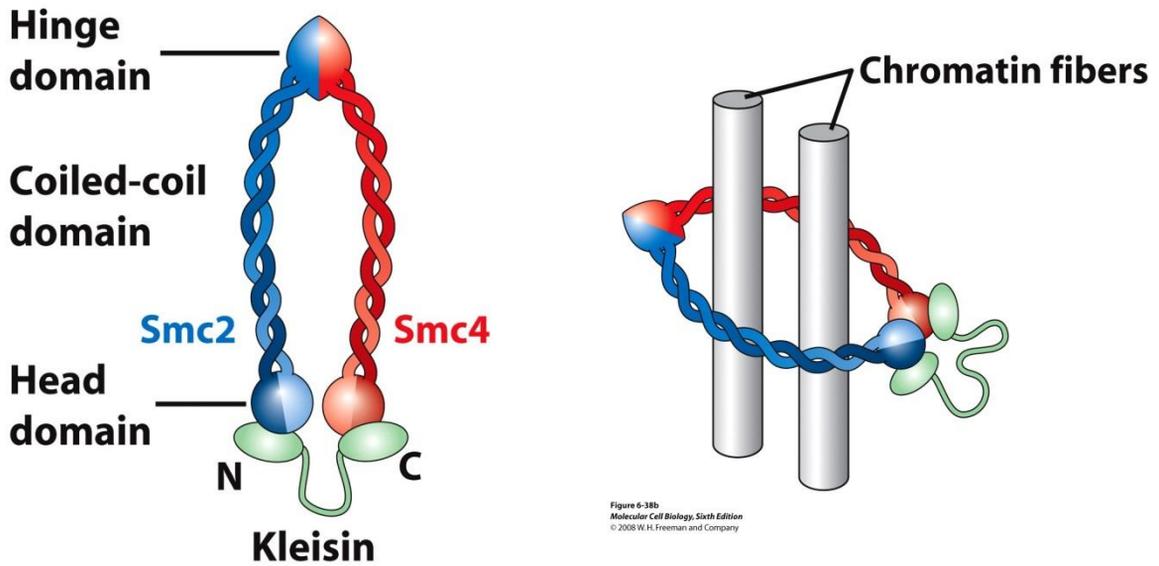


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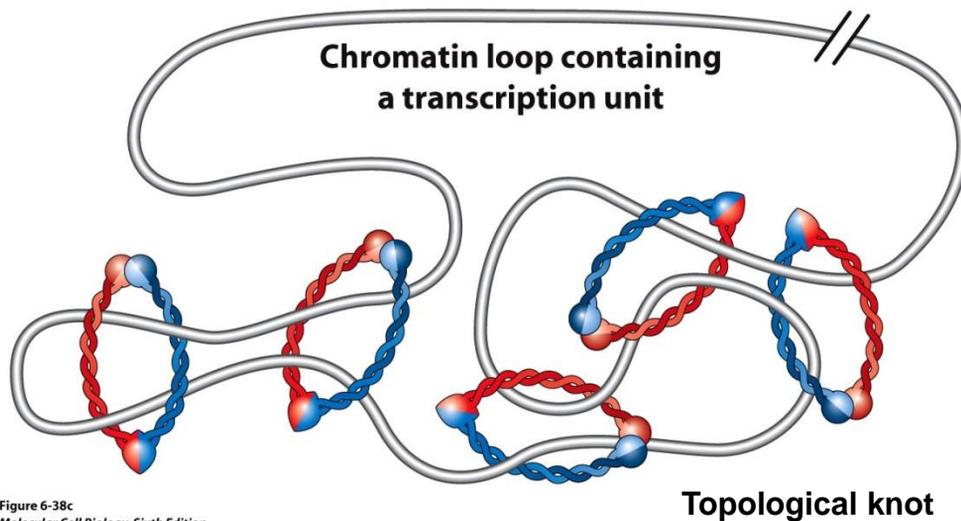


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**Topological knot**

# Ringlike structure of SMC protein complexes

**SMC protein:** Structural maintenance of chromosome protein

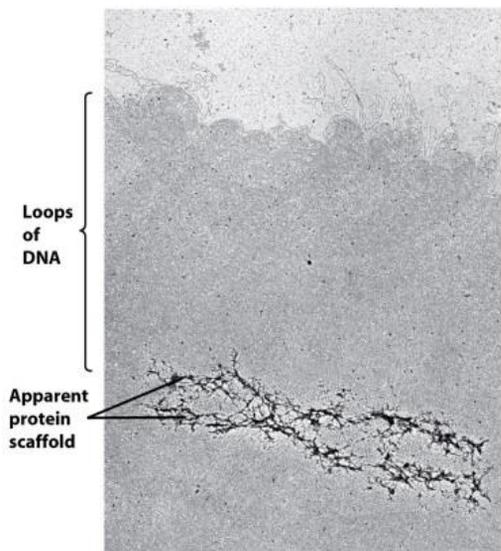


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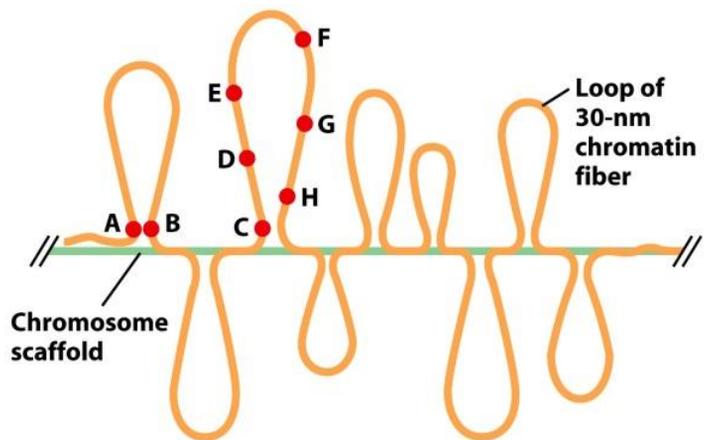


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## Interphase chromosome structure

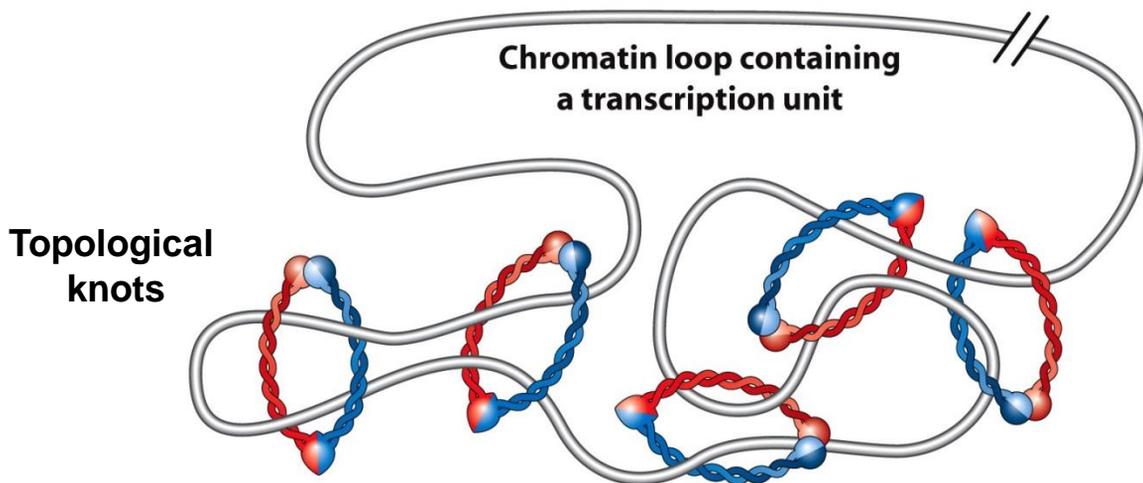


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# Metaphase chromosome structure

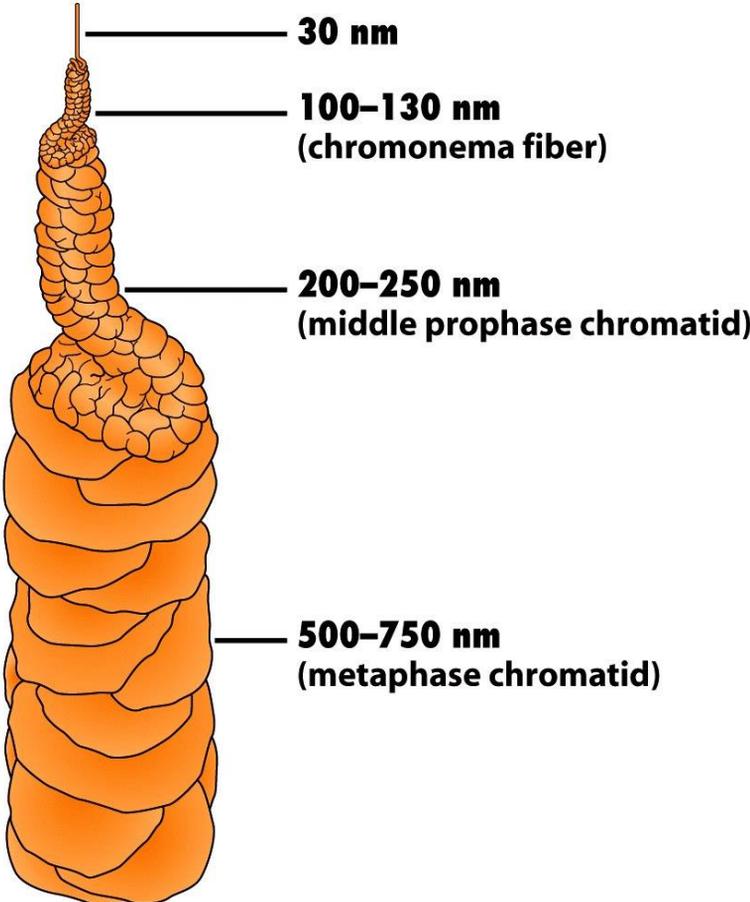


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# Ringlike structure of SMC protein complexes

**SMC protein:** Structural maintenance of chromosome protein

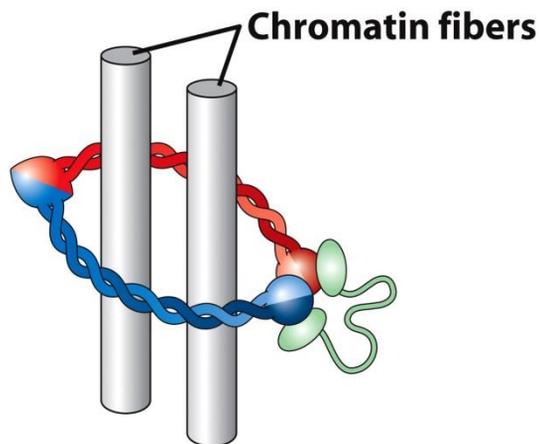
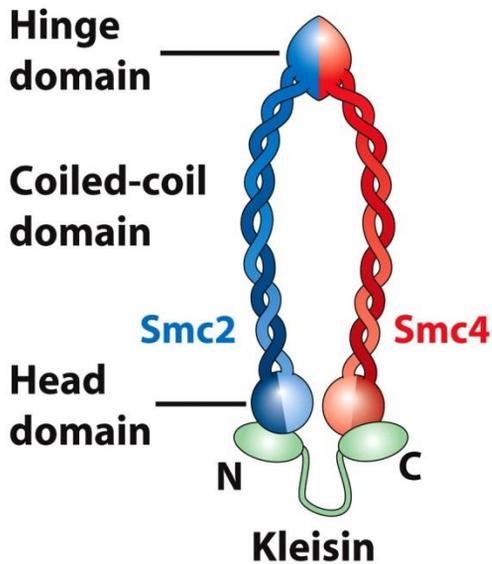


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# Interphase chromosome structure

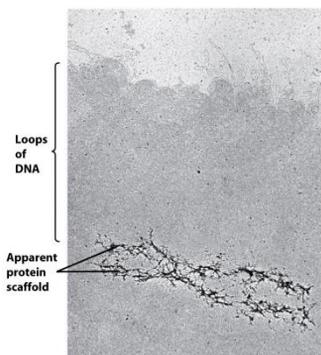


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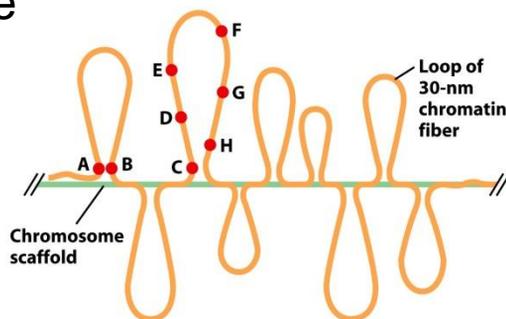


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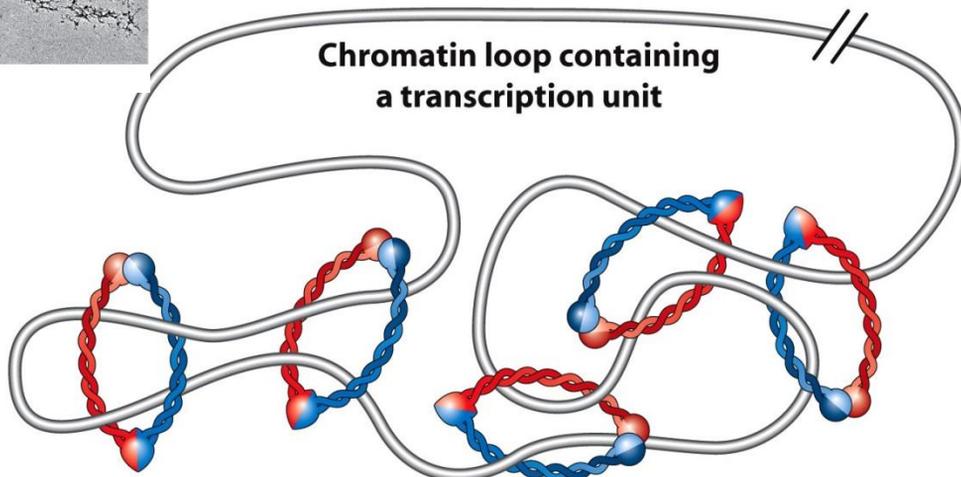


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