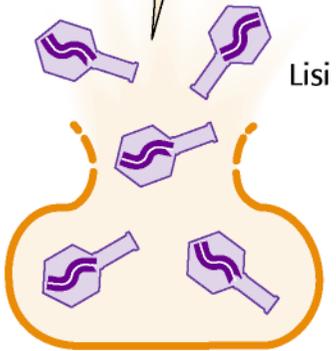


# **La Divisione Cellulare**

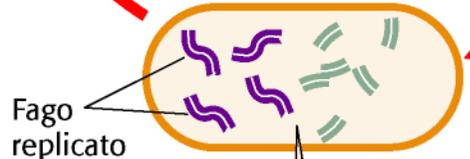
**7** Vengono rilasciati fagi appena formati per iniziare un nuovo ciclo.



**6** L'assemblaggio di nuovi fagi è completo. Un enzima codificato dal fago provoca la lisi della cellula.

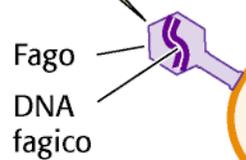


**5** La cellula ospite trascrive e traduce il DNA fagico generando proteine del fago.

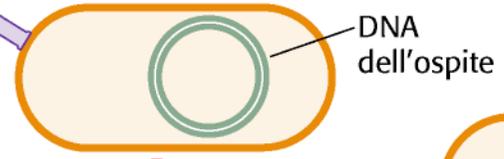


**4** Il DNA fagico si replica utilizzando nucleotidi derivanti dal precedente DNA dell'ospite.

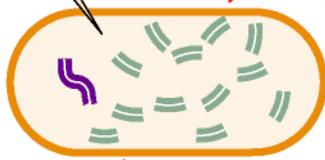
**1** Il fago si lega al batterio.



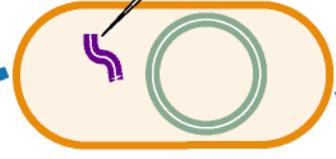
**2** Il DNA fagico entra nella cellula ospite.



**3** Il DNA dell'ospite viene digerito.

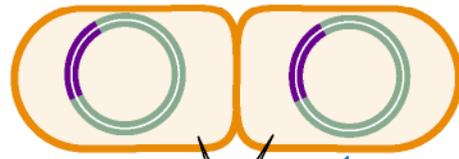


**3** Il profago può distaccarsi e la cellula entrerà nel ciclo litico.

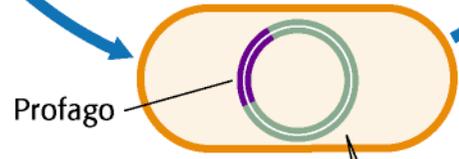


**Ciclo lisogeno**

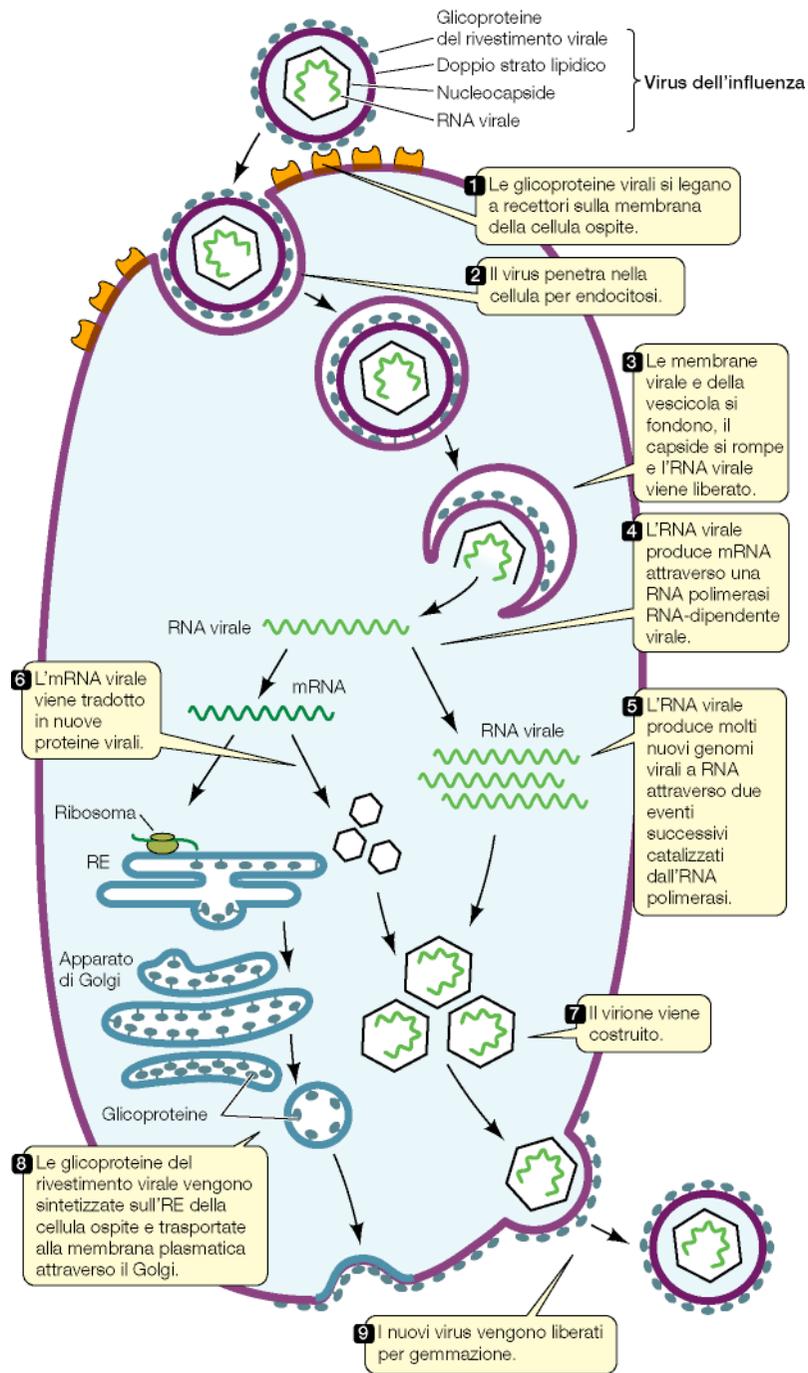
**2** Il cromosoma con un profago integrato si replica; tale evento può continuare per molte divisioni cellulari.

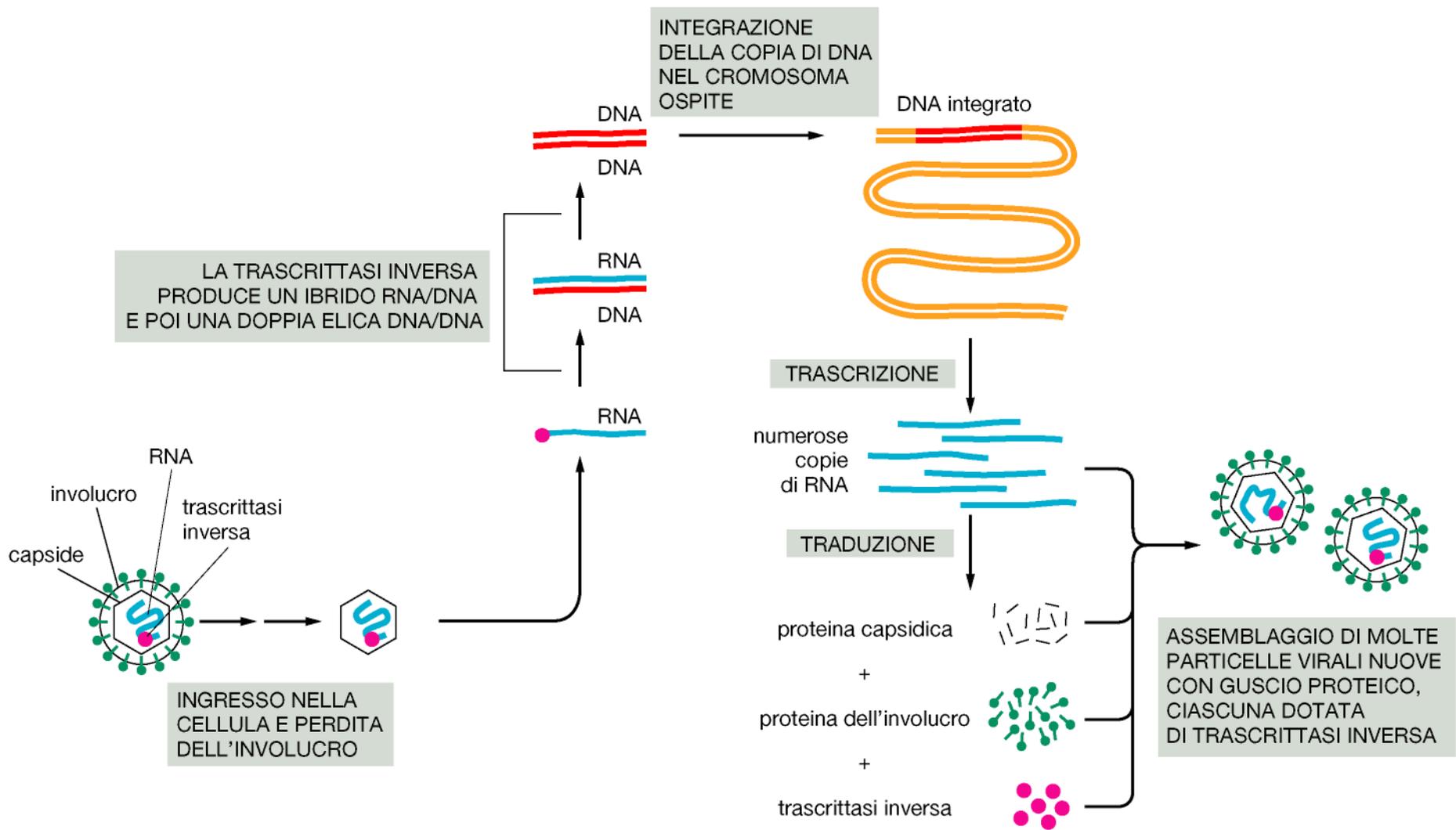


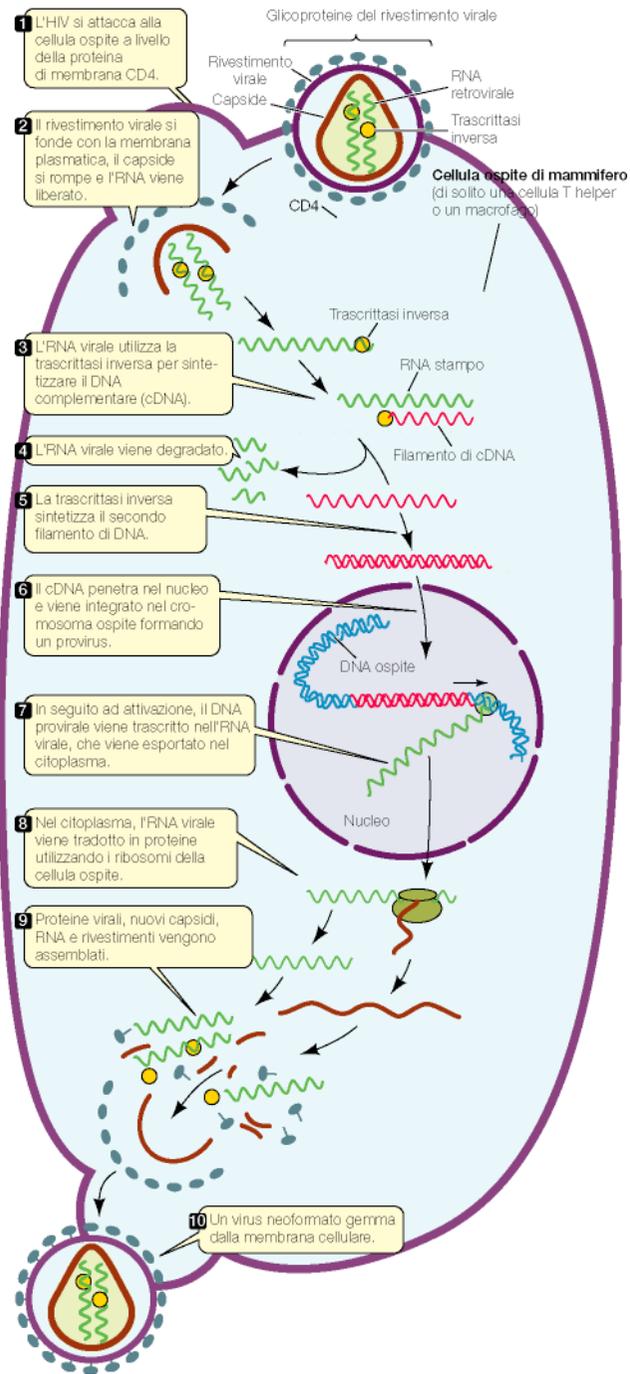
**1** Il DNA fagico si integra nel cromosoma batterico divenendo un profago.



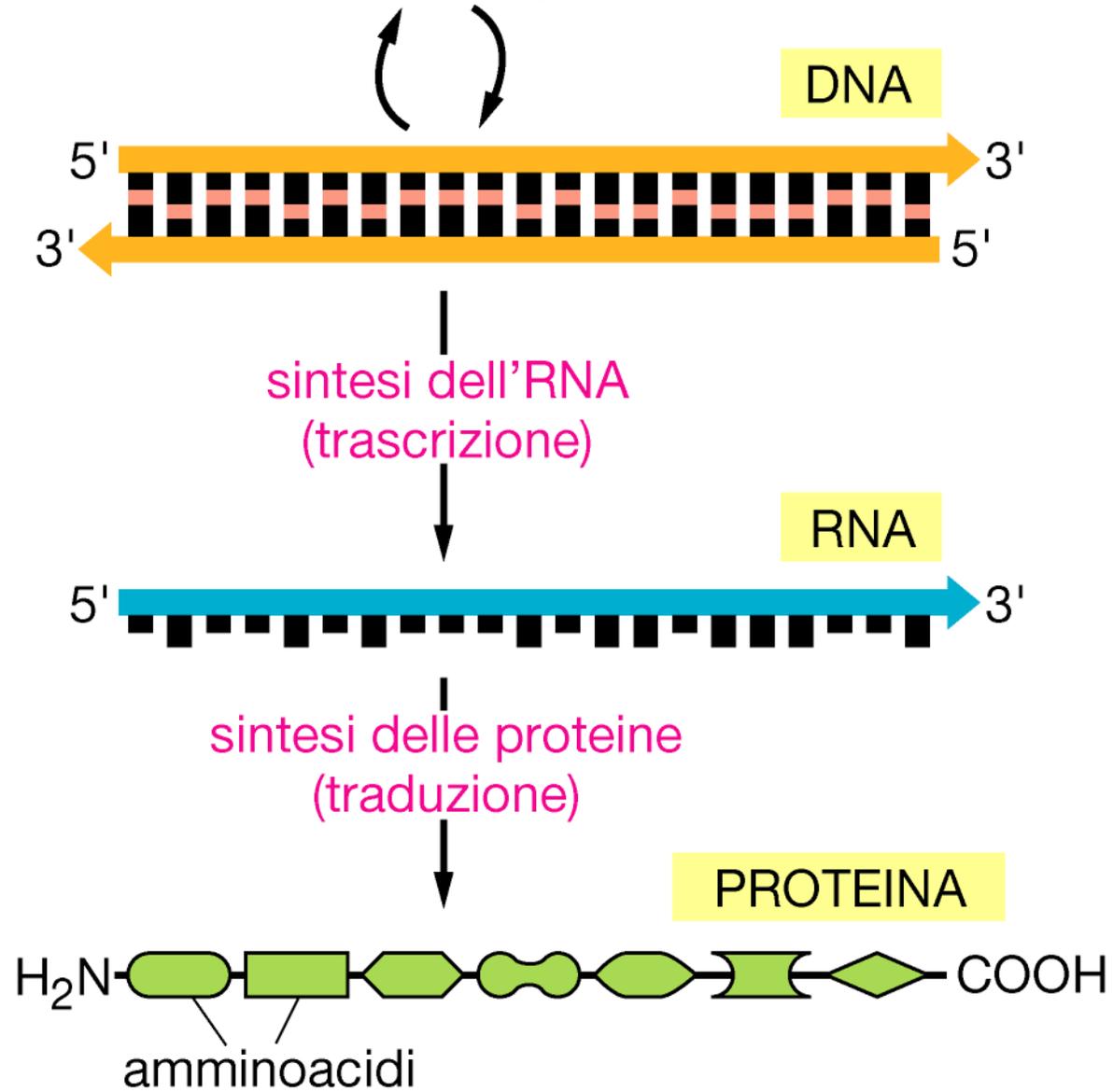
**Ciclo litico**





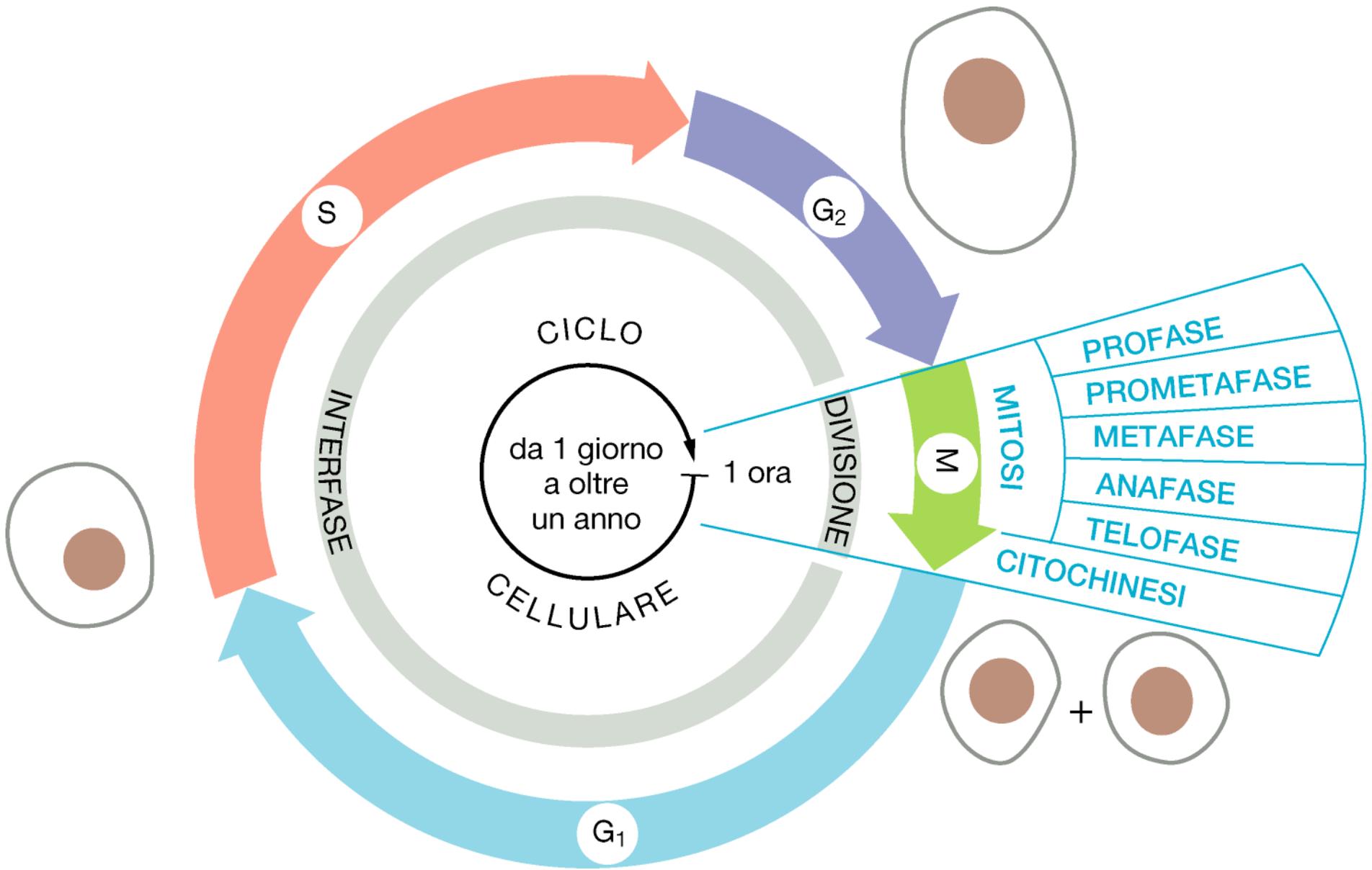


replicazione del DNA  
riparazione del DNA  
ricombinazione genetica

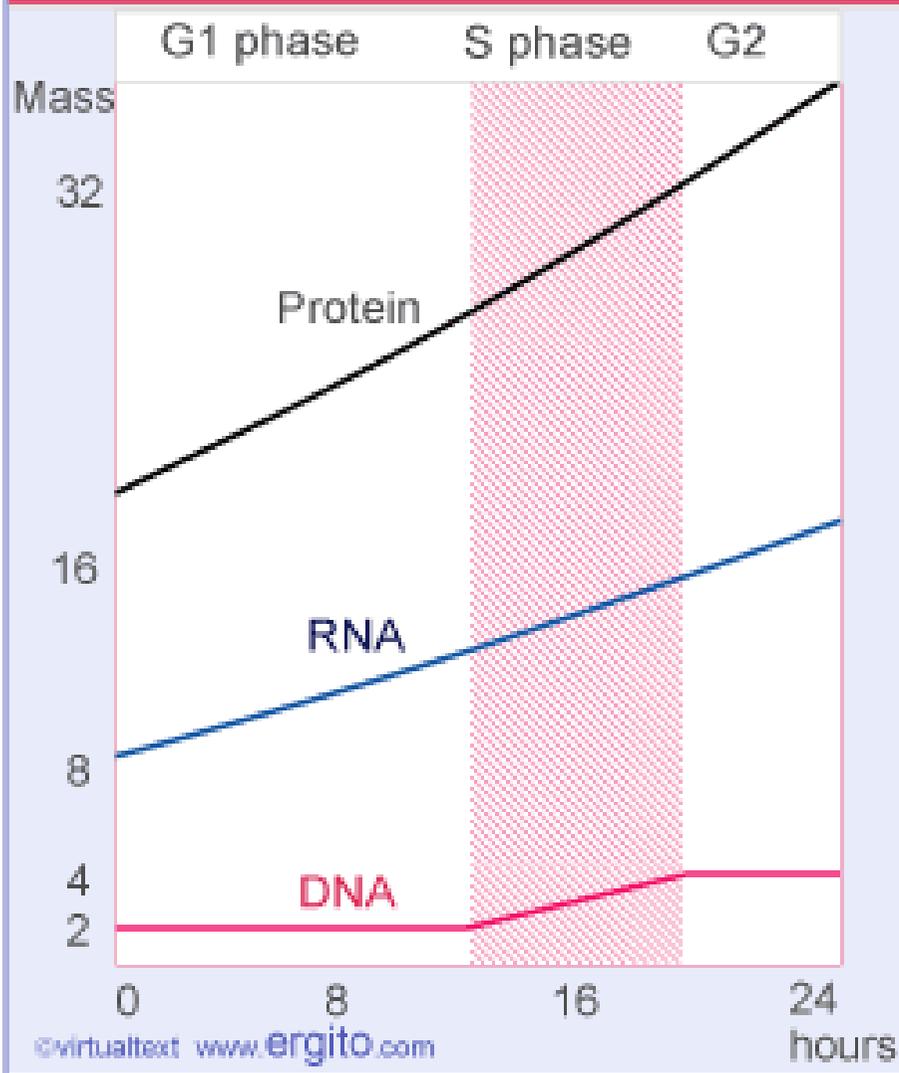


# **La Divisione Cellulare negli Eucarioti**

## **I. La Mitosi**



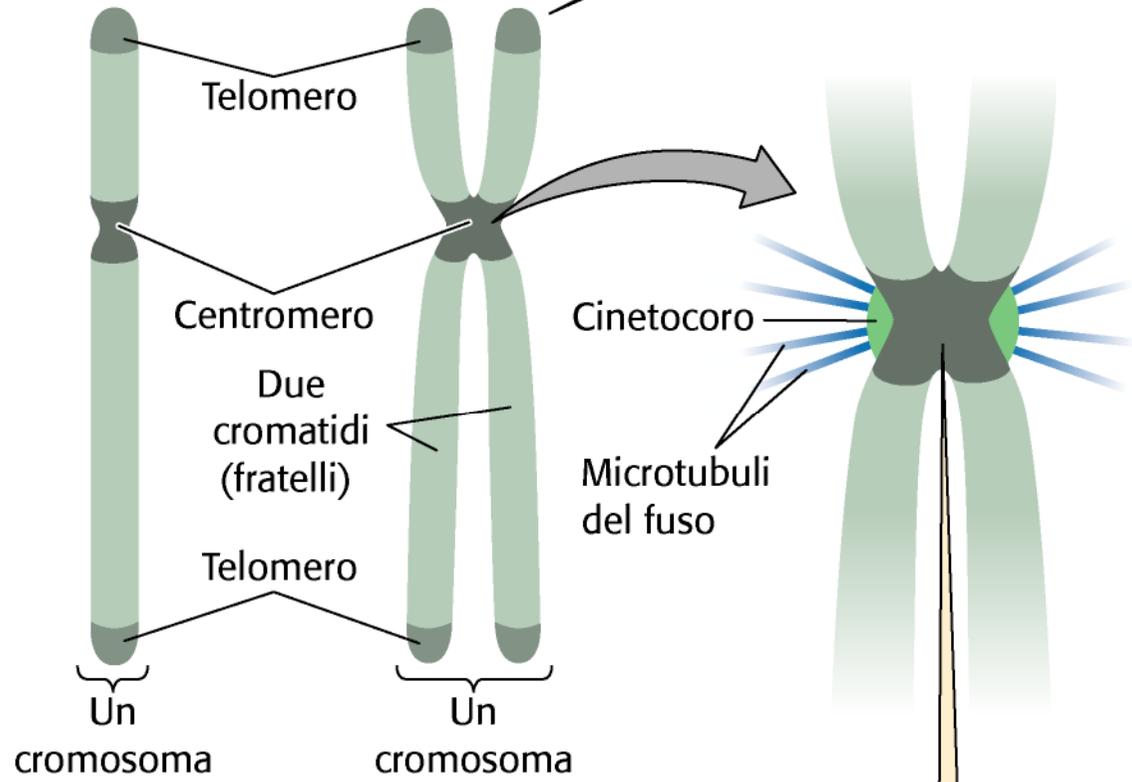
Cell growth is continuous but replication is not



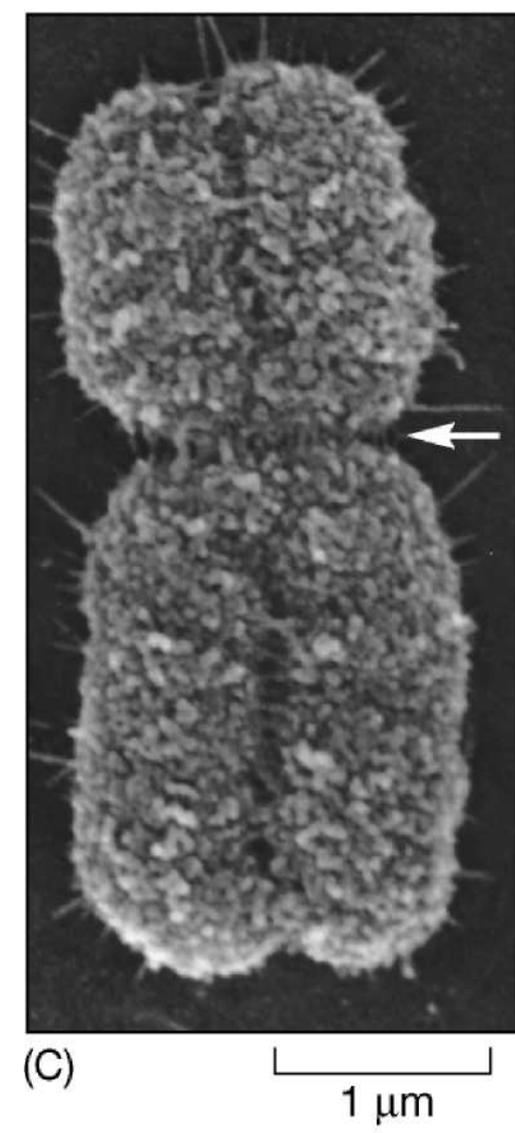
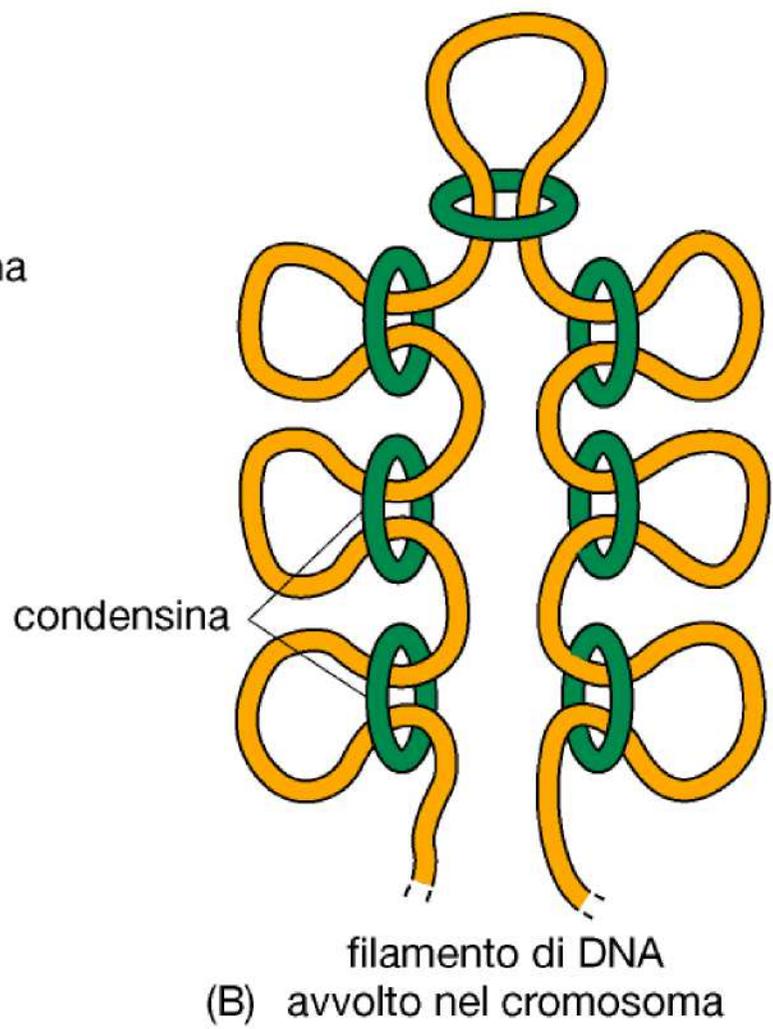
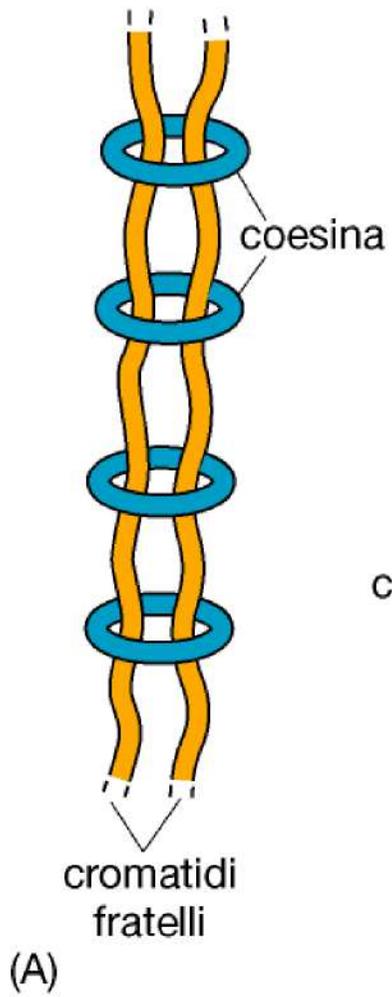
In alcuni momenti un cromosoma è costituito da un singolo cromatide...

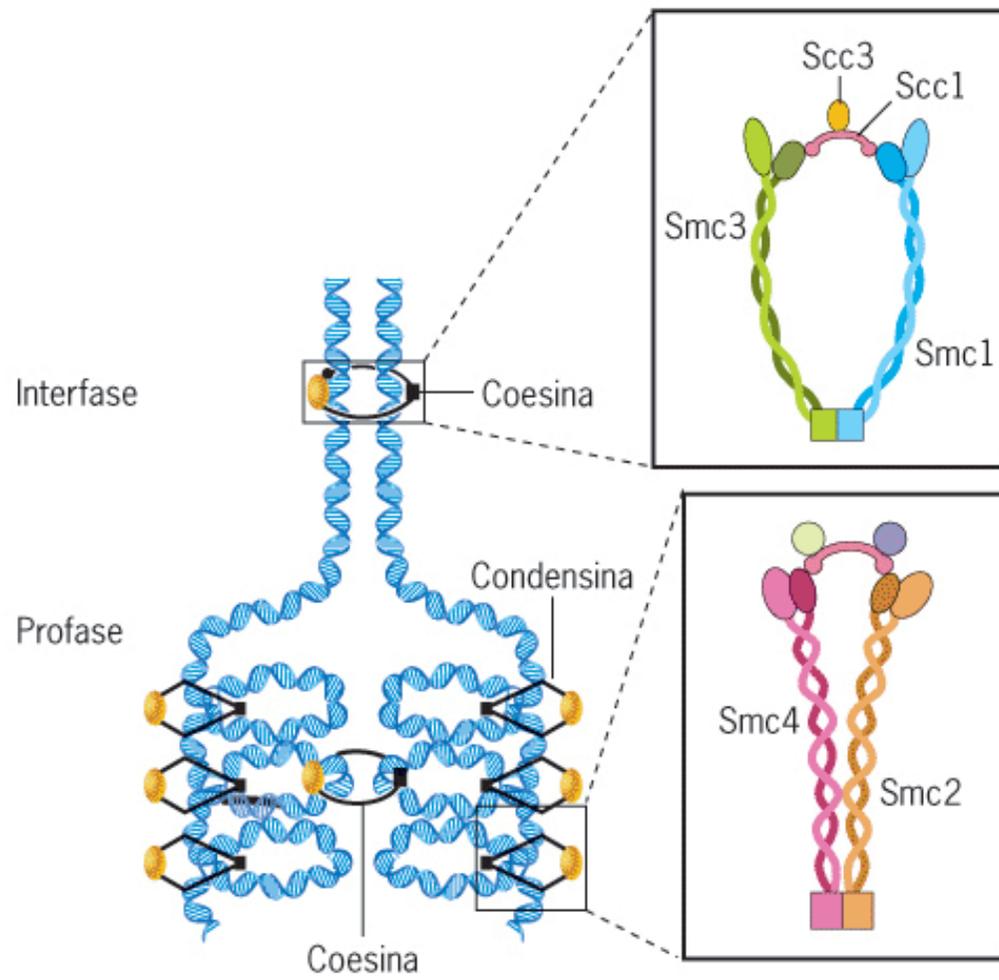
...in altri è formato da due cromatidi (fratelli).

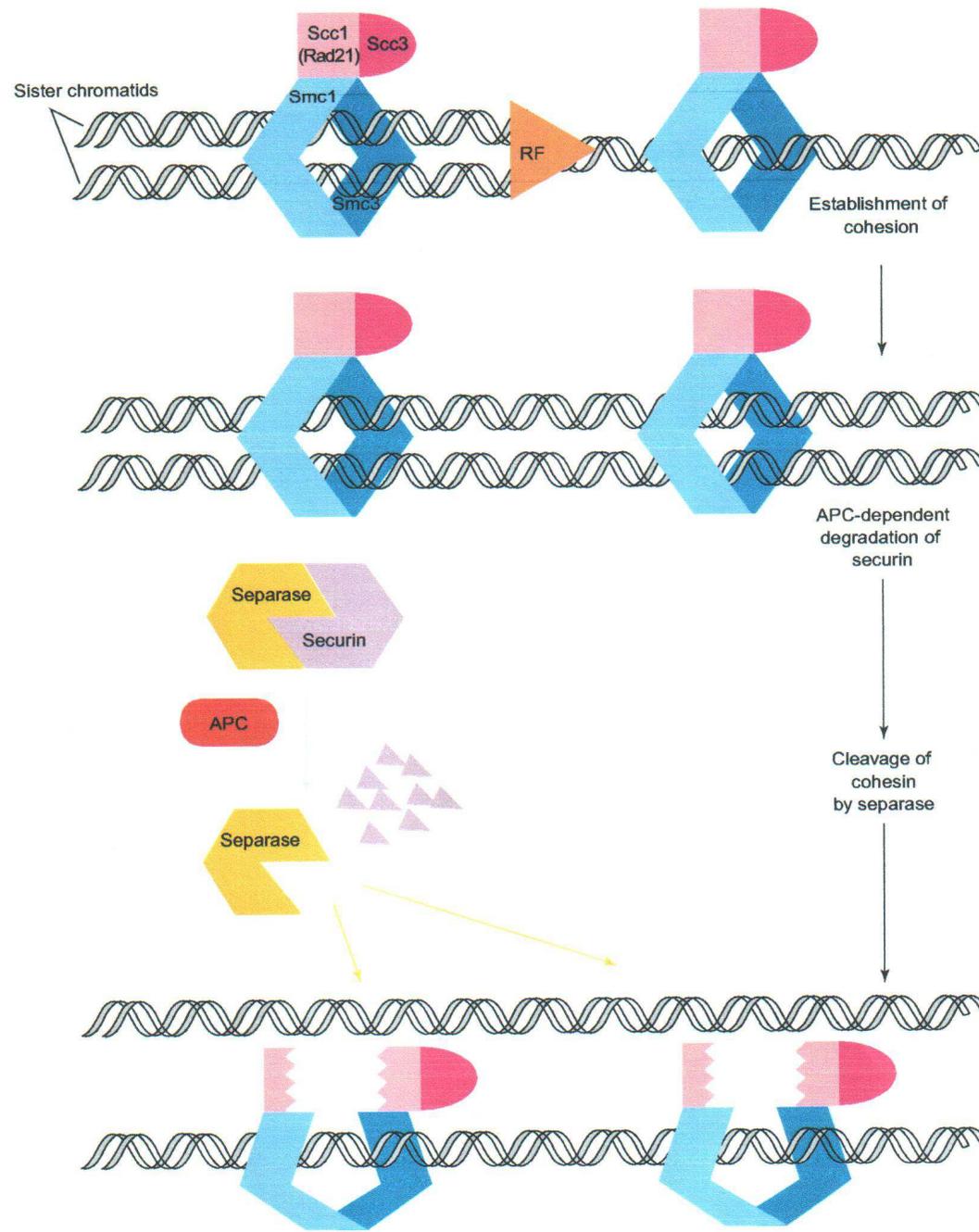
I telomeri rappresentano le estremità stabili dei cromosomi.

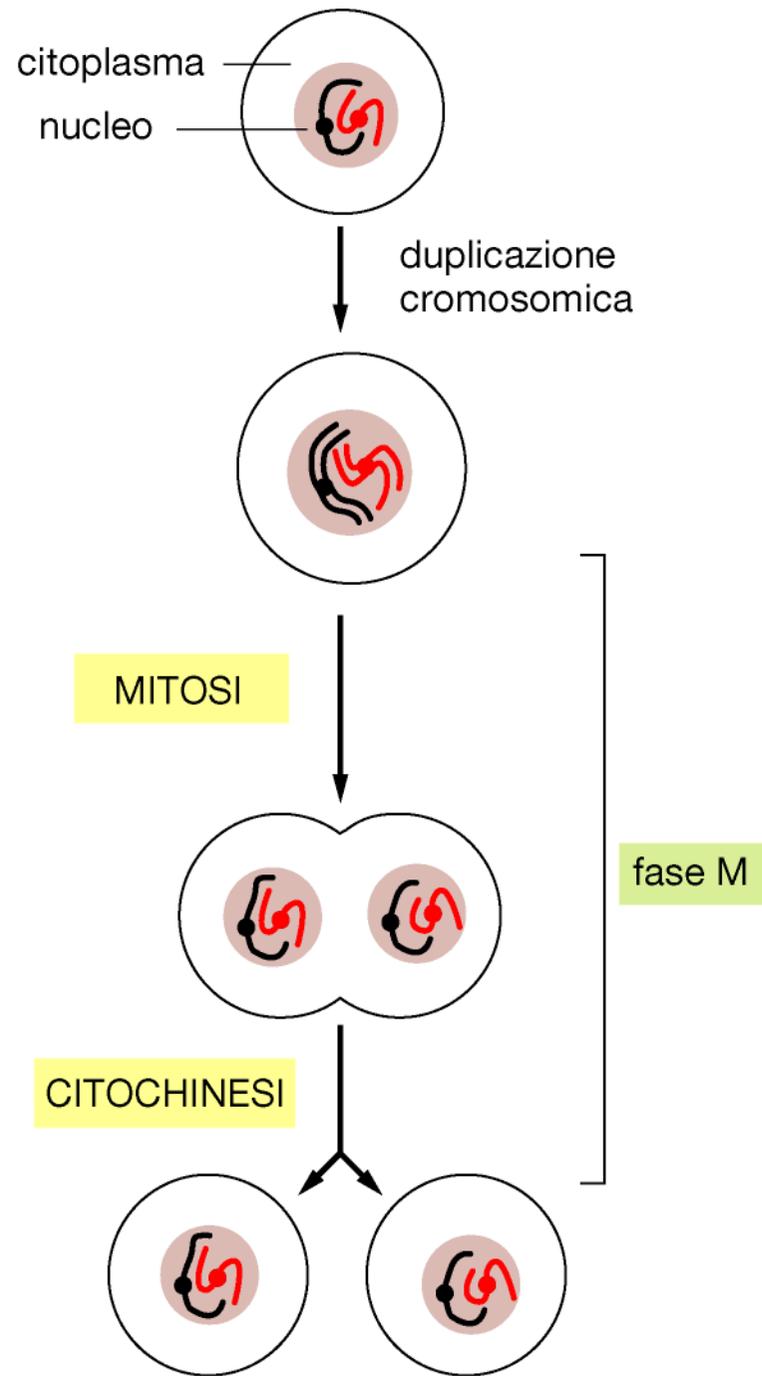


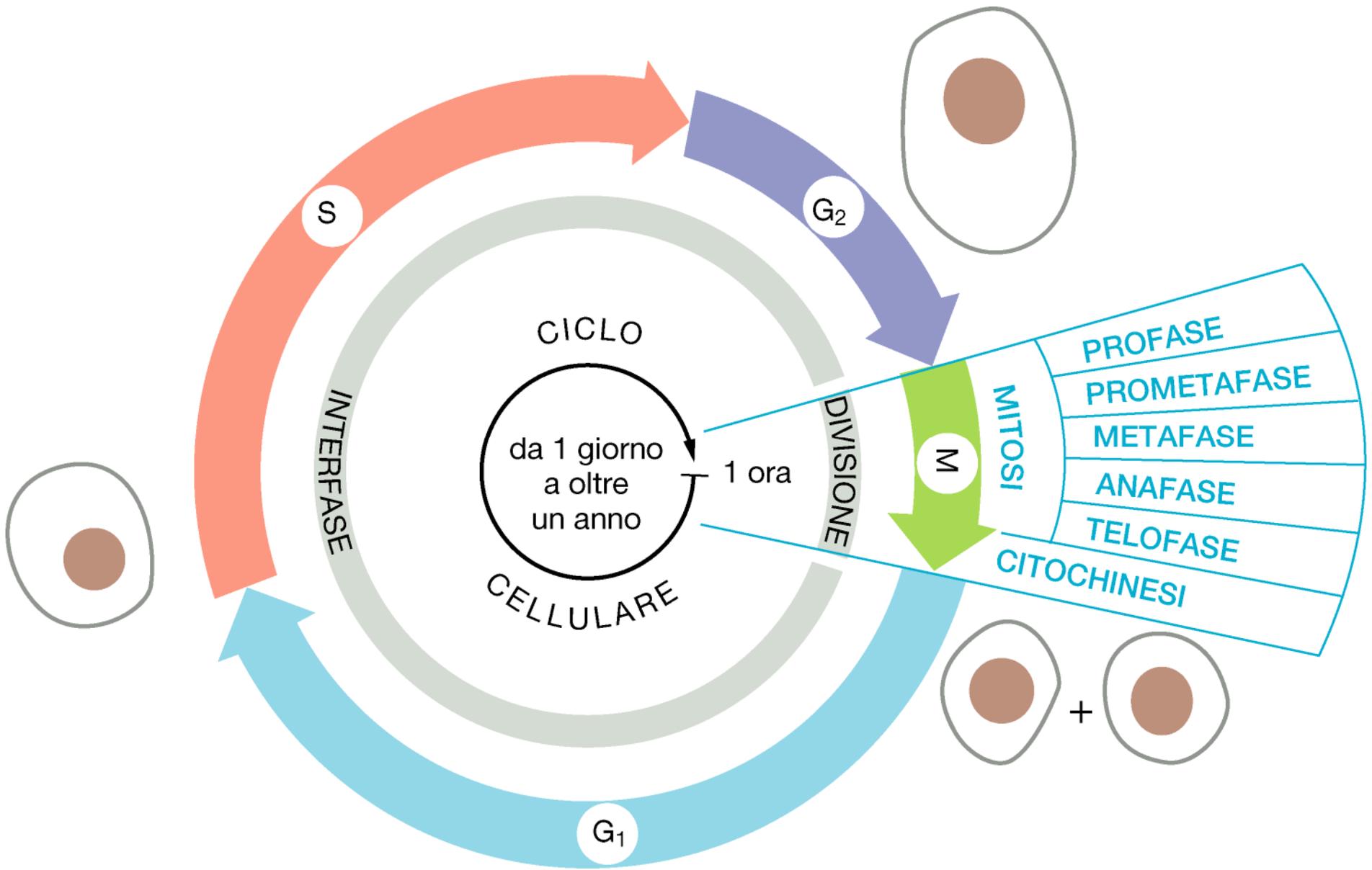
Il centromero è una regione contratta del cromosoma in cui si forma il cinetocoro e a cui si attaccano i microtubuli del fuso.



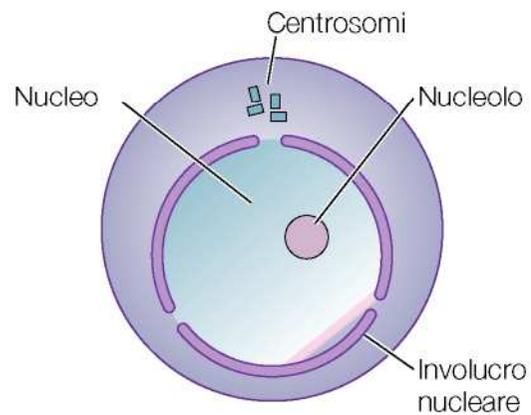
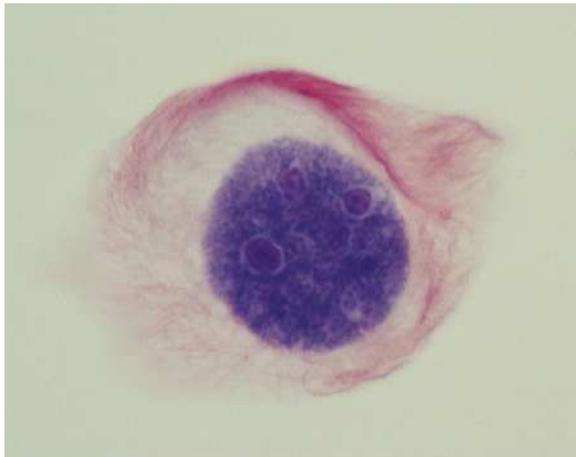






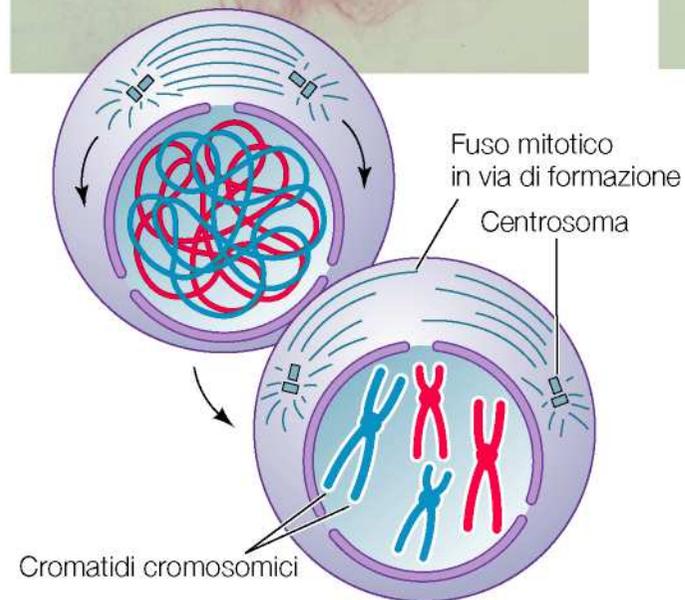
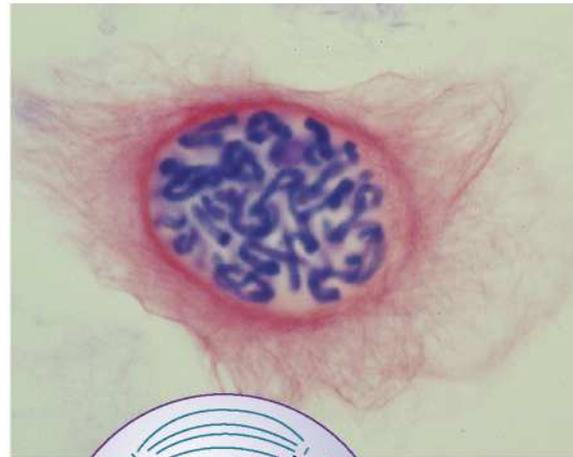


## Interfase



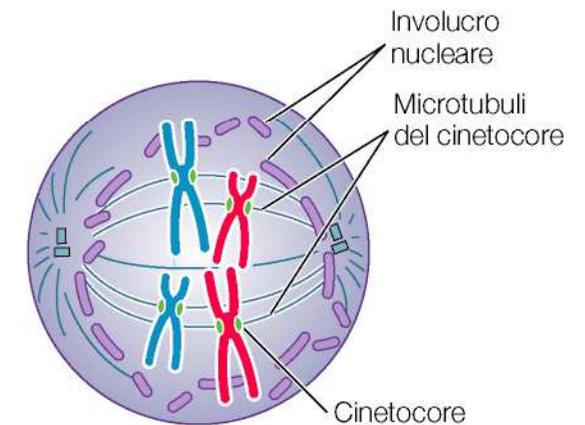
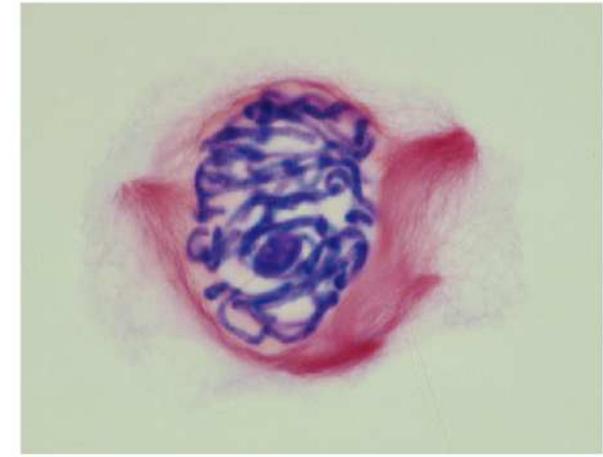
**1** Durante la fase S dell'interfase il nucleo duplica il proprio DNA e i centrosomi.

## Profase

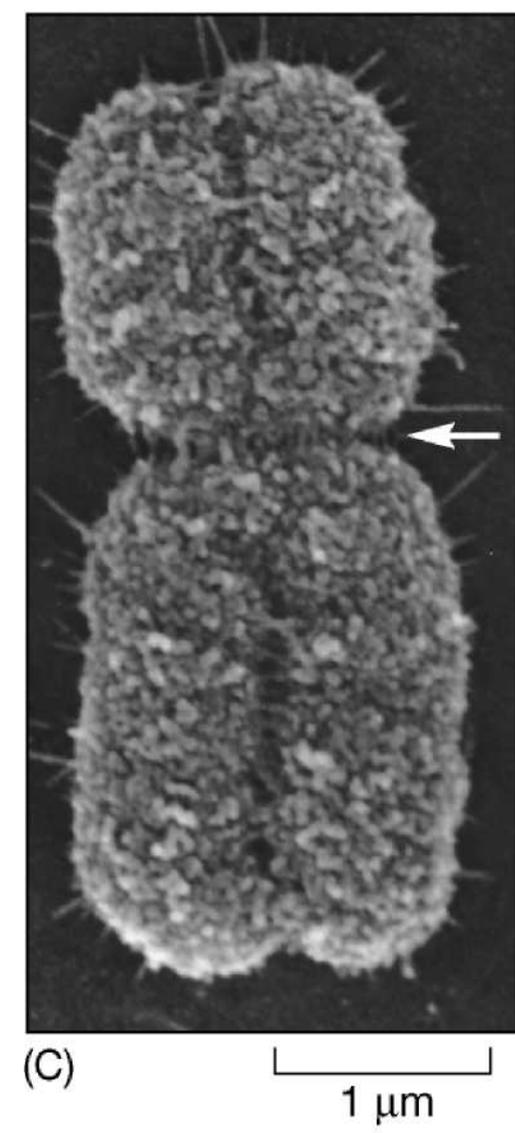
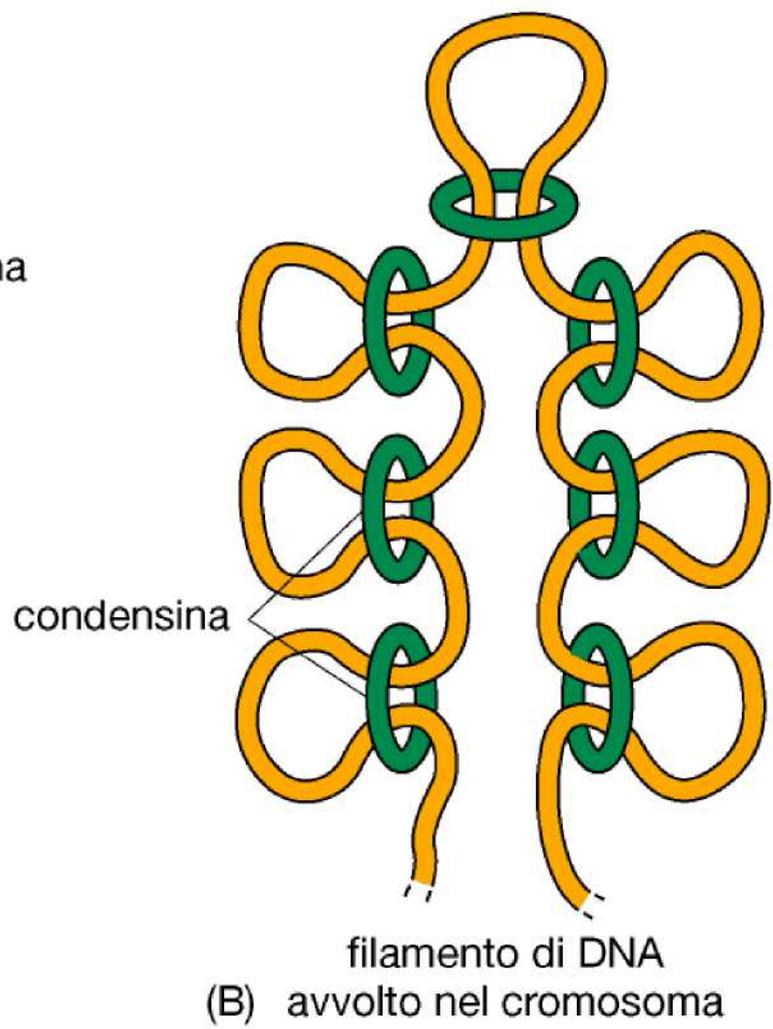
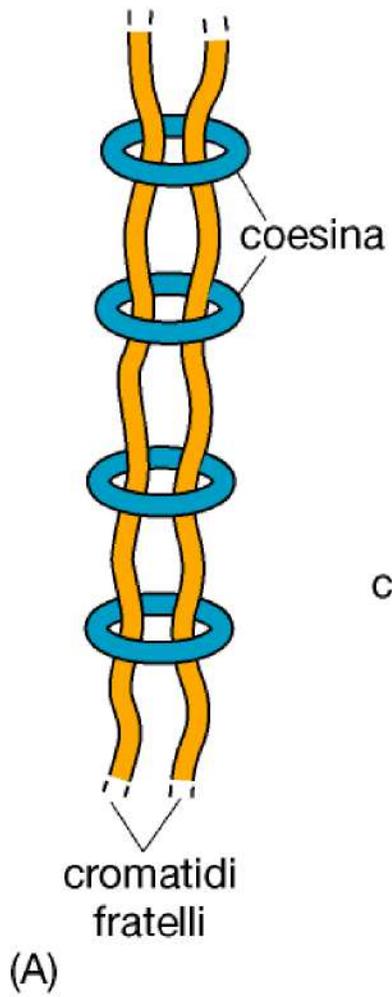


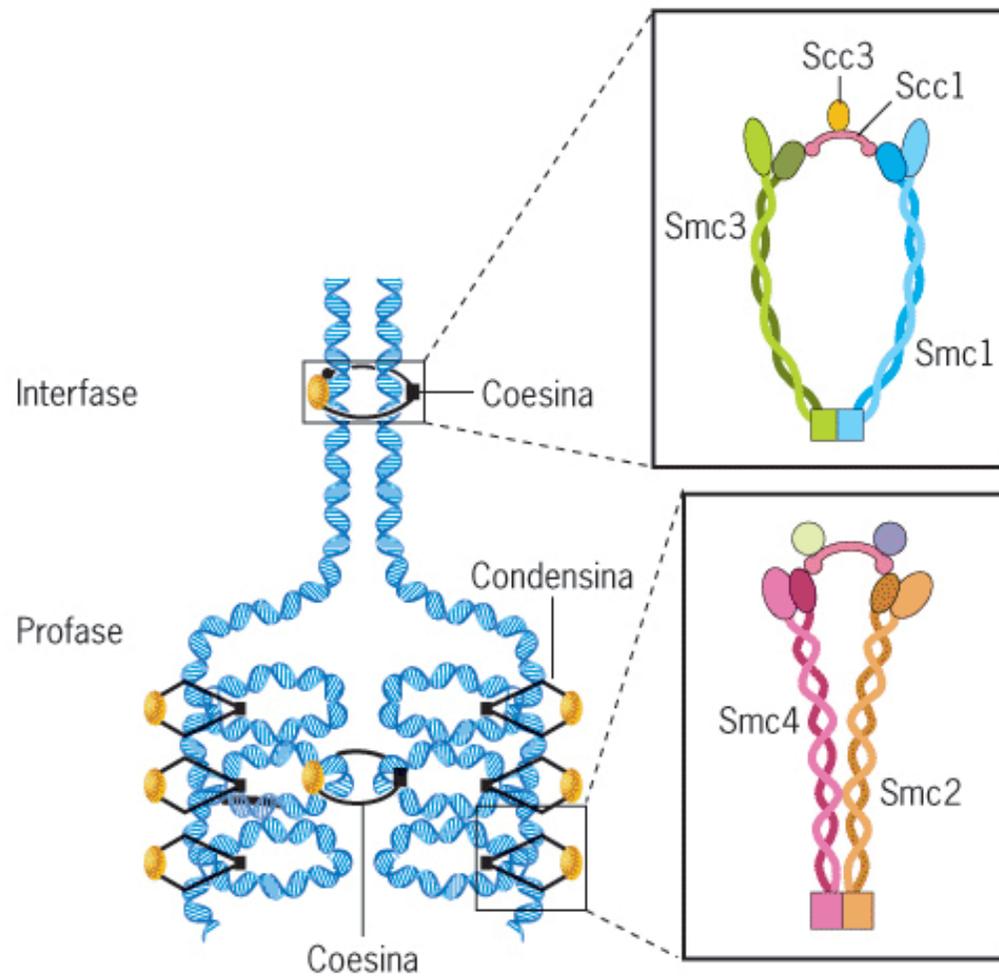
**2** La cromatina si spiralizza e si condensa, diventando sempre più compatta fino ad assumere la forma di cromosomi. I cromosomi sono costituiti da cromatidi fratelli appaiati e identici fra loro.

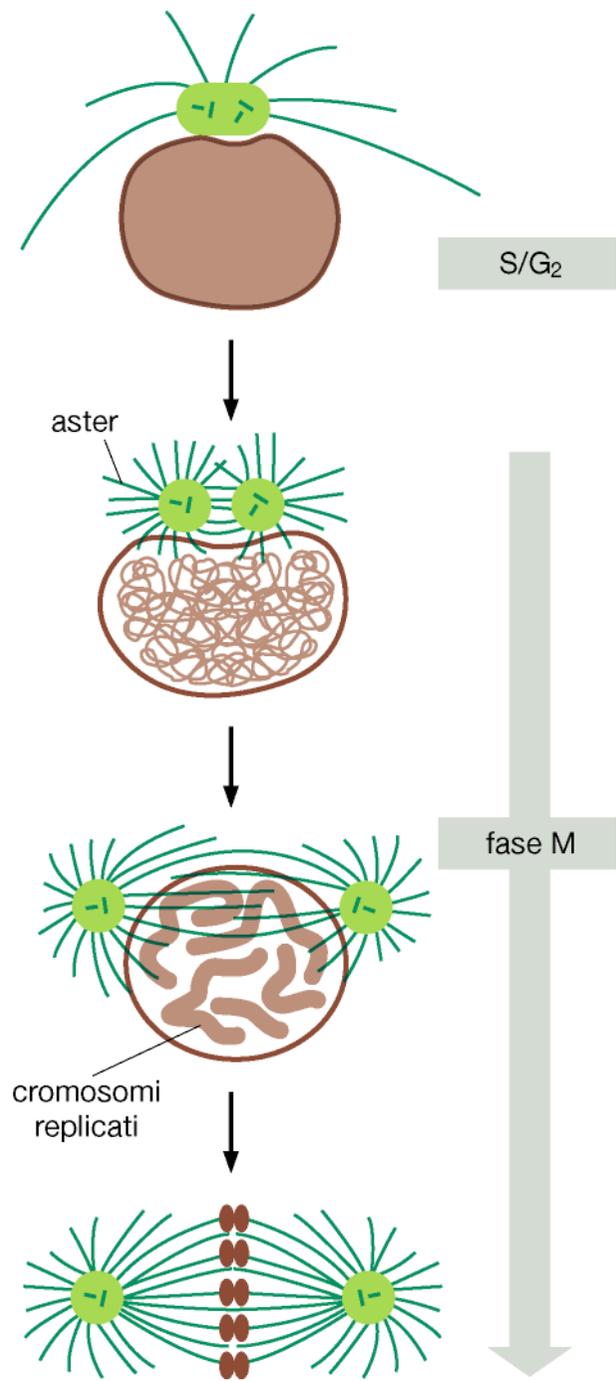
## Prometafase

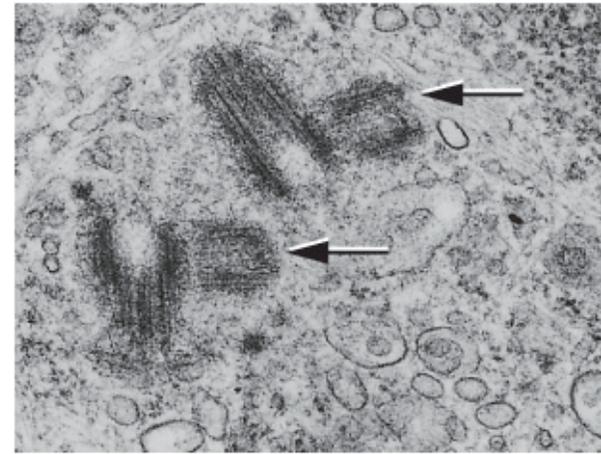
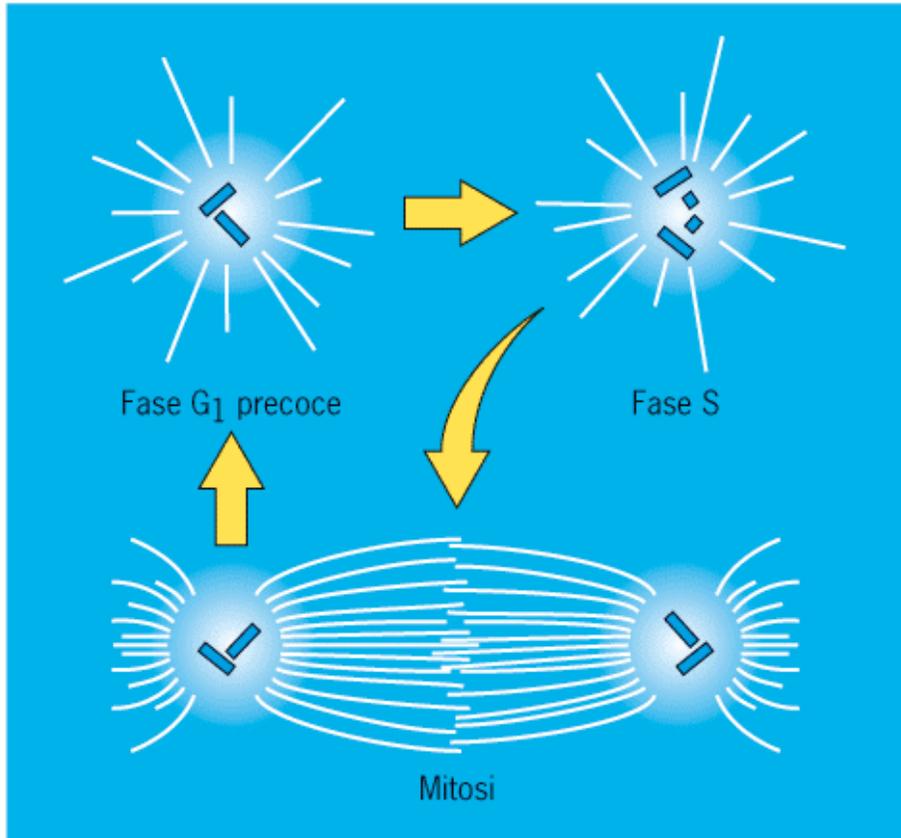


**3** L'involucro nucleare si dissolve, i microtubuli del cinetocore iniziano a organizzarsi e collegano i cinetocori con i centri di organizzazione dei microtubuli.



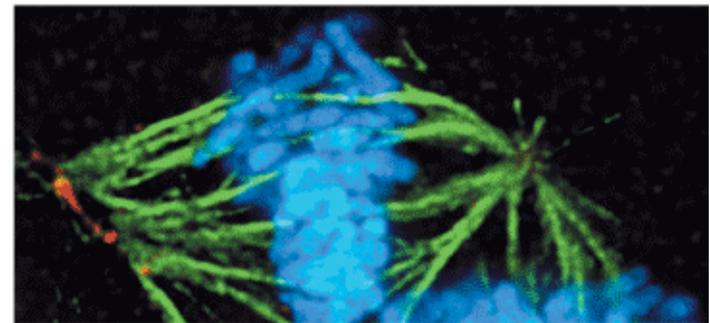




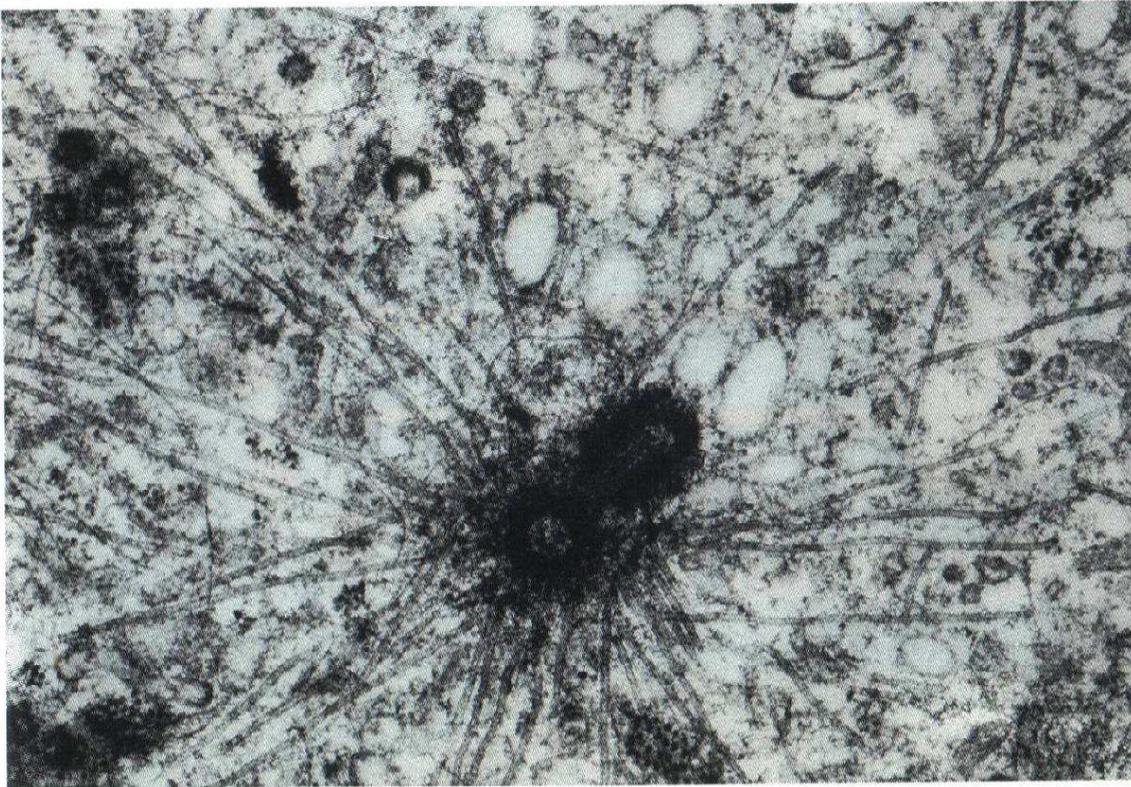


(b)

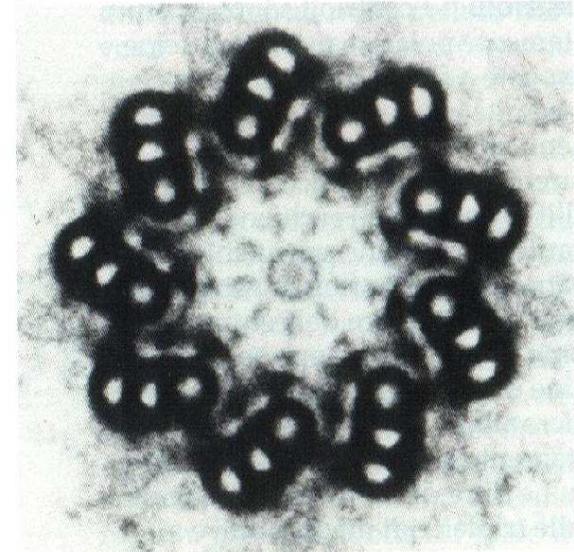
0,3  $\mu$ m



(A)

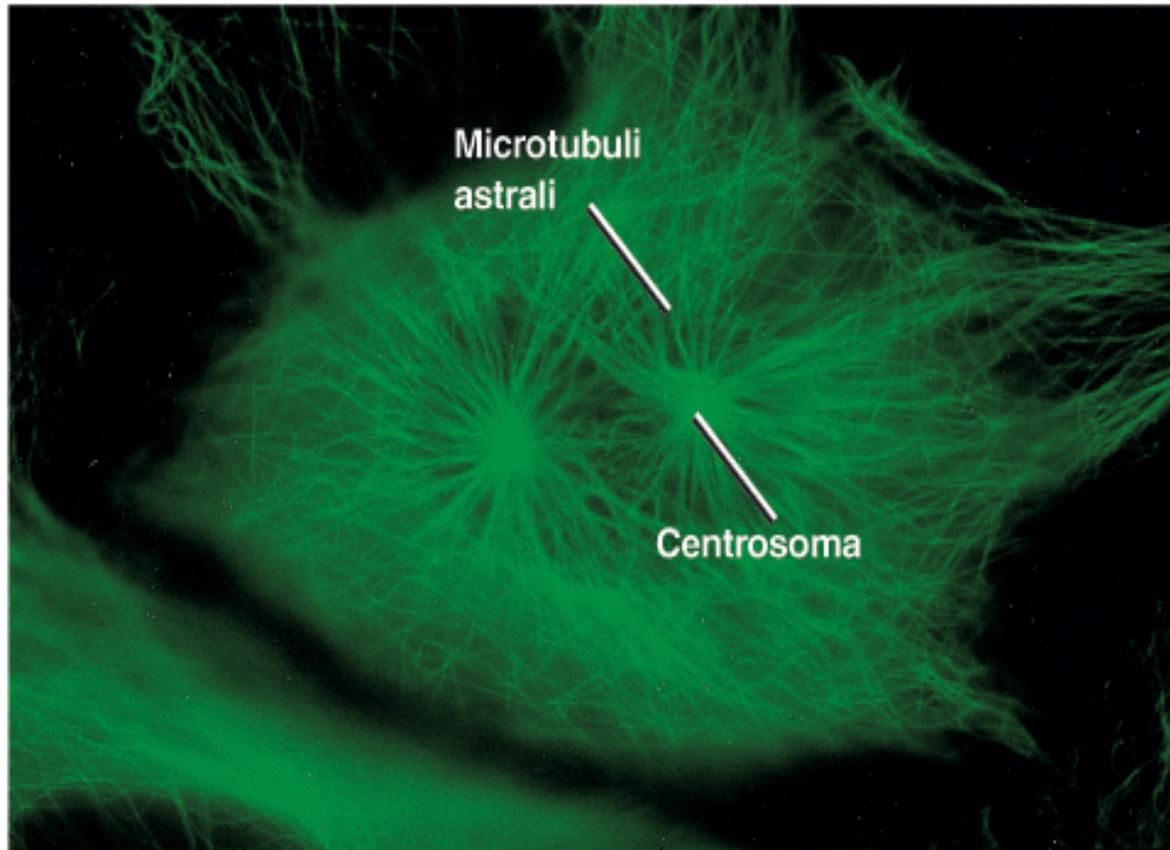


(B)



0,1  $\mu\text{m}$

**FIGURA 12.47** Struttura dei centrosomi (A) Fotografia al microscopio elettronico di un centrosoma.

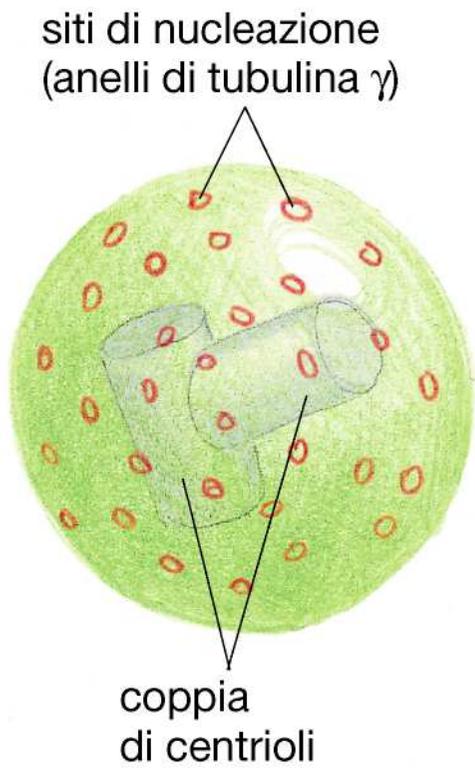


Microtubuli  
astrali

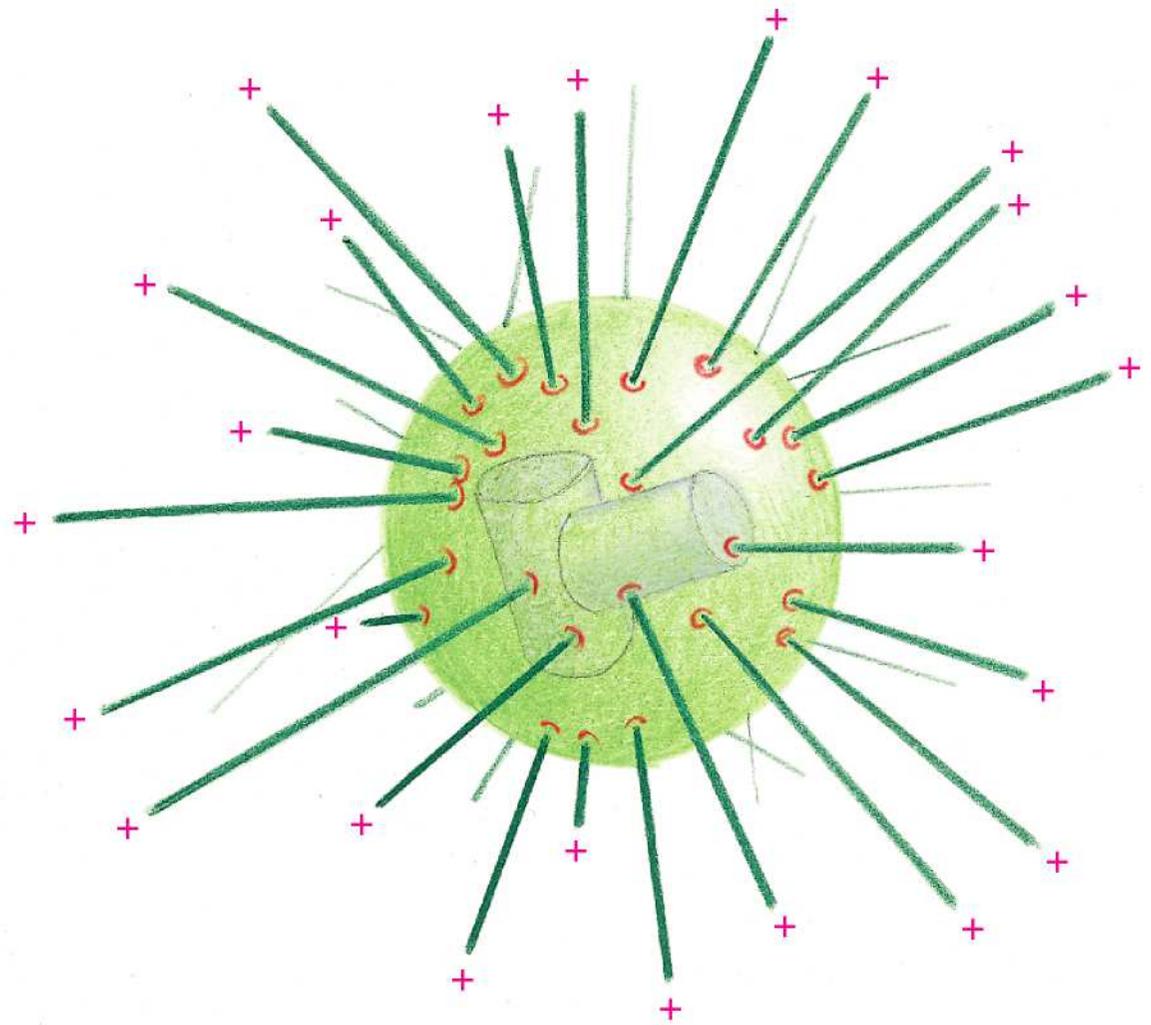
Centrosoma

---

20  $\mu\text{m}$



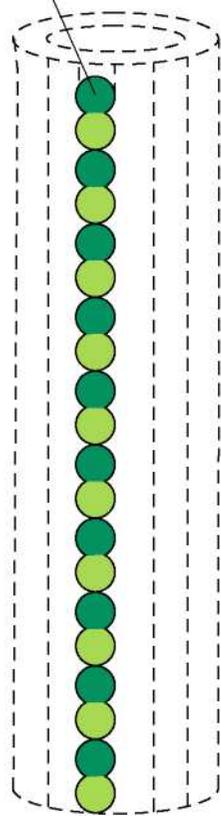
(A)



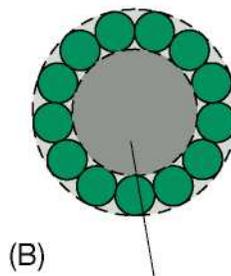
(B) microtubuli che crescono da complessi anulari di tubulina  $\gamma$  del centrosoma

$\beta$   
 $\alpha$   
eterodimero di tubulina  
(=subunità del microtubulo)

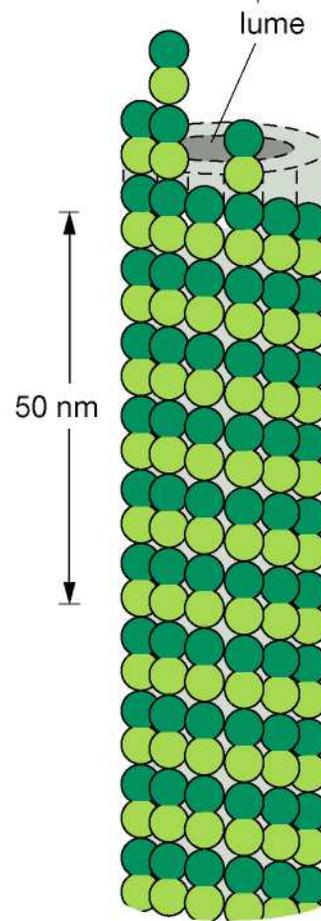
protofilamento



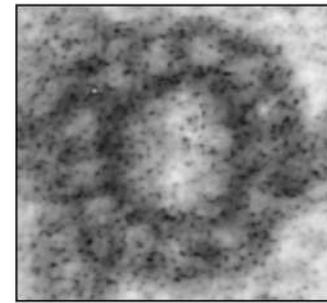
(A)



(B)

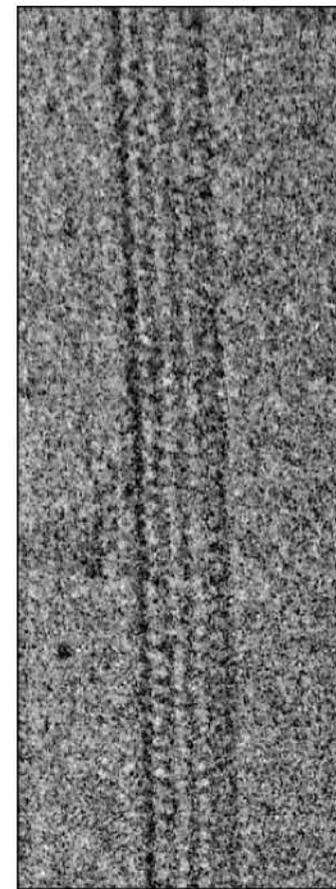


(C) microtubulo



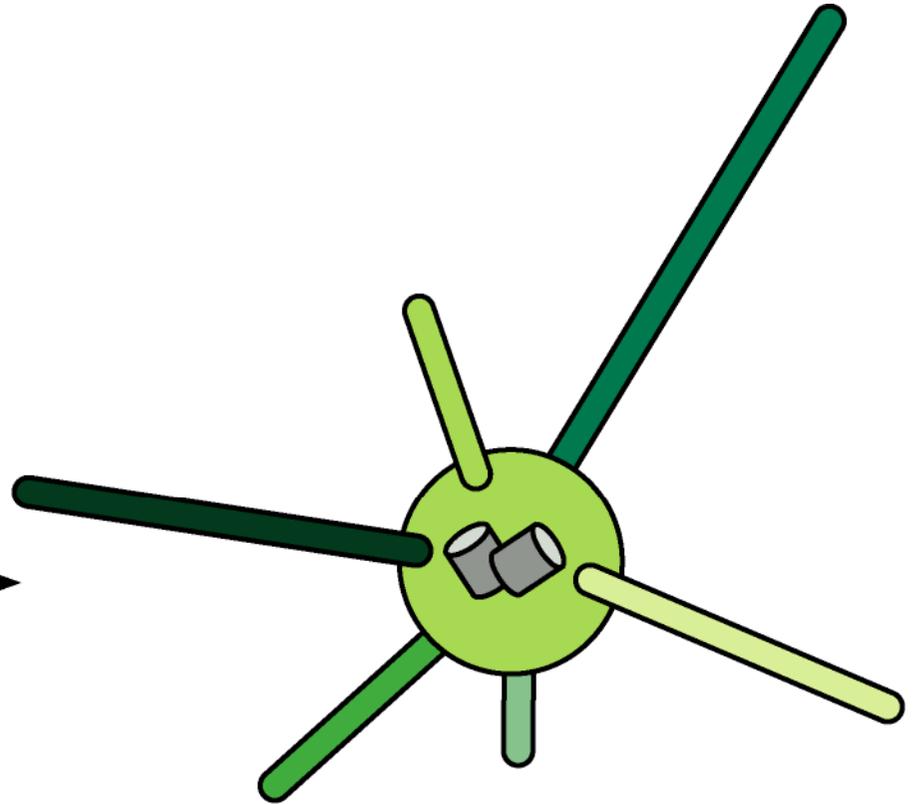
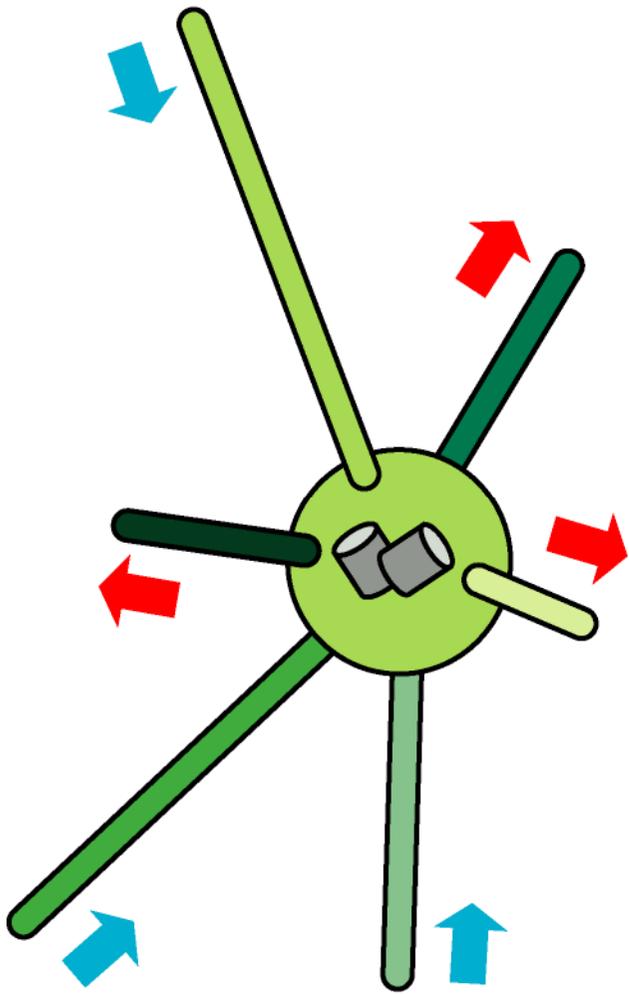
(D)

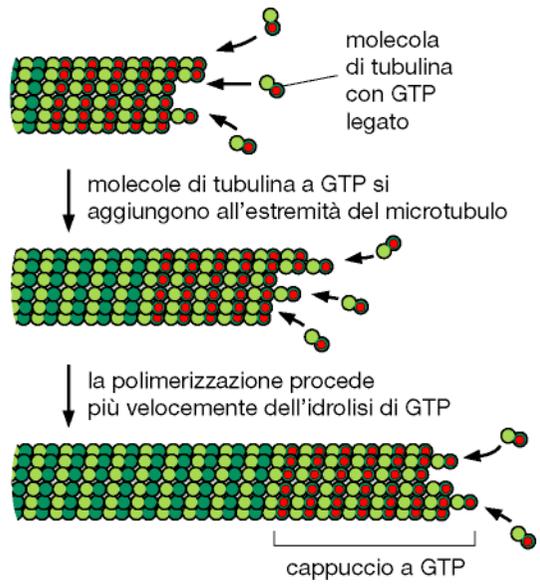
10 nm



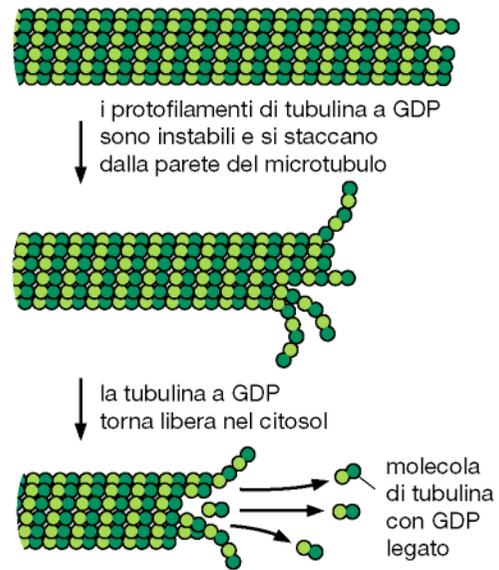
(E)

50 nm

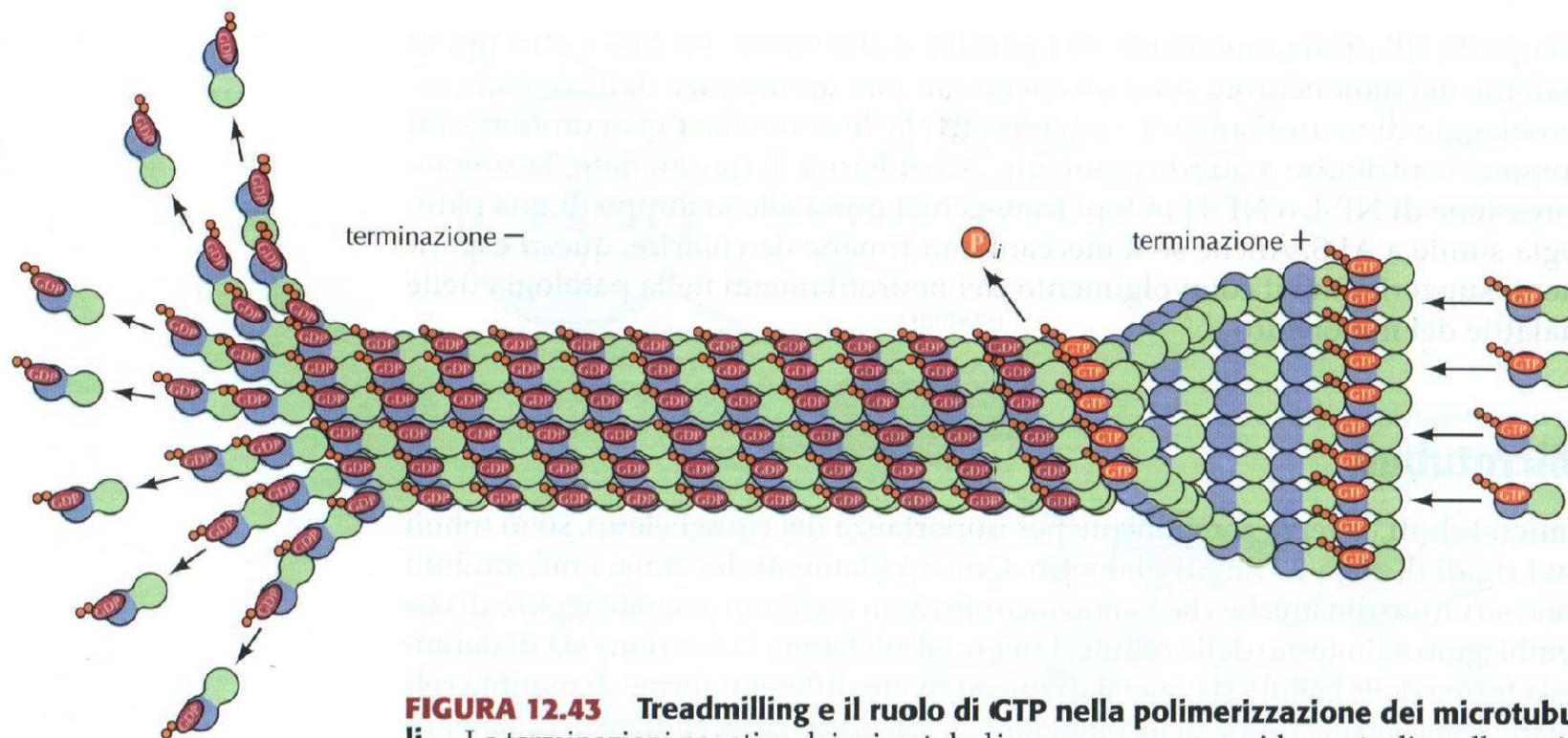




MICROTUBULO IN ALLUNGAMENTO

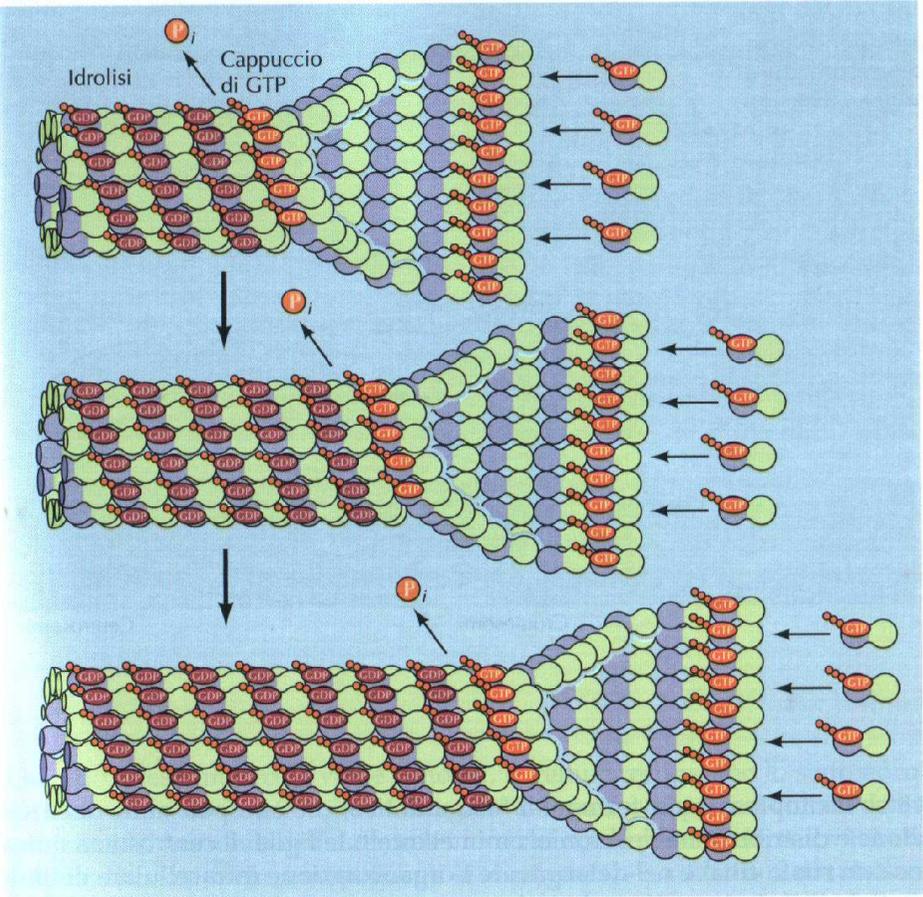


MICROTUBULO IN ACCORCIAMENTO

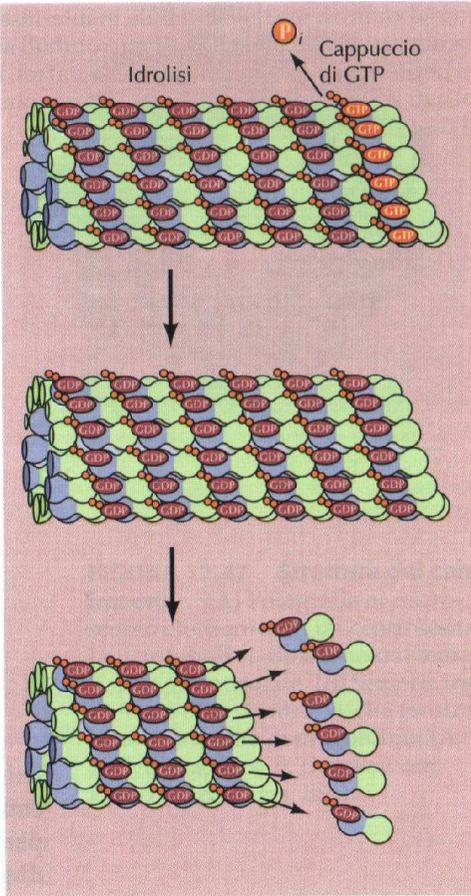


**FIGURA 12.43 Treadmilling e il ruolo di GTP nella polimerizzazione dei microtubuli.** Le terminazioni negative dei microtubuli crescono meno rapidamente di quelle positive. Questa differenza nelle velocità di accrescimento dipende dalla differenza nelle...

Alta concentrazione di tubulina legata a GTP

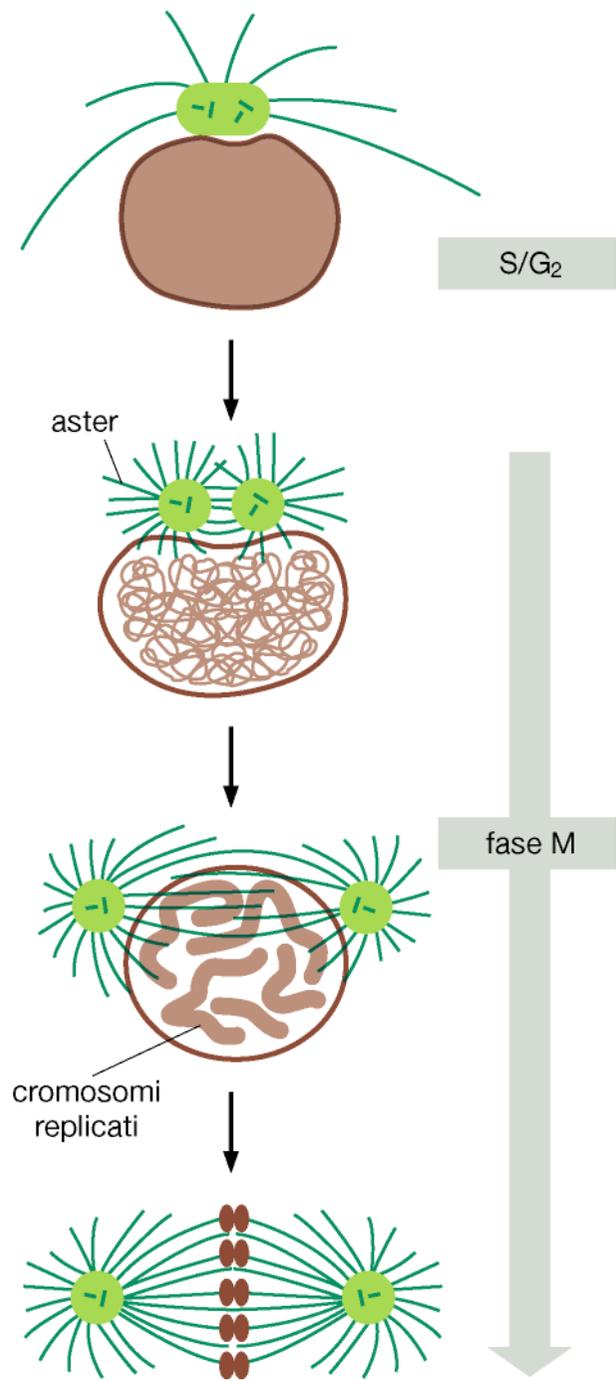


Bassa concentrazione di tubulina legata a GTP

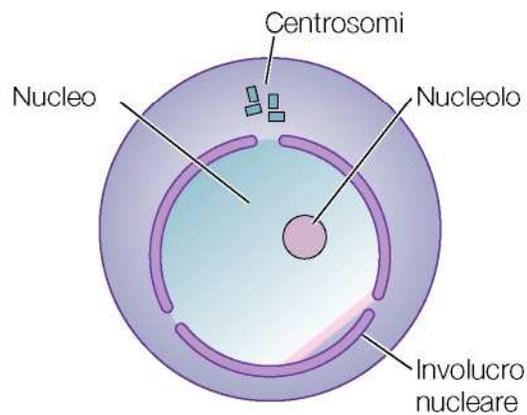


# Cambiamenti citologici nella profase

- I cromatidi si compattano, diventando più spessi e più corti. Al termine della profase sono visibili tutti i cromosomi, che sono costituiti da due cromatidi fratelli.
- Comincia ad organizzarsi il **fuso mitotico**. Dai due centrosomi si irradiano fibre che formano gli astri. I due astri si muovono verso i poli opposti della cellula, e sono connessi tramite le fibre del fuso.

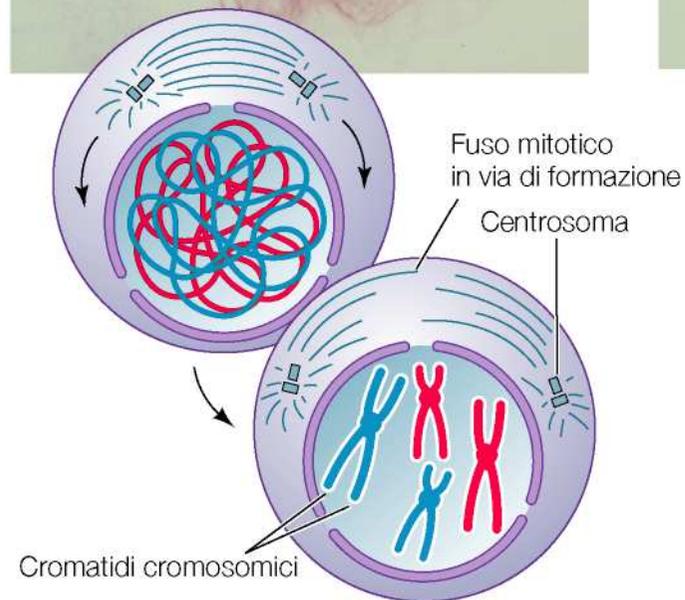
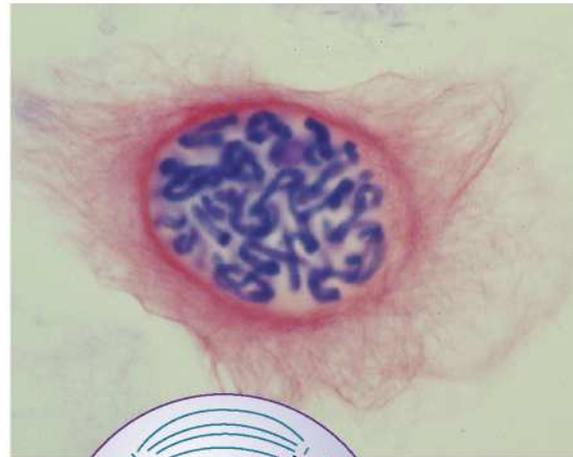


## Interfase



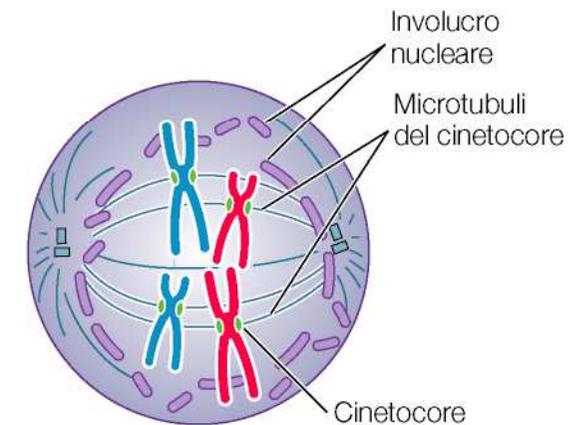
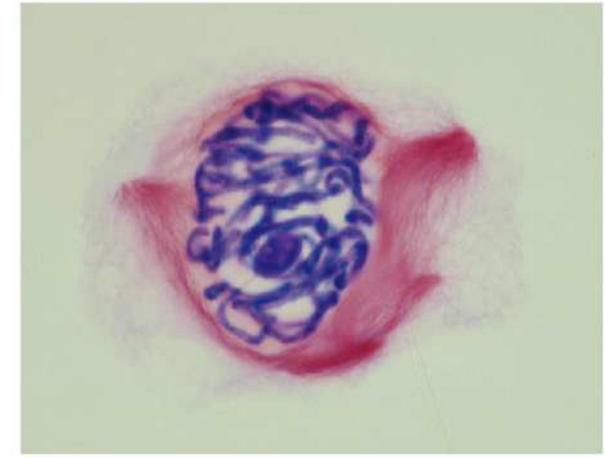
**1** Durante la fase S dell'interfase il nucleo duplica il proprio DNA e i centrosomi.

## Profase

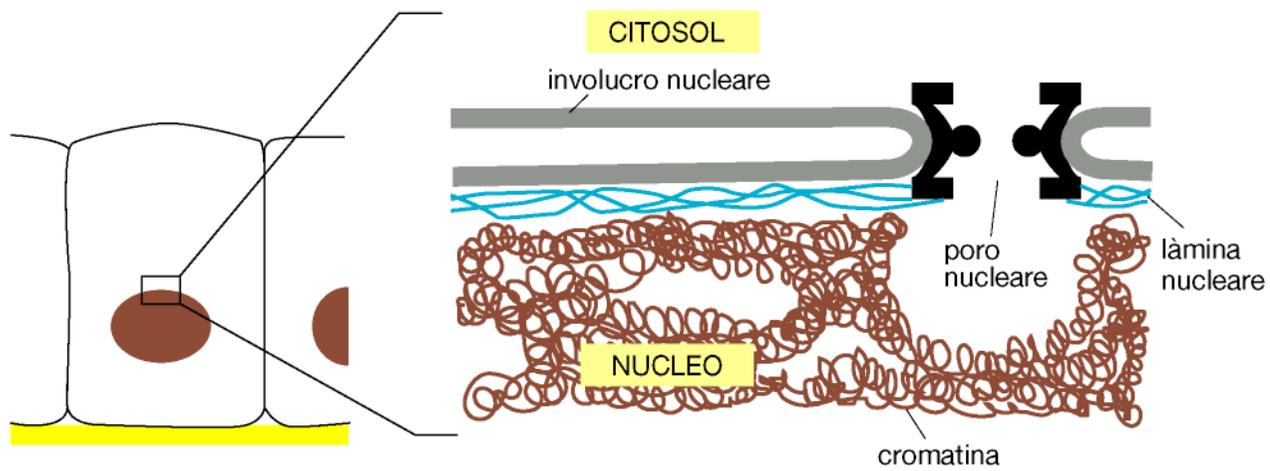


**2** La cromatina si spiralizza e si condensa, diventando sempre più compatta fino ad assumere la forma di cromosomi. I cromosomi sono costituiti da cromatidi fratelli appaiati e identici fra loro.

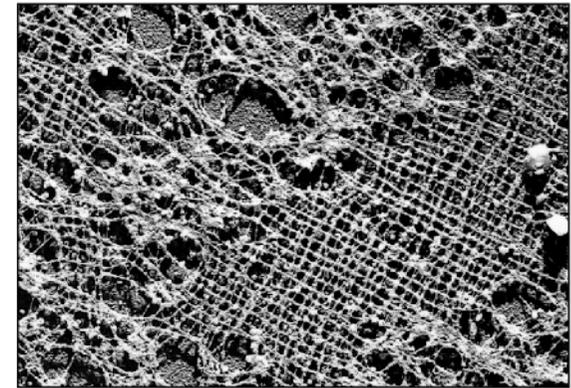
## Prometafase



**3** L'involucro nucleare si dissolve, i microtubuli del cinetocore iniziano a organizzarsi e collegano i cinetocori con i centri di organizzazione dei microtubuli.

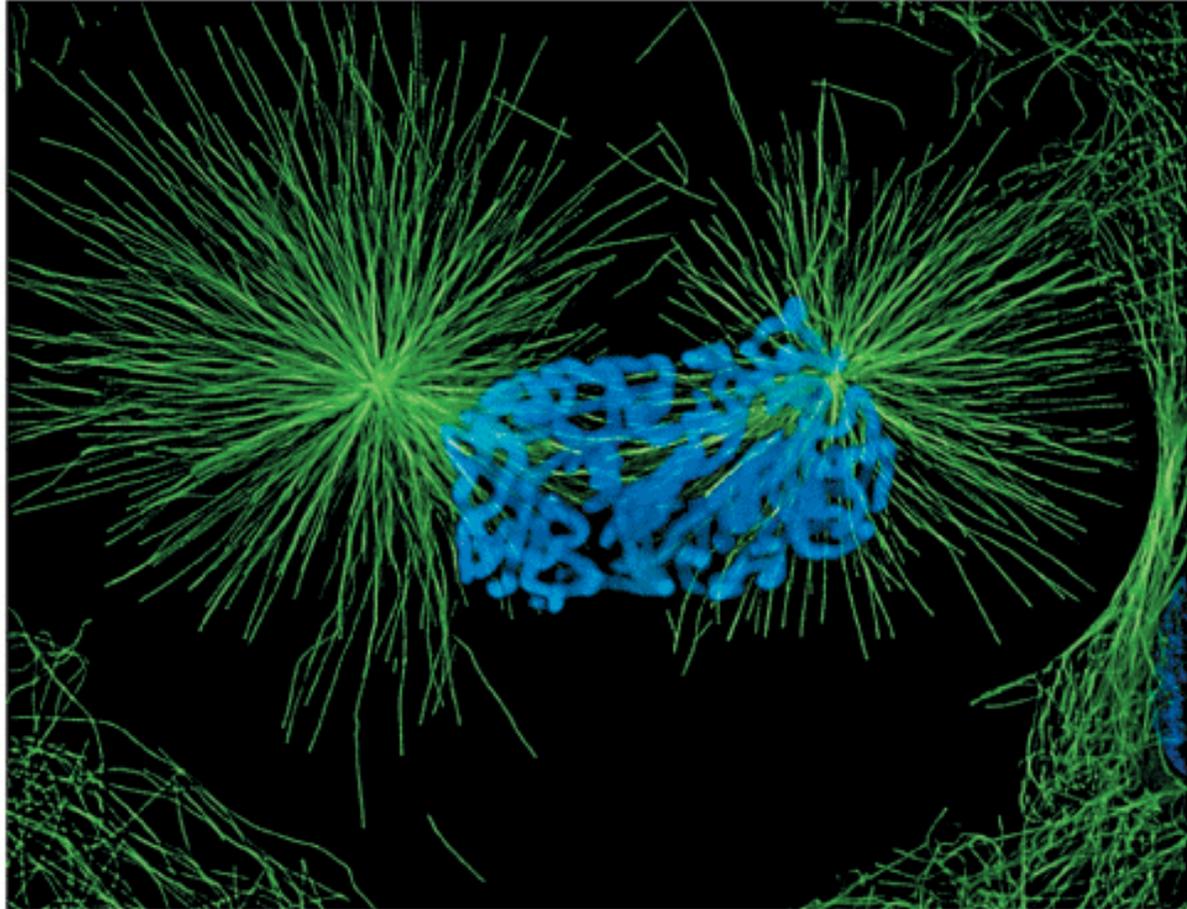


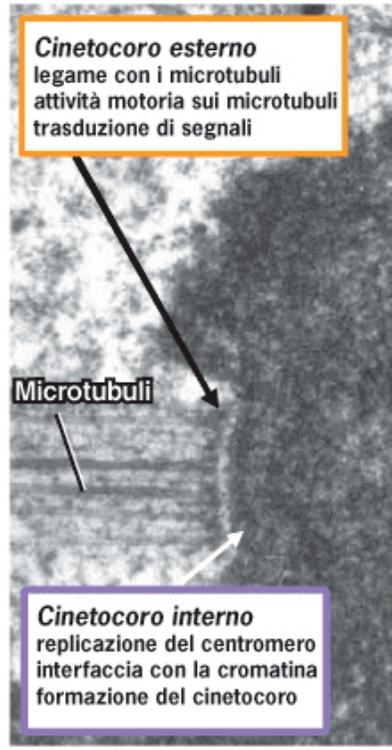
(A)



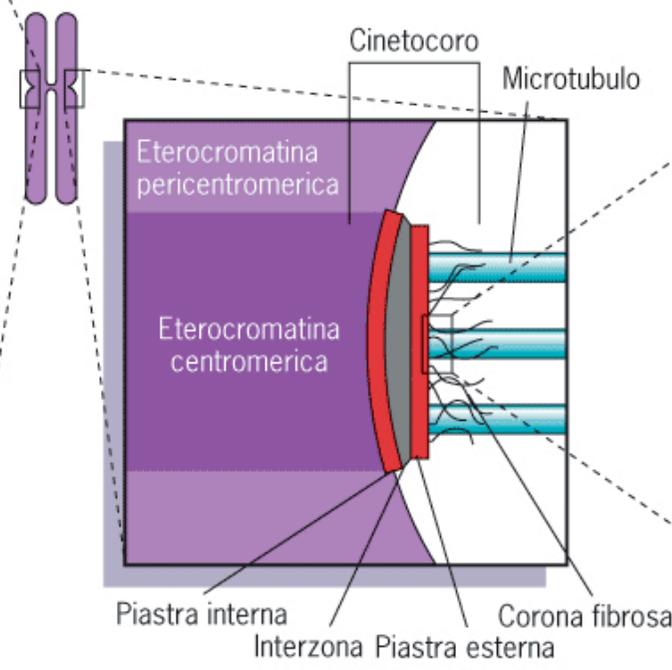
(B)

1 µm

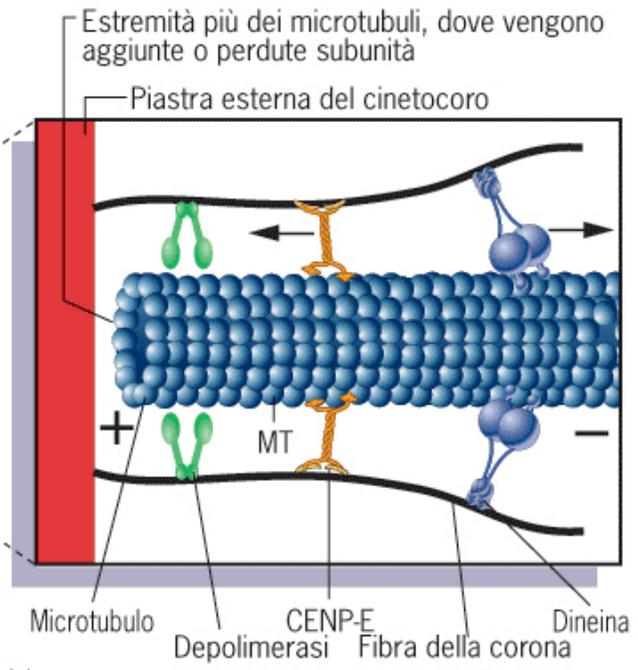




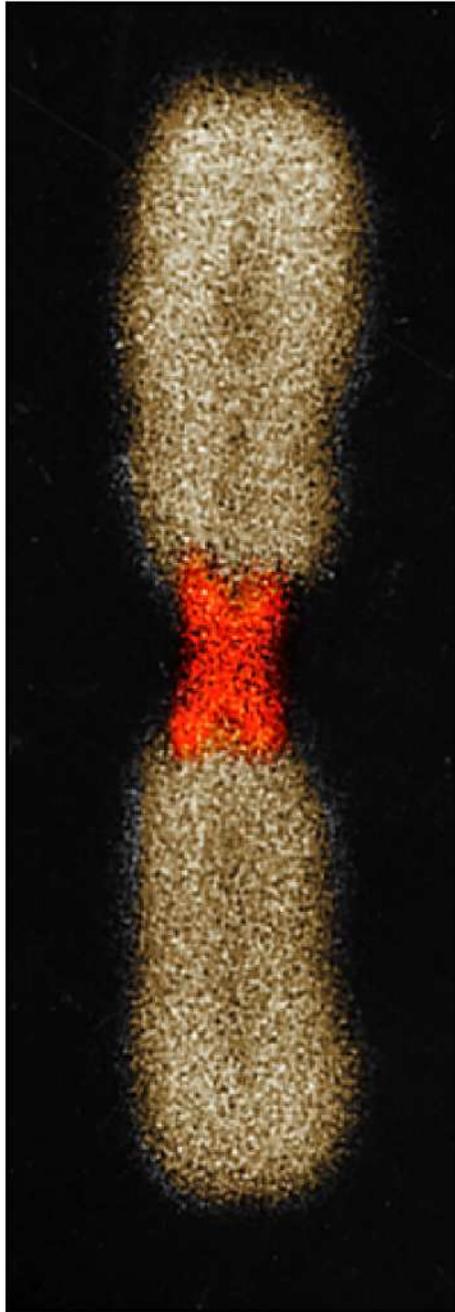
(a) 0,2 μm



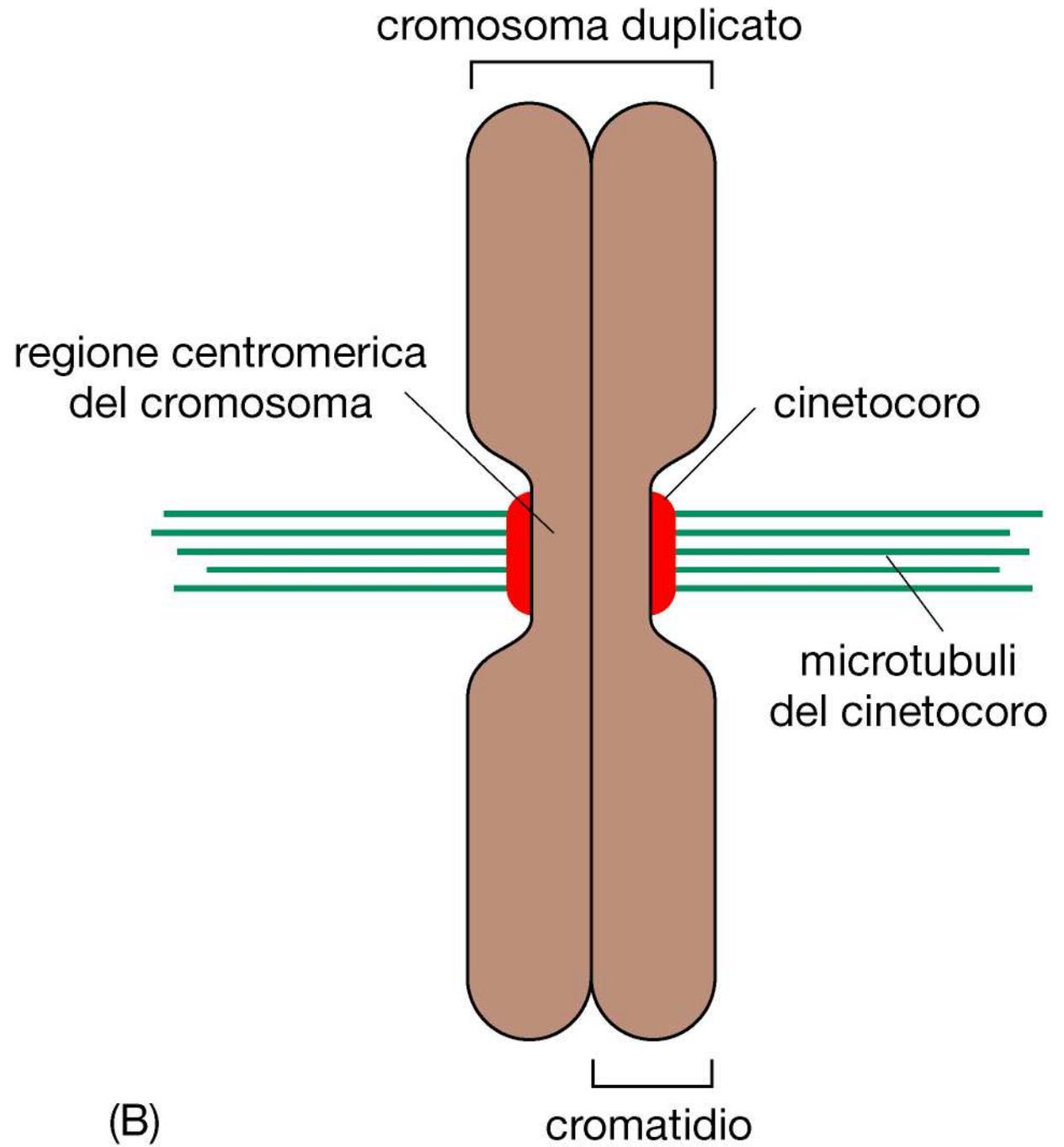
(b)



(c)



(A)



(B)

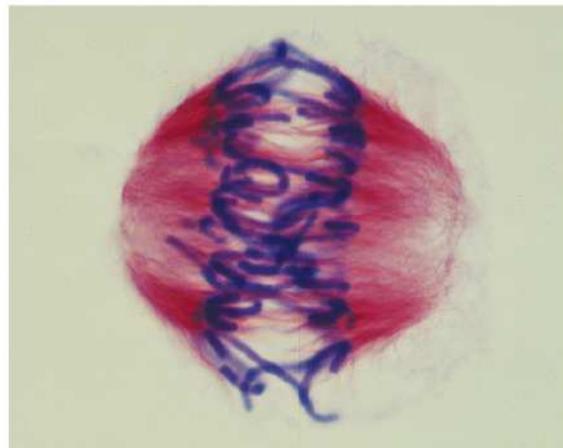
# Cambiamenti citologici nella pro-metafase

- Scomparsa della membrana nucleare.
- Completamento del fuso mitotico.
- I cinetocori (uniti al centromero durante la profase) prendono contatto con i microtubuli del fuso mitotico.

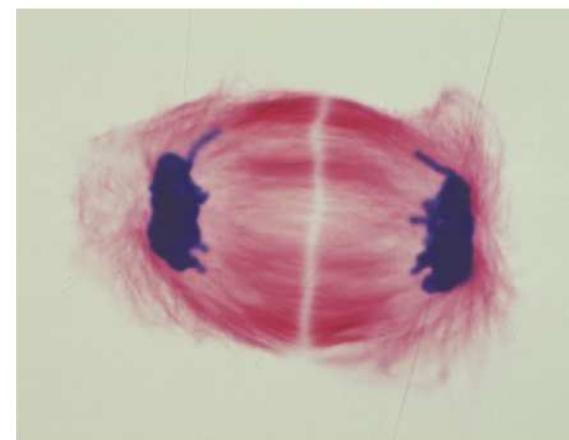
Metafase



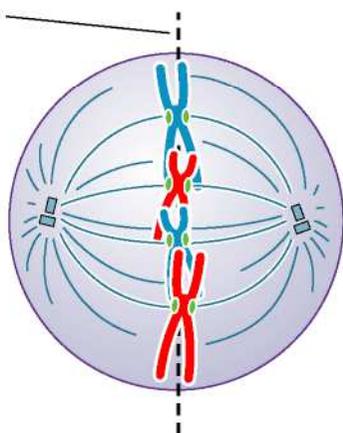
Anafase



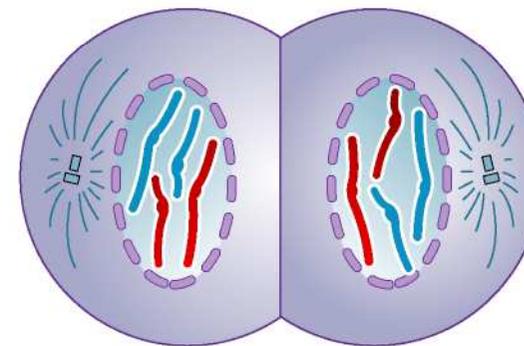
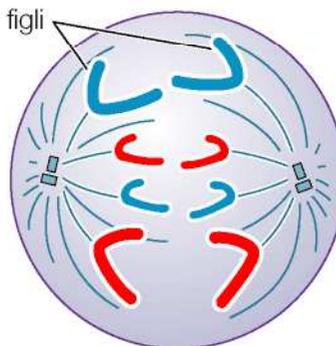
Telofase



Piastra equatoriale (o metafase)



Cromosomi figli

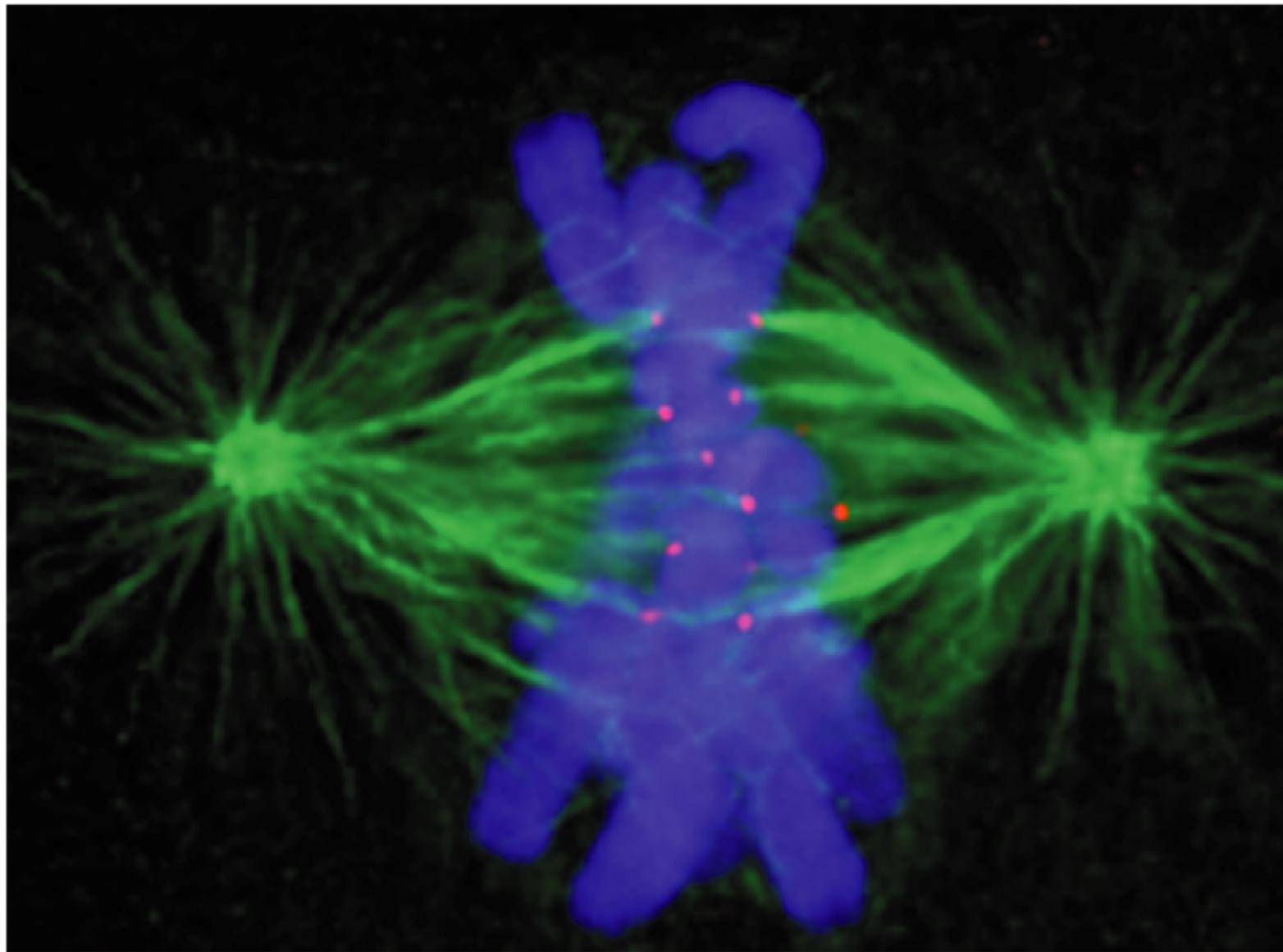


**4** I centromeri (regioni che connettono i cromatidi appaiati) si allineano sul piano equatoriale della cellula.

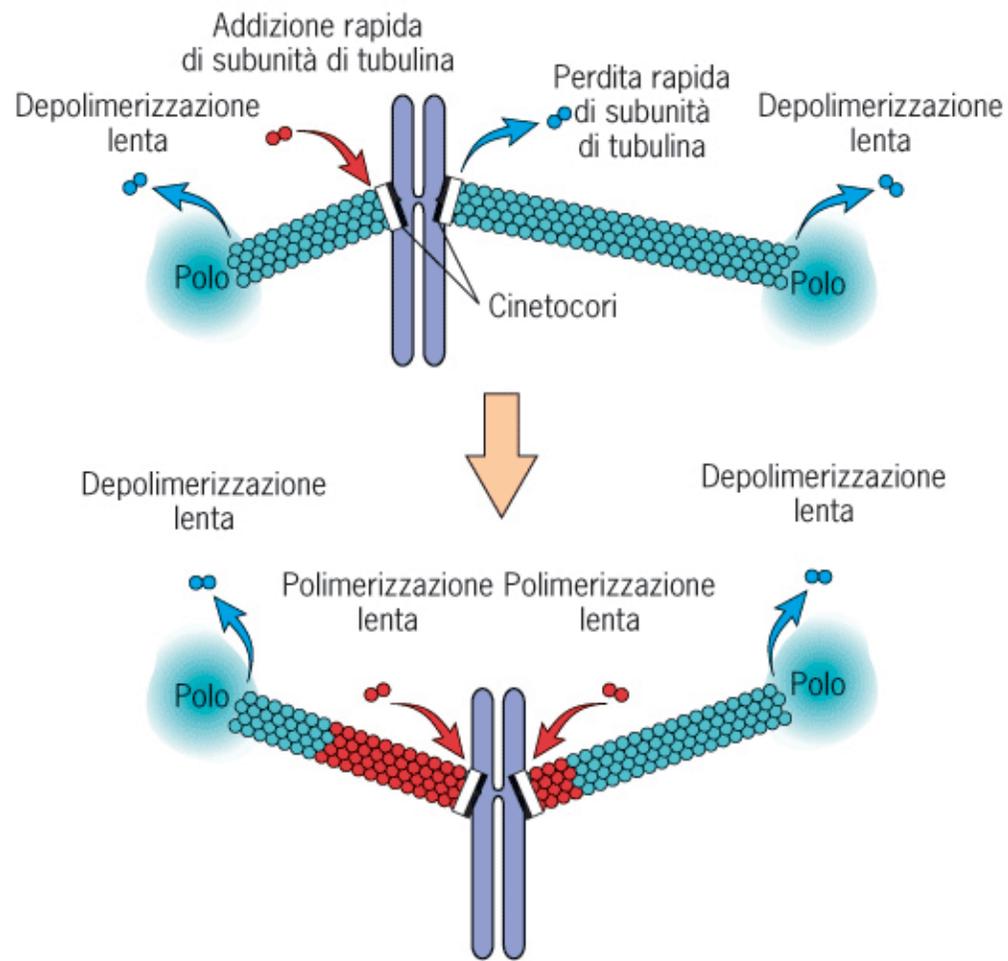
**5** I cromatidi appaiati si separano e i cromosomi figli iniziano a migrare verso i poli opposti della cellula.

**6** I cromosomi figli raggiungono i poli della cellula e la cellula entra in interfase quando l'involucro nucleare e i nucleoli si riorganizzano e la cromatina si despiralizza.

(B)



5  $\mu\text{m}$

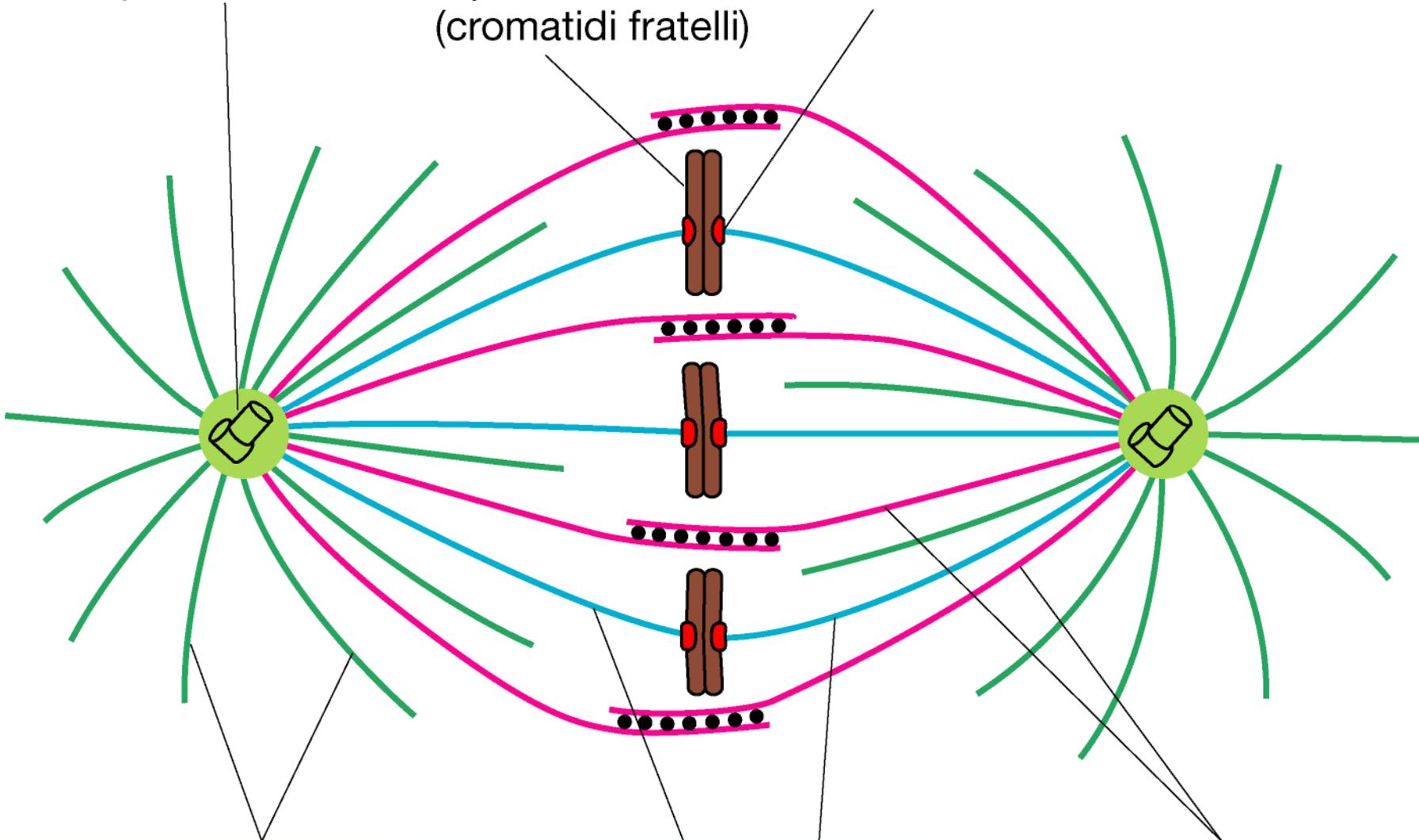


(A)

polo del fuso

cromosoma replicato (cromatidi fratelli)

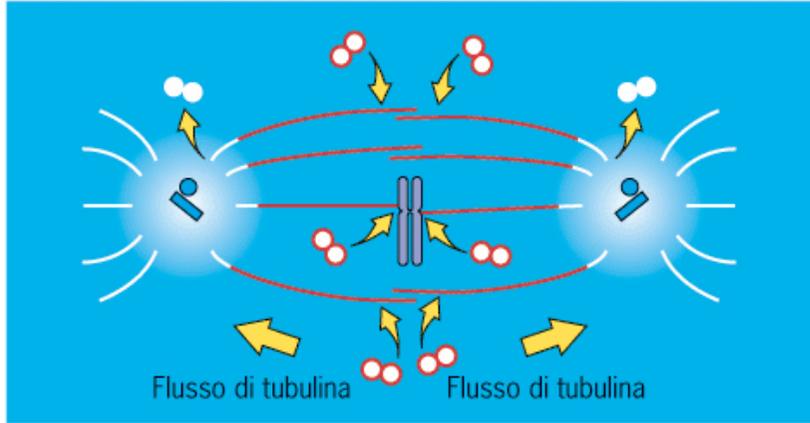
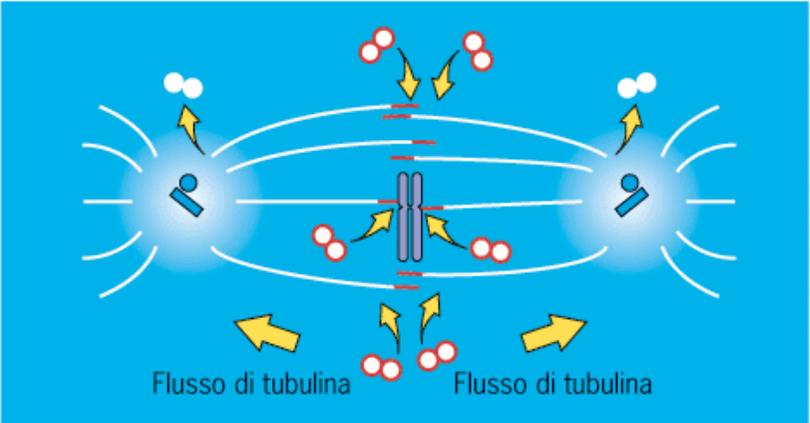
cinetocoro



microtubuli dell'aster

microtubuli del cinetocoro

microtubuli interpolari



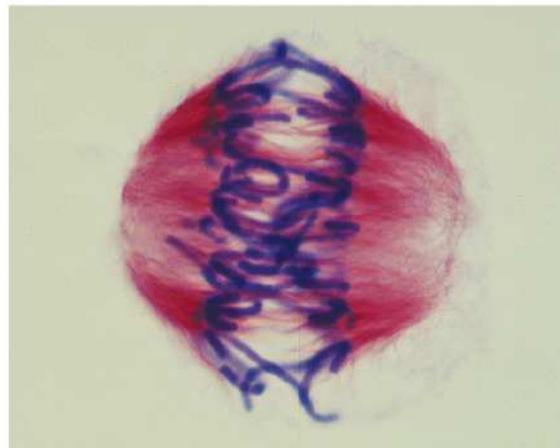
# Cambiamenti citologici nella metafase

- I cromosomi, al loro massimo grado di spiralizzazione, si allineano lungo la **piastra equatoriale**, a metà strada tra i due poli del fuso.
- I cromosomi sono disposti con il loro asse longitudinale perpendicolare all'asse del fuso mitotico.
- L'orientamento dei cromosomi è determinato dalla interazione dei centromeri con i microtubuli del cinetocoro

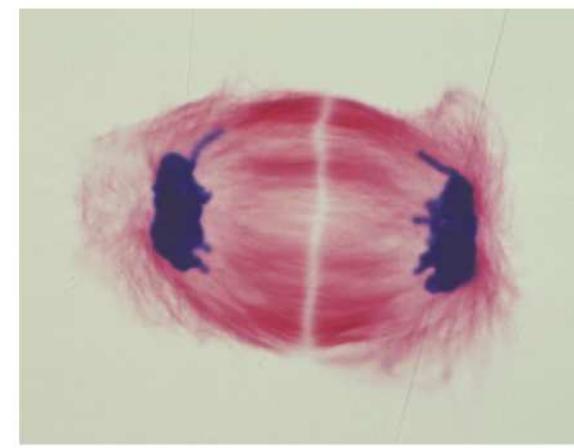
Metafase



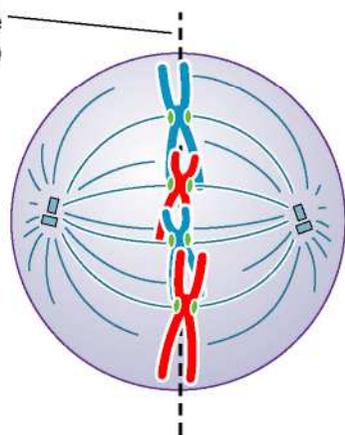
Anafase



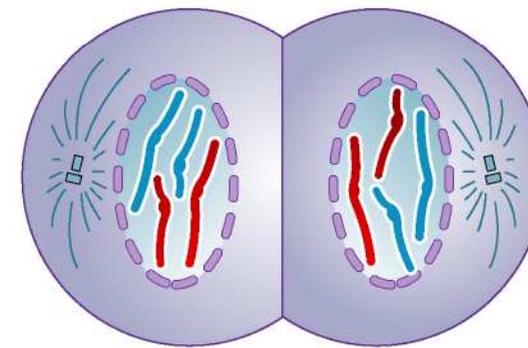
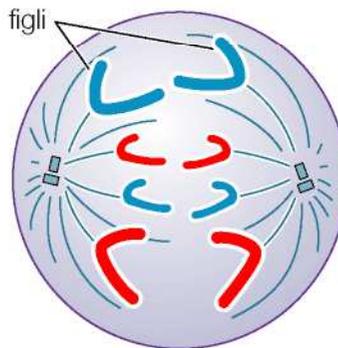
Telofase



Piastra equatoriale (o metafasica)



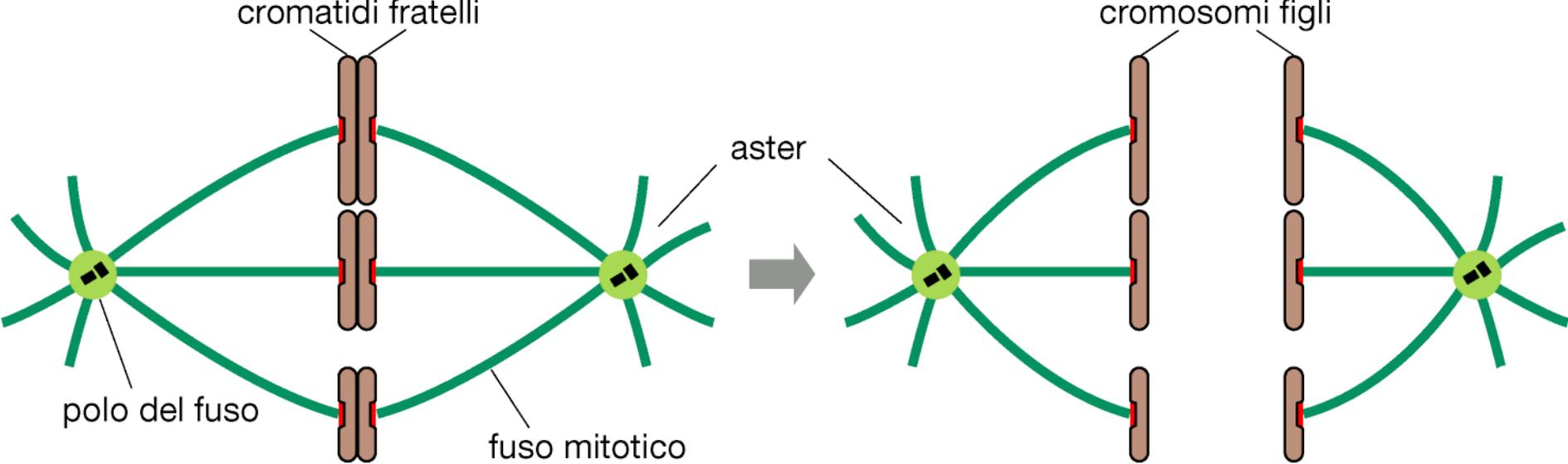
Cromosomi figli



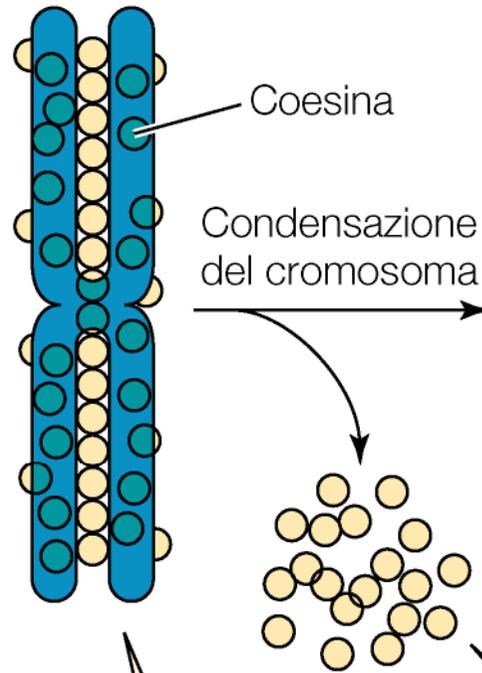
**4** I centromeri (regioni che connettono i cromatidi appaiati) si allineano sul piano equatoriale della cellula.

**5** I cromatidi appaiati si separano e i cromosomi figli iniziano a migrare verso i poli opposti della cellula.

**6** I cromosomi figli raggiungono i poli della cellula e la cellula entra in interfase quando l'involucro nucleare e i nucleoli si riorganizzano e la cromatina si despiralizza.



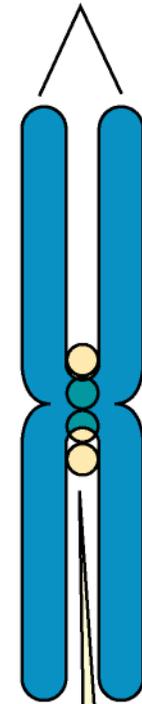
## Profase



**1** Dopo la replicazione, i due cromatidi sono reciprocamente uniti da molecole di coesina.

## Metafase

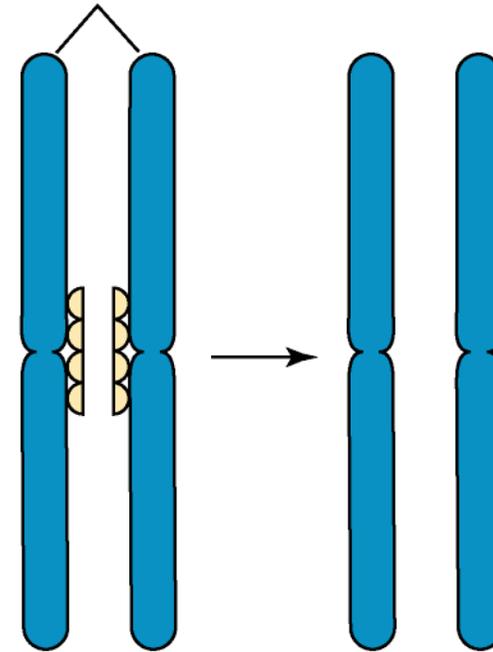
Cromatidi



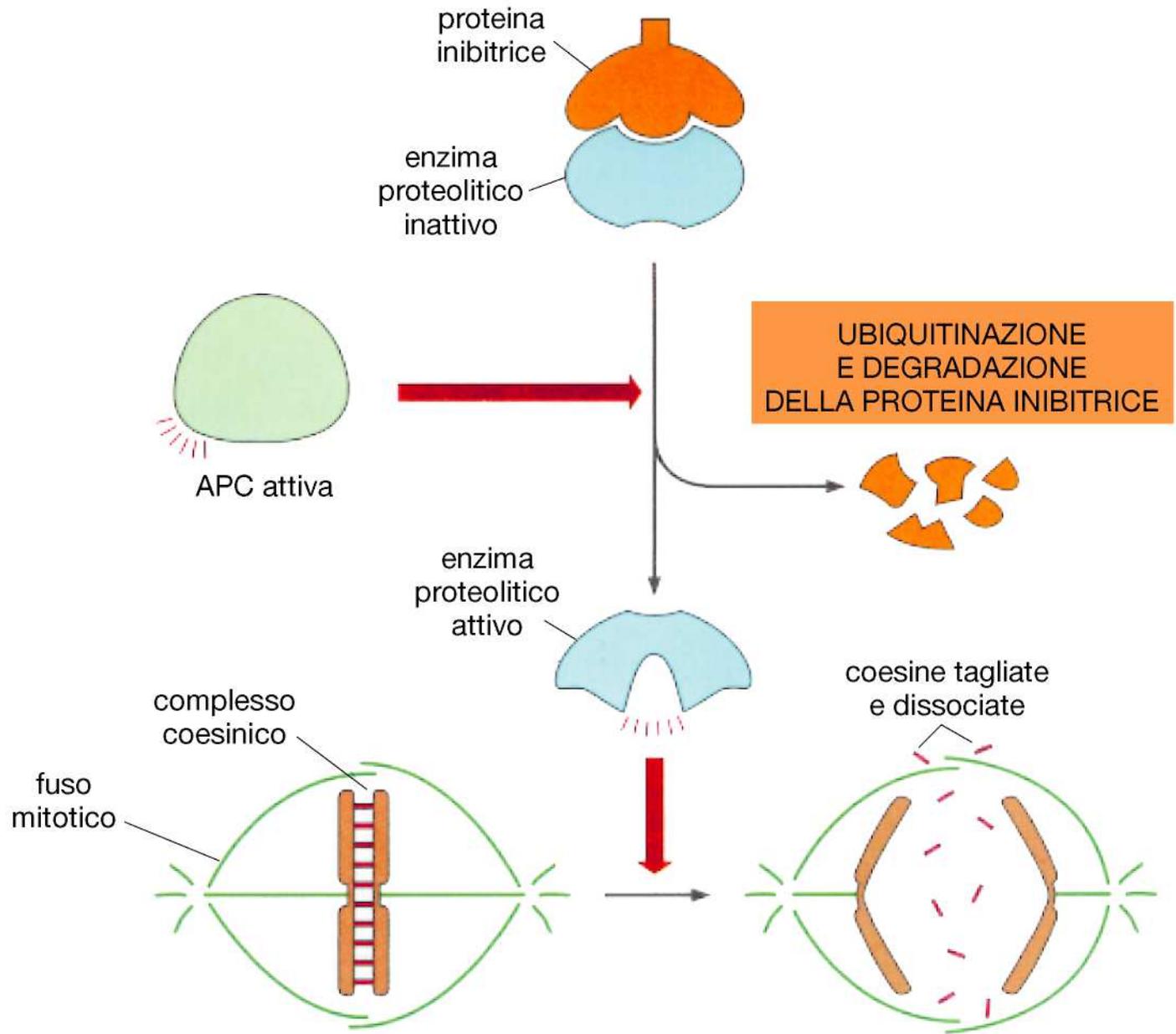
**2** Durante la metafase gran parte della coesina viene rimossa, a eccezione di quella presente in corrispondenza del centromero.

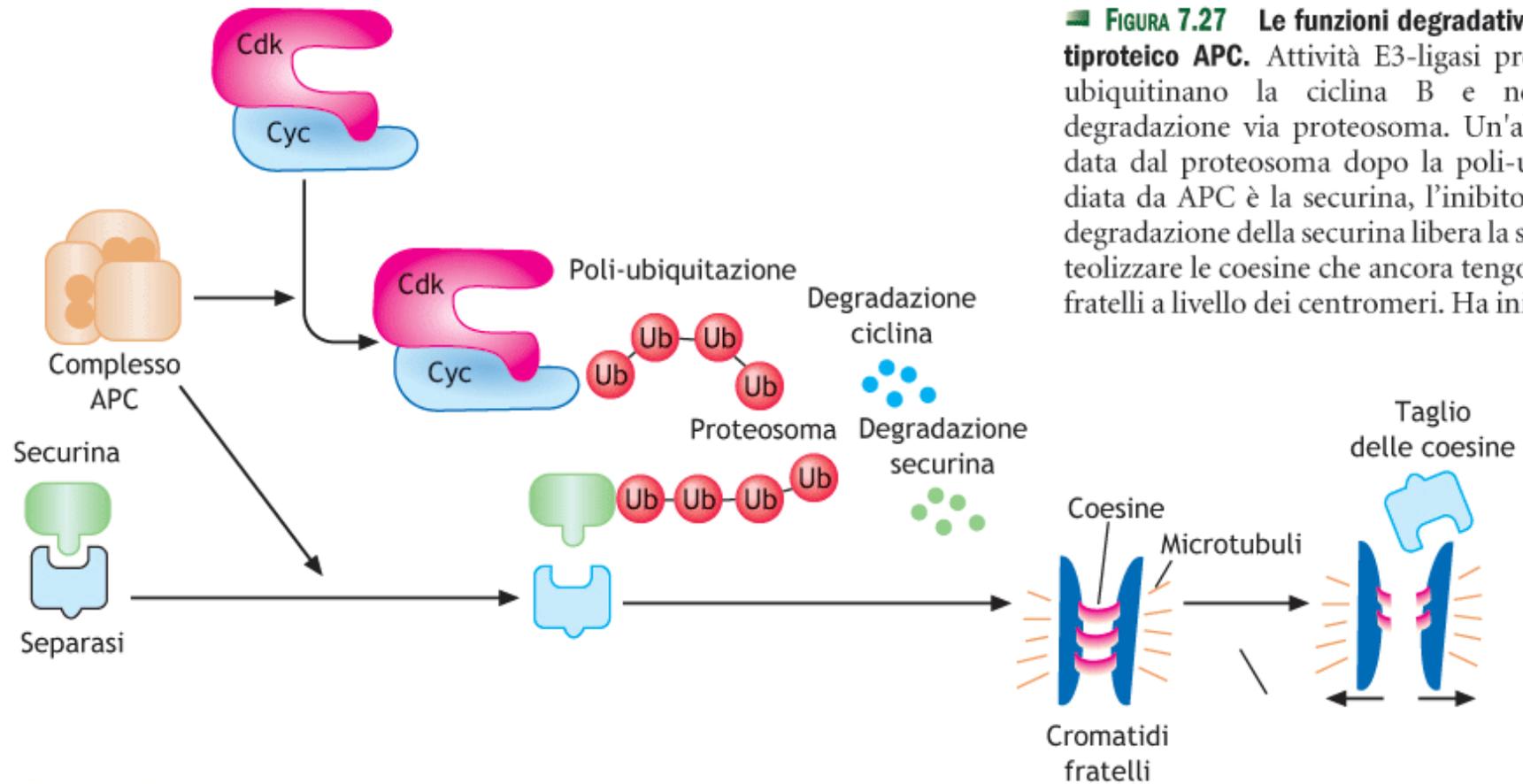
## Anafase

Cromosomi figli

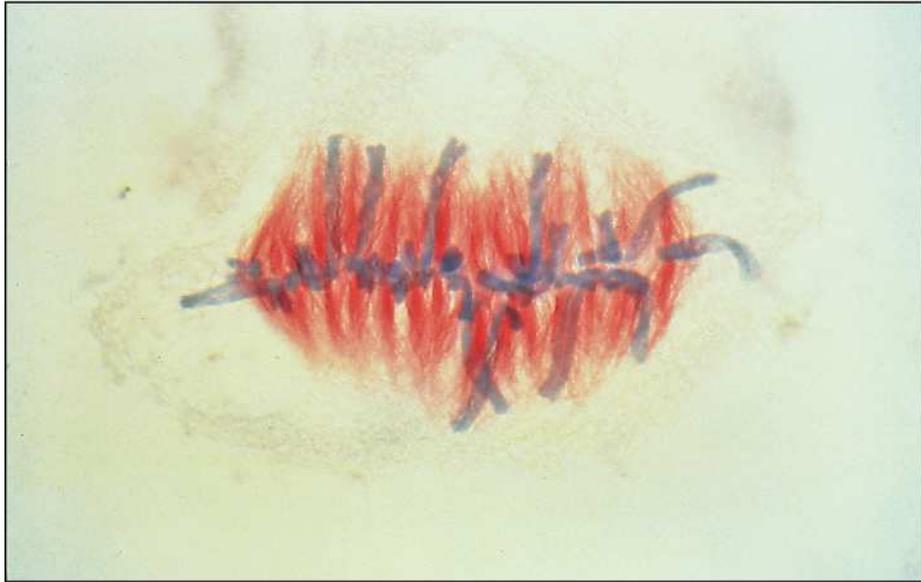


**3** Durante l'anafase, la securina, una subunità di inibizione della separasi, viene idrolizzata. La separasi idrolizza la coesina rimanente.





**FIGURA 7.27 Le funzioni degradative tiproteico APC.** Attività E3-ligasi pres ubiquitinano la ciclina B e ne degradazione via proteosoma. Un'alt data dal proteosoma dopo la poli-ub diata da APC è la securina, l'inibitore degradazione della securina libera la sep teolizzare le coesine che ancora tengon fratelli a livello dei centromeri. Ha inizi

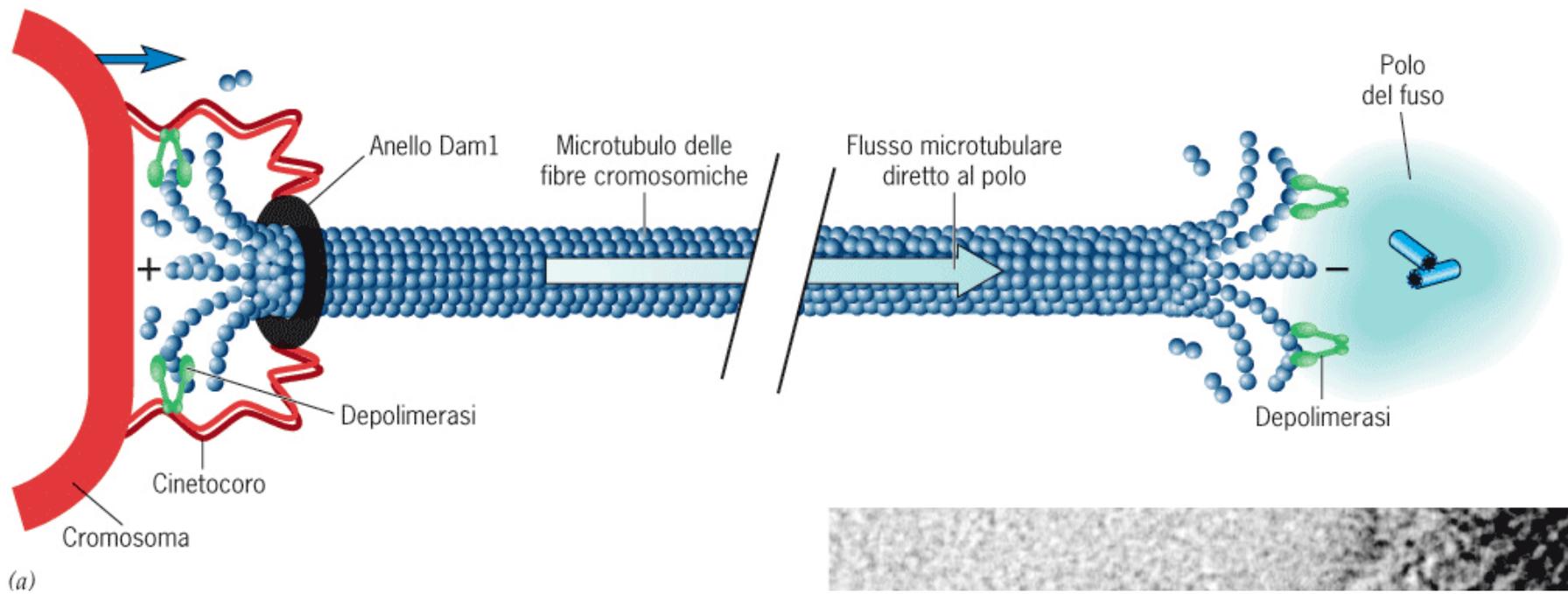


(A)

20  $\mu$ m

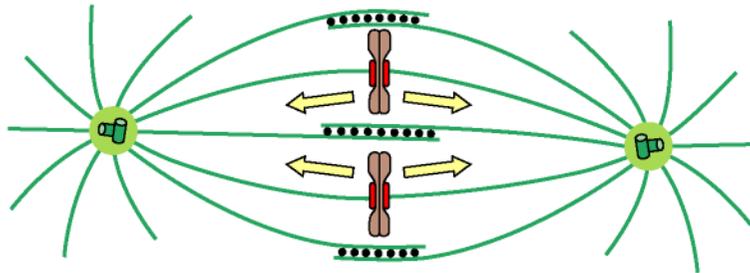


(B)

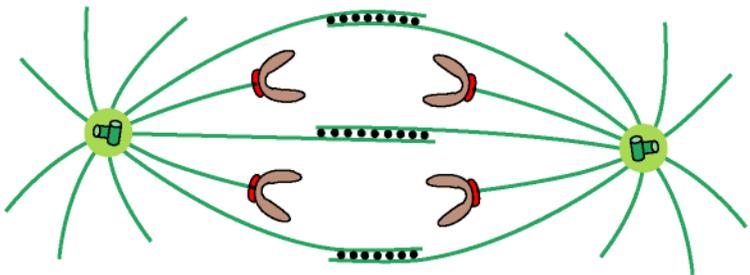


### ANAFASE A

I CROMOSOMI VENGONO TIRATI VERSO I POLI

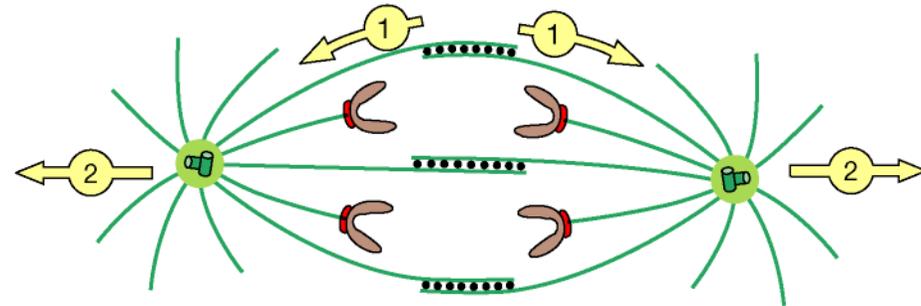


accorciamento dei microtubuli del cinetocoro: ai cinetocori si genera la forza che muove i cromosomi figli verso il polo del fuso cui sono connessi

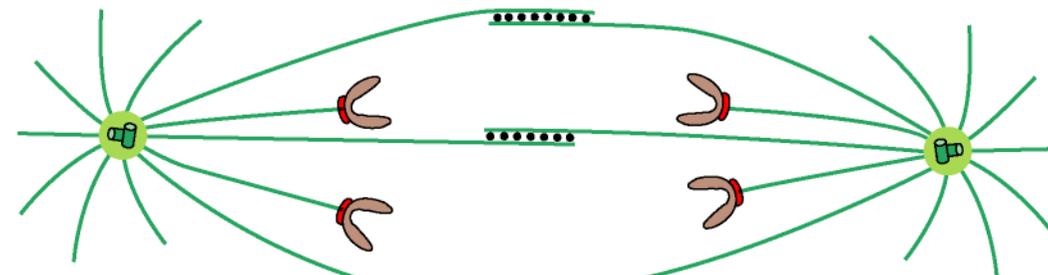


### ANAFASE B

I POLI SONO SIA SPINTI SIA TIRATI IN MODO DA ALLONTANARSI TRA LORO

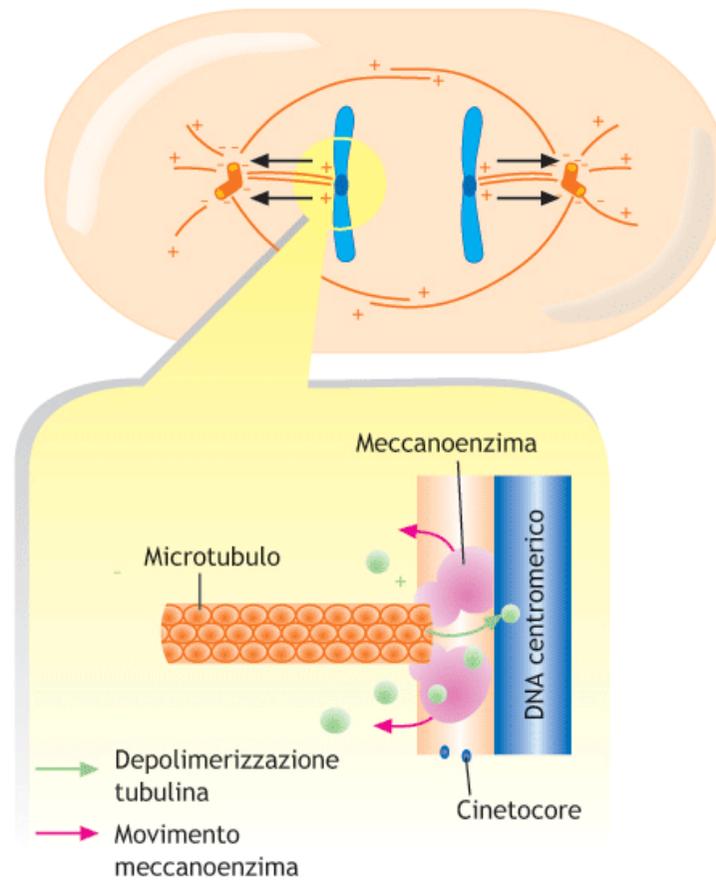


si genera una forza di scorrimento (1) tra microtubuli interpolarì di poli opposti che spinge i poli ad allontanarsi; una forza di trazione (2) agisce direttamente sui poli facendoli allontanare

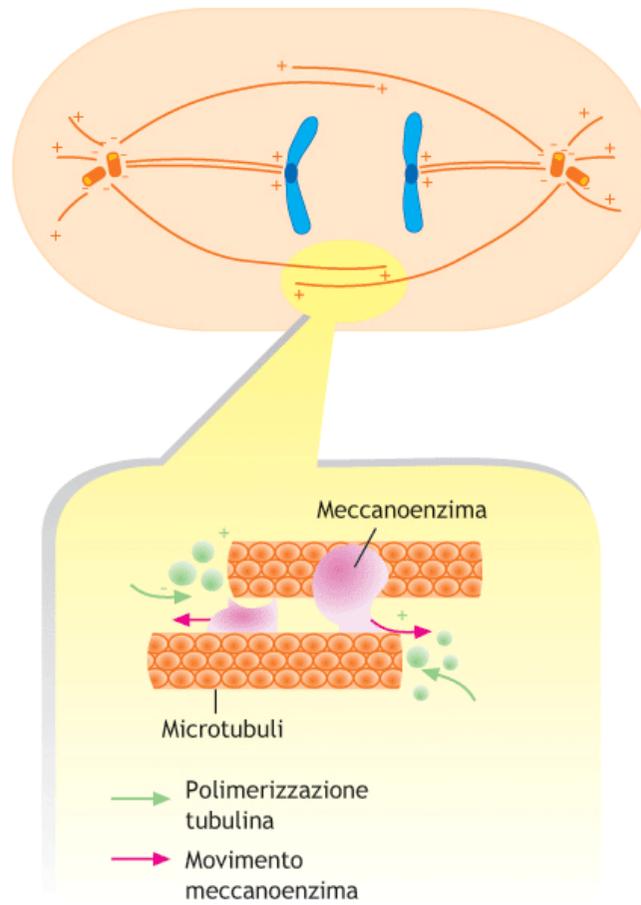


crescita dei microtubuli all'estremità più dei microtubuli interpolarì

ANAFASE A: SI ACCORCIANO LE FIBRE DEL CINETOCORE

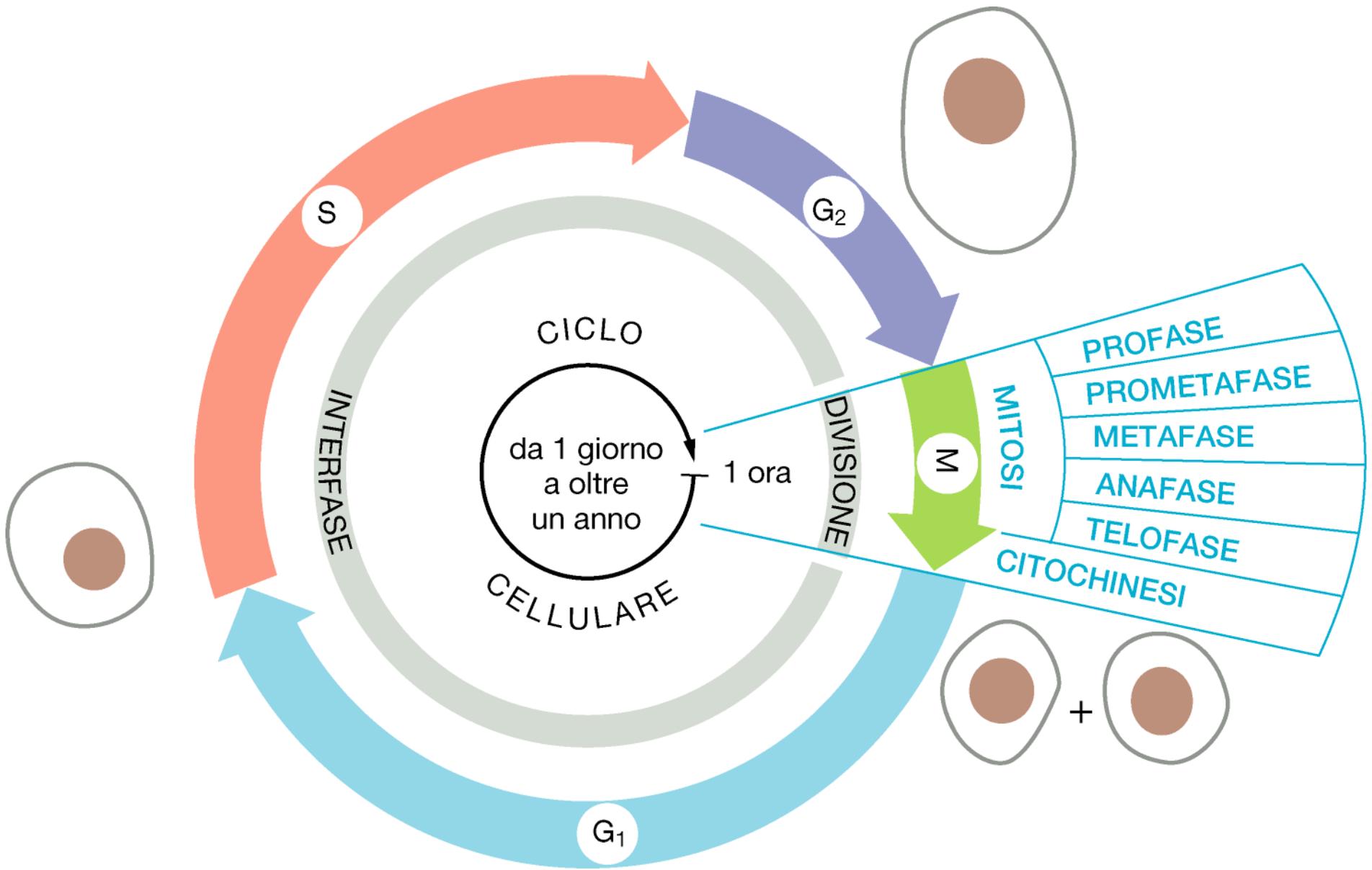


ANAFASE B: SI ALLUNGANO LE FIBRE INTERPOLARI



# Cambiamenti citologici nella anafase

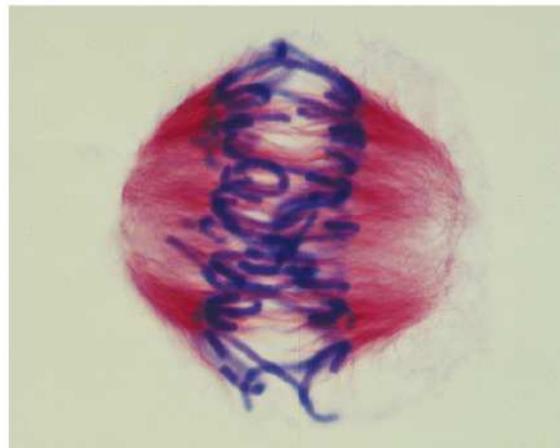
- Separazione dei centromeri dei cromatidi fratelli.
- I cromatidi fratelli (ora cromosomi mono-cromatidici) si disgiungono e migrano verso i poli opposti della cellula.
- Al termine dell'anafase ha inizio la citochinesi, ovvero la divisione citoplasmatica.



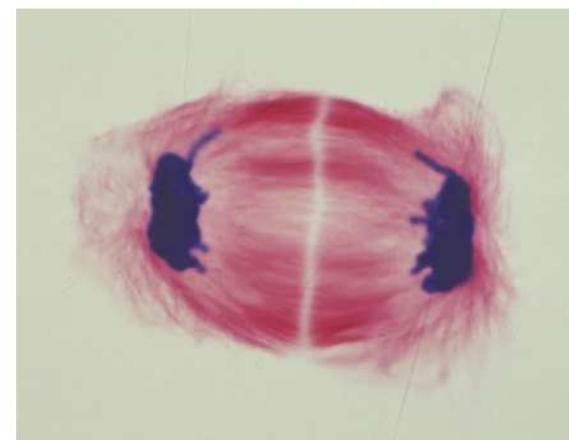
Metafase



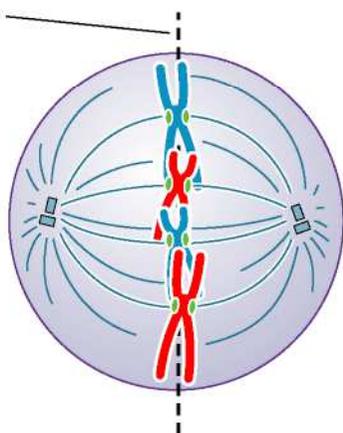
Anafase



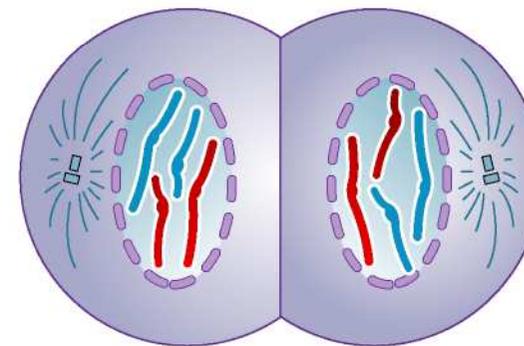
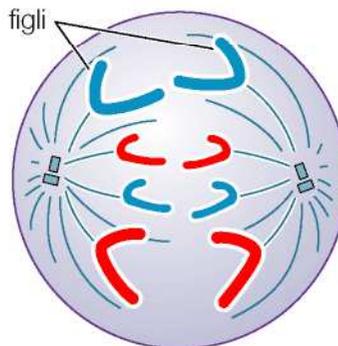
Telofase



Piastra equatoriale (o metafase)



Cromosomi figli



**4** I centromeri (regioni che connettono i cromatidi appaiati) si allineano sul piano equatoriale della cellula.

**5** I cromatidi appaiati si separano e i cromosomi figli iniziano a migrare verso i poli opposti della cellula.

**6** I cromosomi figli raggiungono i poli della cellula e la cellula entra in interfase quando l'involucro nucleare e i nucleoli si riorganizzano e la cromatina si despiralizza.

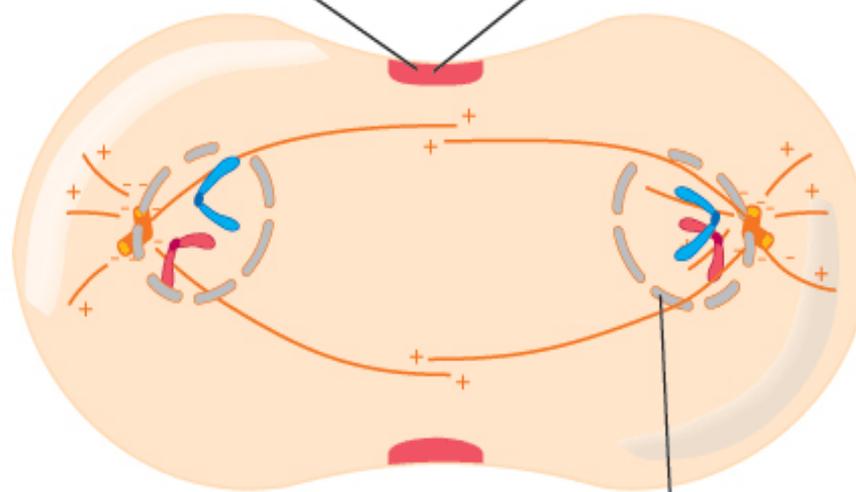
# Cambiamenti citologici nella telofase

- Si completa la migrazione dei cromosomi verso i rispettivi poli. I cromosomi cominciano a despiralizzarsi.
- Si forma una membrana nucleare intorno ai cromosomi. Si riforma il nucleolo.
- Si disassembla il **fuso mitotico**.
- Si completa la citochinesi.

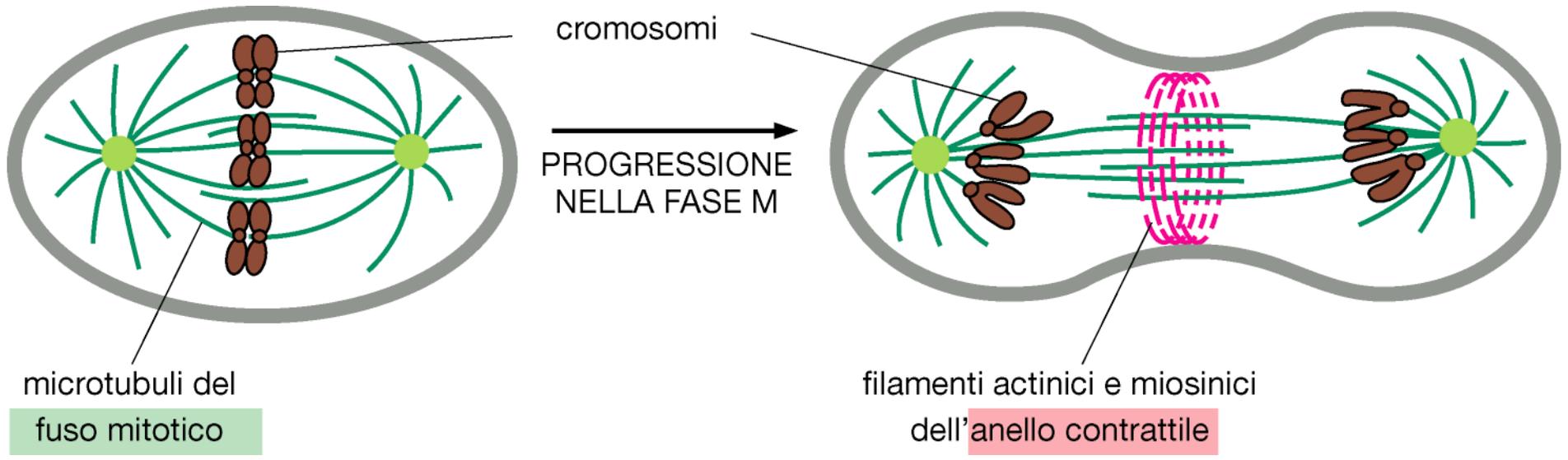
## TELOFASE

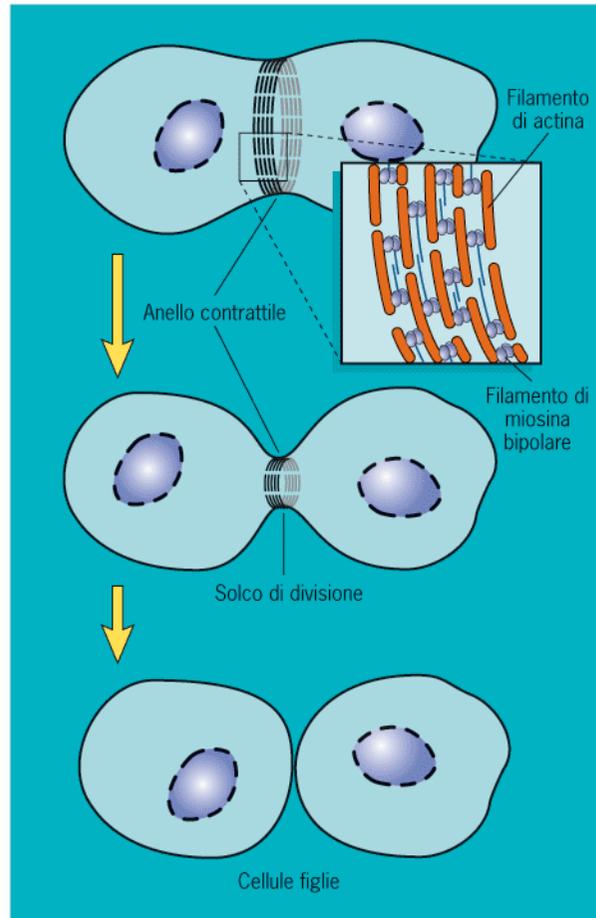
Invaginazione  
della membrana  
plasmatica

Inizia ad evidenziarsi  
l'anello contrattile

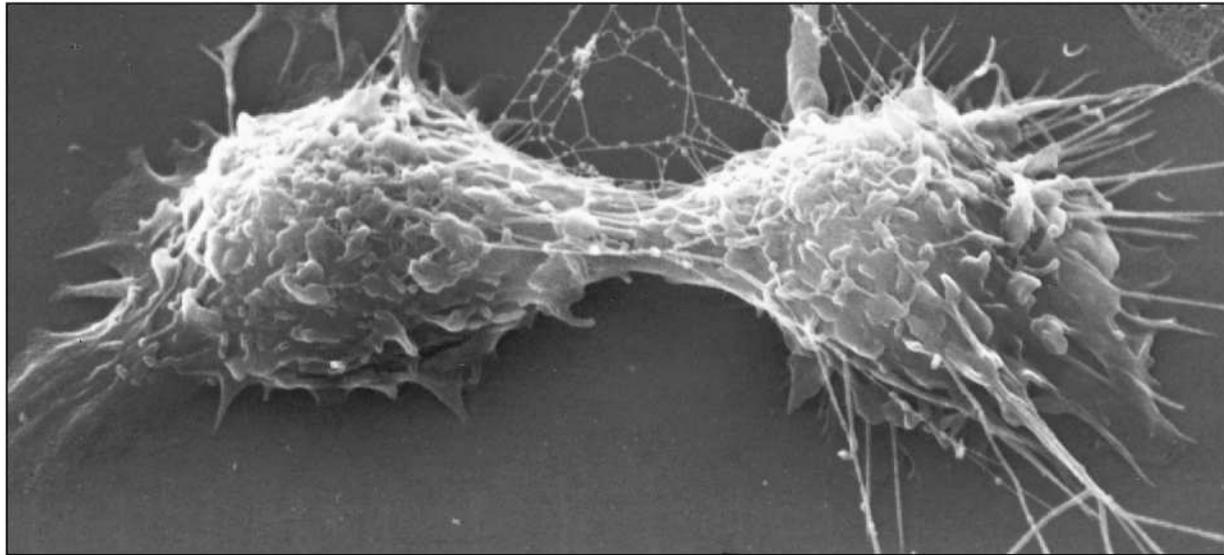


Si riorganizza  
l'involucro  
nucleare



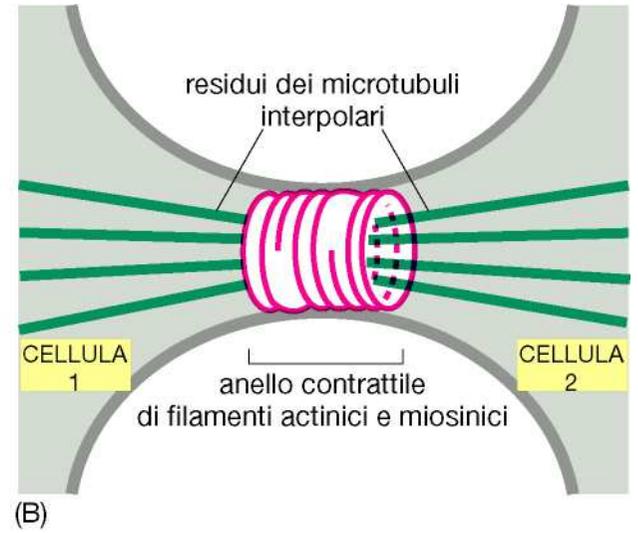


(a)

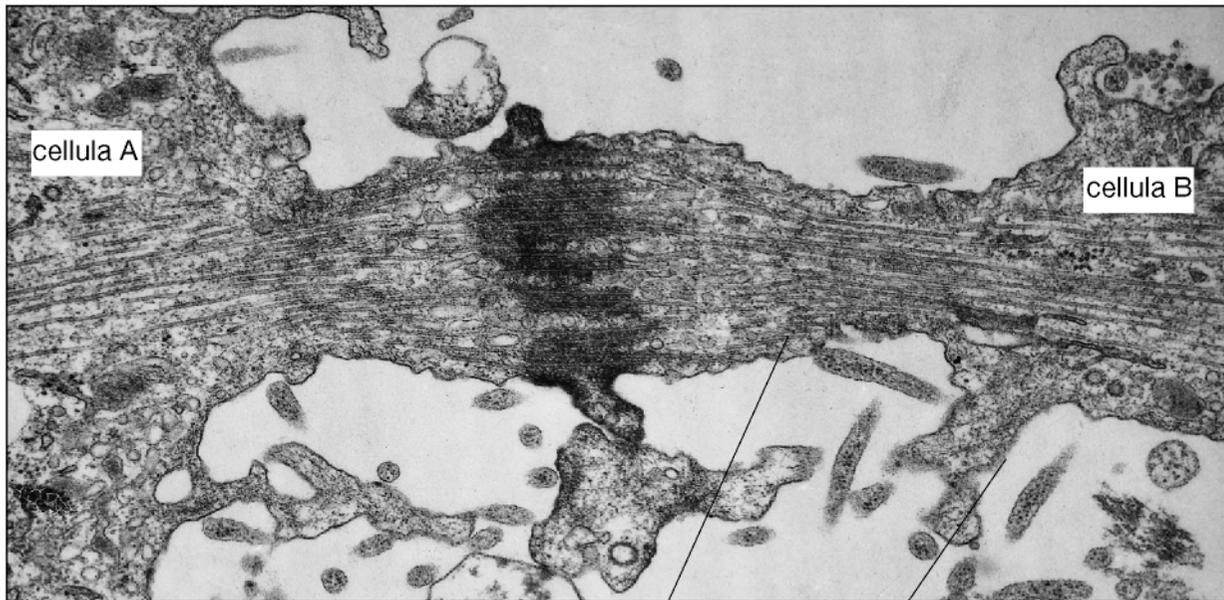


(A)

10 μm



(B)



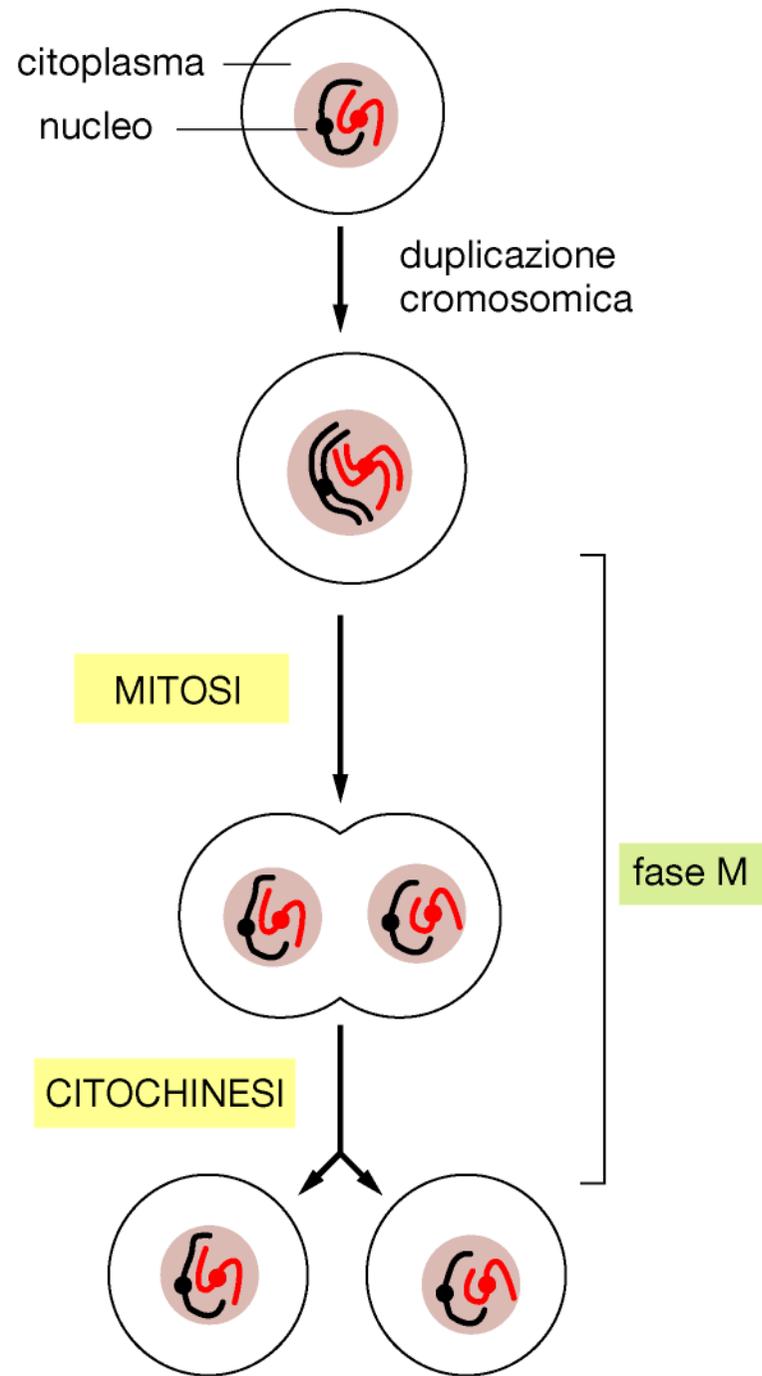
(C)

microtubuli interpolari residui    membrana plasmatica

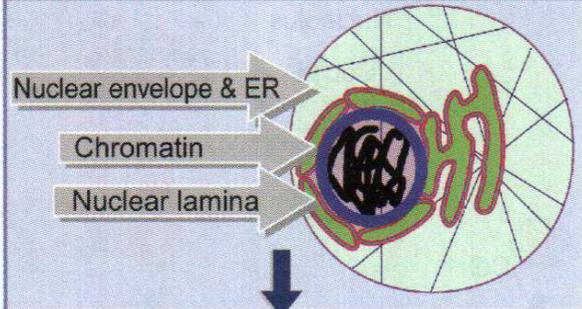
1 μm

# Cambiamenti citologici nella citochinesi

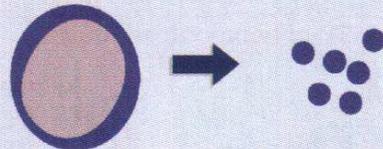
Nelle cellule animali si nota una costrizione al centro della cellula (visibile già in anafase). Tale costrizione, dovuta ad un anello contrattile di **actina**, prosegue fino alla separazione delle cellule.



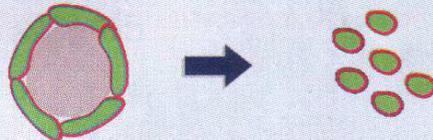
Interphase cell has a nucleus and cytoplasm



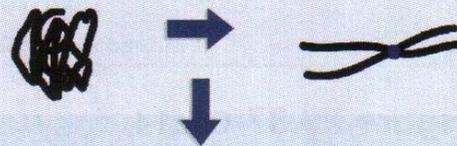
M phase kinase phosphorylates lamins



Membrane disaggregation: cause unknown



M phase kinase phosphorylates H1



Mitotic cell has a spindle

