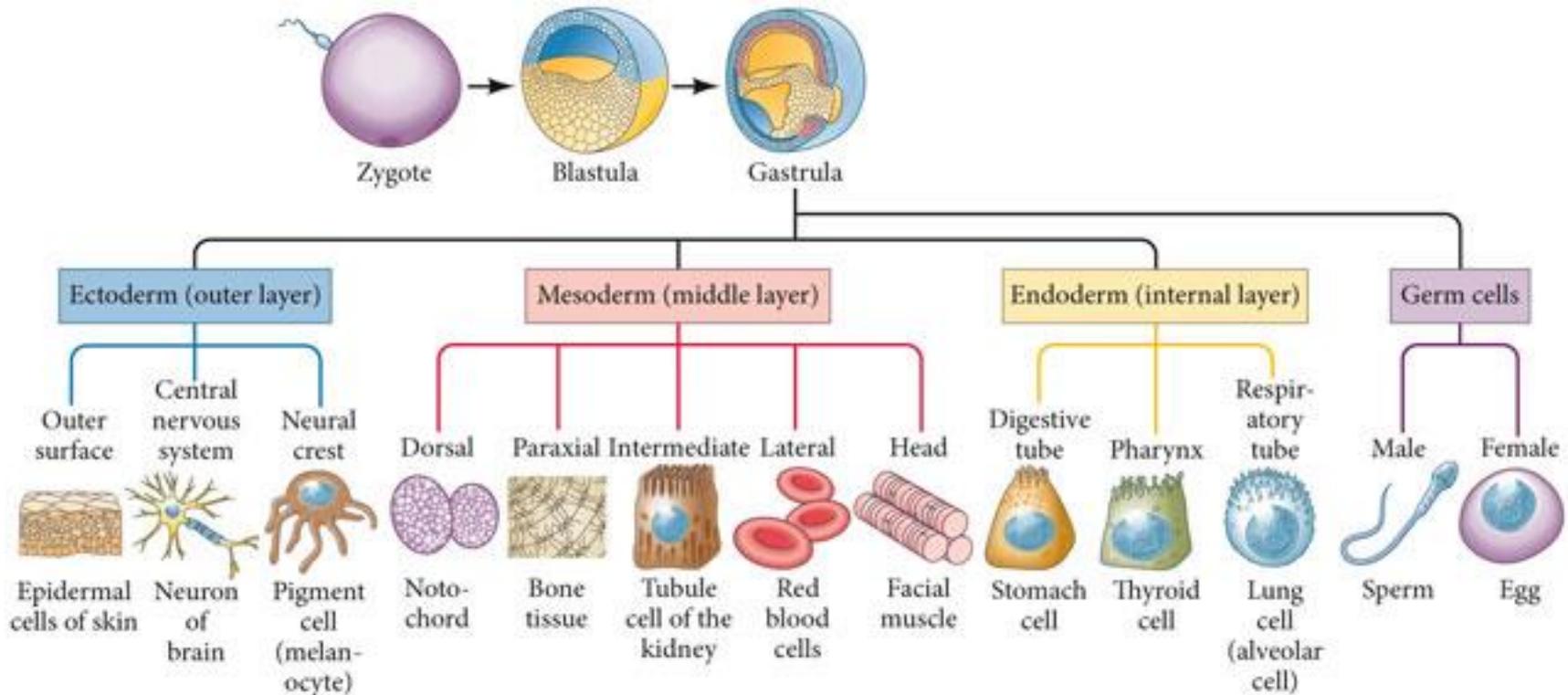
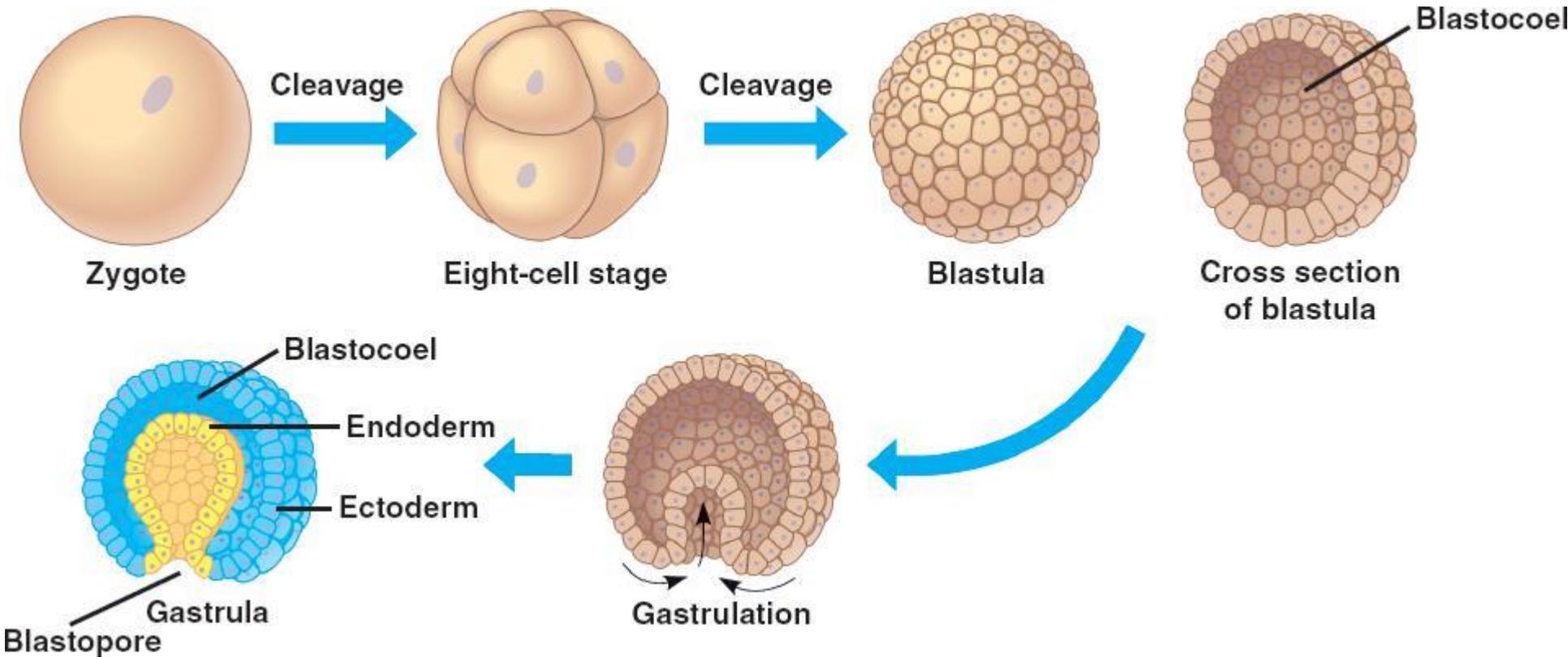


# LO SVILUPPO EMBRIONALE INIZIA CON LA FECONDAZIONE E SI SVOLGE ATTAVERSO LE FASI DI SEGMENTAZIONE, GASTRULAZIONE E ORGANOGENESI



# SEGMENTAZIONE: FORMAZIONE DI UNA BLASTULA PLURICELLULARE A PARTIRE DALLO ZIGOTE



- Modalità di segmentazione (totale, ineguale o parziale)
- Inclinazione dei piani di divisione
- Tempi di segmentazione (es. divisioni veloci o lente, sincrone o asincrone)

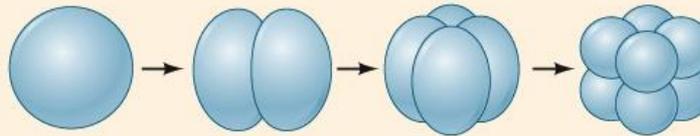
- Il tuorlo crea un ostacolo all'insorgenza dei piani di divisione cellulare
- La modalità della segmentazione dipende dalla quantità e dalla distribuzione del tuorlo presente nell'uovo
- La citodieresi si verifica all'equatore del fuso mitotico
- L'orientamento dei piani di segmentazione è dipendente dalla posizione dei fusi mitotici, che può essere influenzata dal tuorlo ma anche da altri fattori

## I. HOLOBLASTIC (COMPLETE) CLEAVAGE

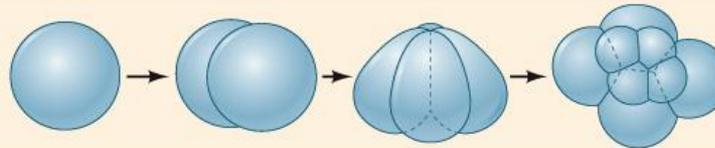
### A. Isolecithal

(Sparse, evenly distributed yolk)

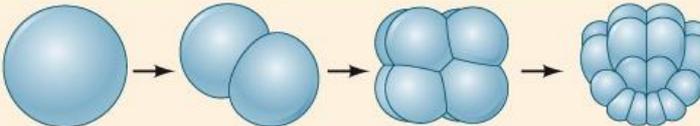
1. Radial cleavage  
Echinoderms, amphioxus



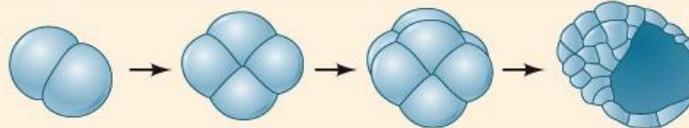
2. Spiral cleavage  
Annelids, molluscs,  
flatworms



3. Bilateral cleavage  
Tunicates



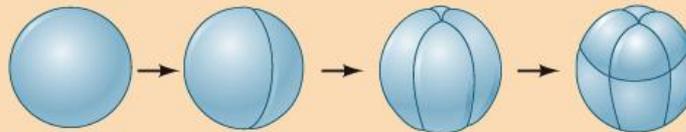
4. Rotational cleavage  
Mammals, nematodes



### B. Mesolecithal

(Moderate vegetal yolk disposition)

Displaced radial cleavage  
Amphibians

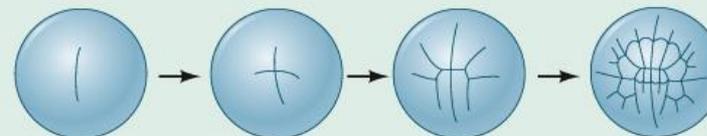


## II. MEROBLASTIC (INCOMPLETE) CLEAVAGE

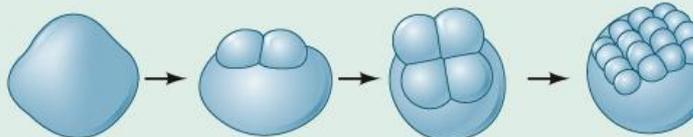
### A. Telolecithal

(Dense yolk throughout most of cell)

1. Bilateral cleavage  
Cephalopod molluscs



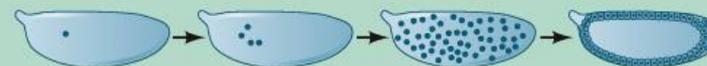
2. Discoidal cleavage  
Fish, reptiles, birds



### B. Centrolecithal

(Yolk in center of egg)

Superficial cleavage  
Most insects



# TABELLA 1

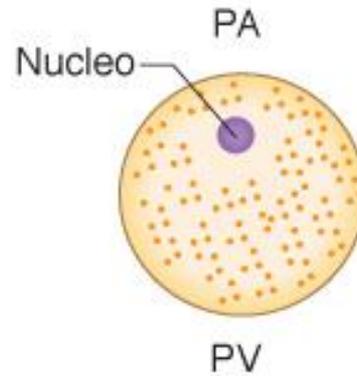
## Classificazione dei tipi di uova in base alla quantità di vitello.

Tipo di uova	Quantità di vitello	Distribuzione citoplasmatica	Dimensioni	Es. Taxa
Alecitico	Senza vitello		Circa 70 $\mu\text{m}$	Mammiferi Euteri
Oligolecitico	Scarso vitello	Abbastanza omogenea	Circa 100 $\mu\text{m}$	Echinodermi
Mesolecitico	Quantità medie	Ineguale, a gradiente	Circa 1 mm	Anfibi, Anellidi
Centrolecitico	Abbondante	Massa centrale	Circa 1 mm	Insetti
Telolecitico	Molto abbondante	Occupava tutto l'uovo tranne una piccola zona al polo animale, in cui è situato il citoplasma	Fino a oltre 10 cm	Cefalopodi molti pesci Sauropsidi (Rettili e Uccelli) Mammiferi ovipari (Monotremi)

Uova macrolecitiche

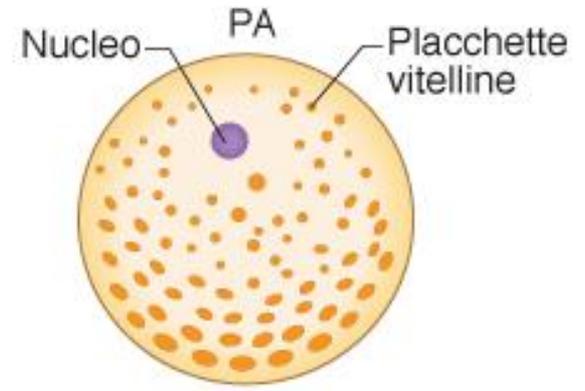
# ESEMPI DI UOVA CON DIVERSA QUANTITA' DI VITELLO

**A**



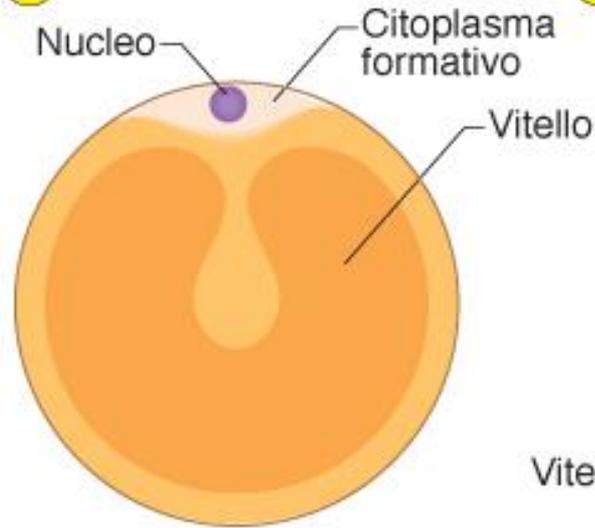
**Oligolecitico**

**B**



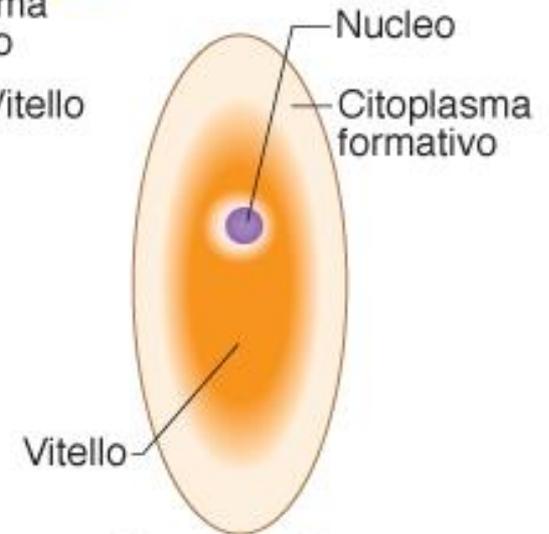
**Mesolecitico**

**C**



**Telolecitico**

**D**



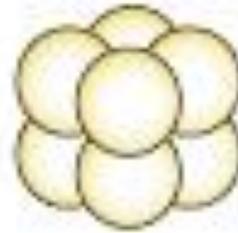
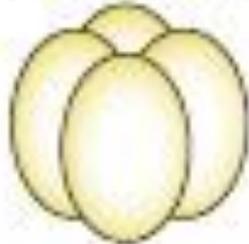
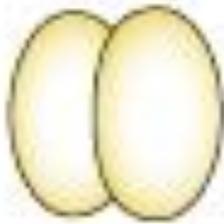
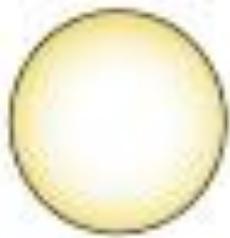
**Centrolecitico**

**Macrolecitico**

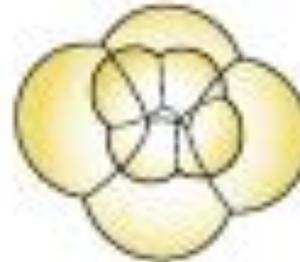
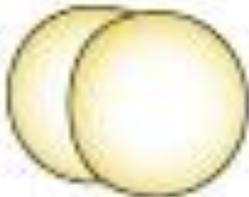
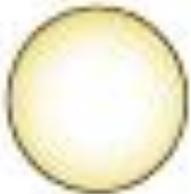
# LA QUANTITA' DI VITELLO PRESENTE NELL'UOVO DETERMINA LE MODALITA' DI SEGMENTAZIONE EMBRIONALE

## I) SEGMENTAZIONE OLOBLASTICA (TOTALE)

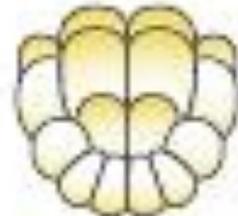
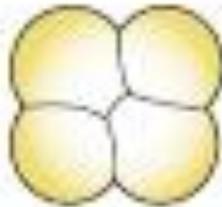
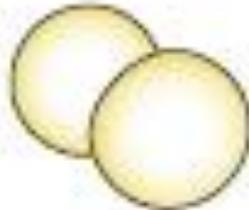
A. Uova oligolecitiche Isolecittiche  
(Vitello scarso uniformemente distribuito)



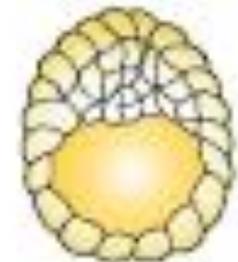
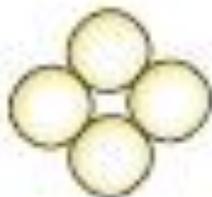
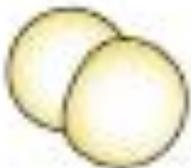
1) Segmentazione radiale  
Echinodermi, anfiosso



2) Segmentazione spirale  
Anellidi, Molluschi, Pluteiminti

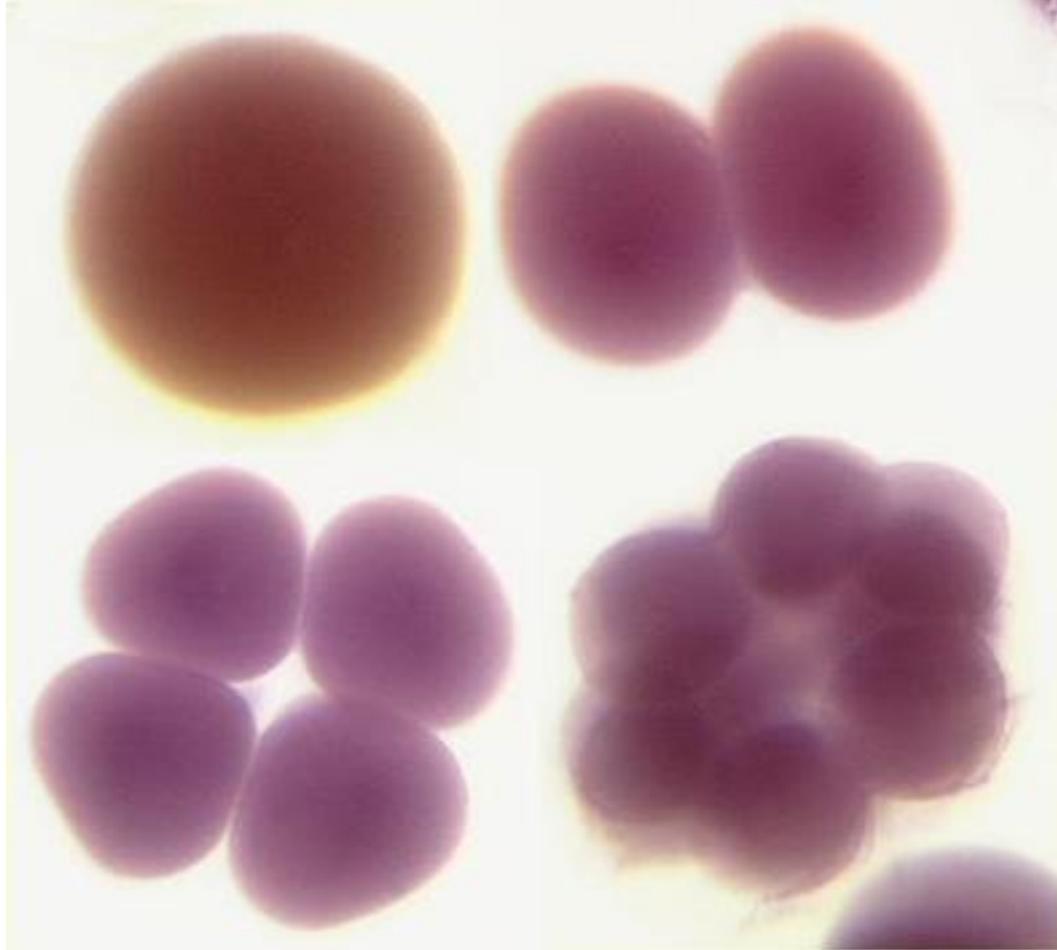


3) Segmentazione bilaterale  
Tunicati



4) Segmentazione rotazionale  
Mammiferi Euteri con uova  
alecittiche, Nematodi

# SEGMENTAZIONE OLOBLASTICA IN EMBRIONI DI STELLA MARINA



# IN UOVA CON MOLTO VITELLO LA SEGMENTAZIONE AVVIENE IN MANIERA INEGUALE O PARZIALE

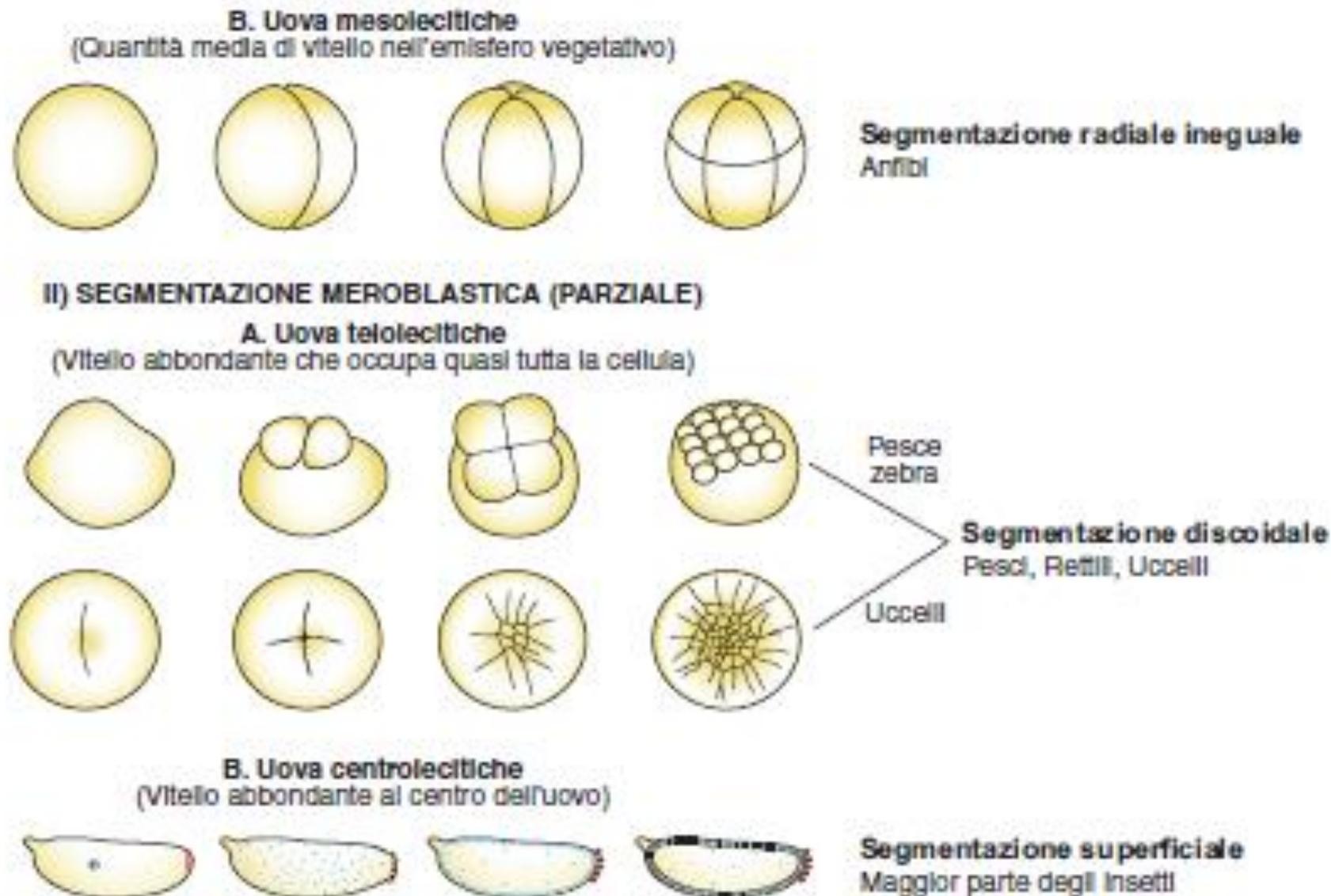
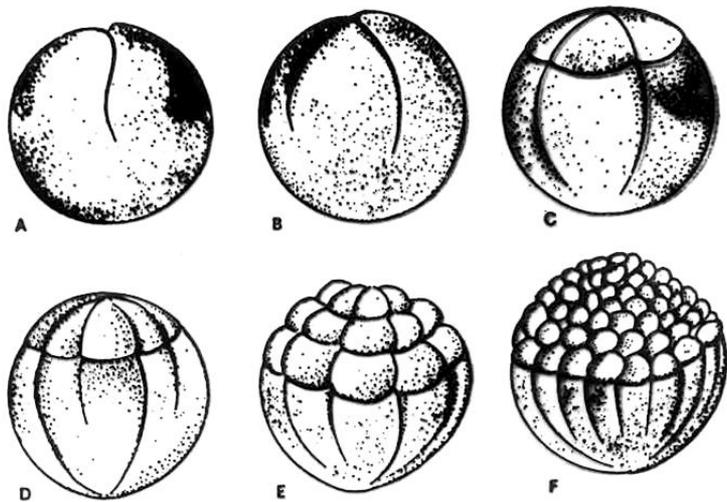
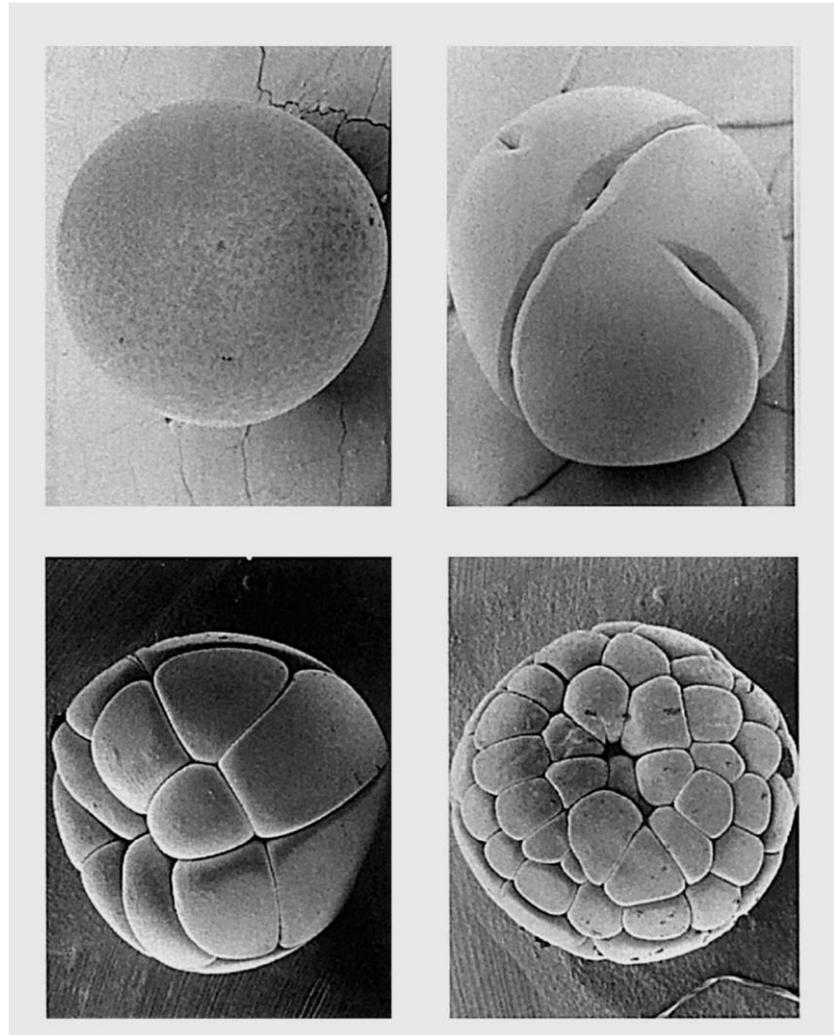


Figura 5

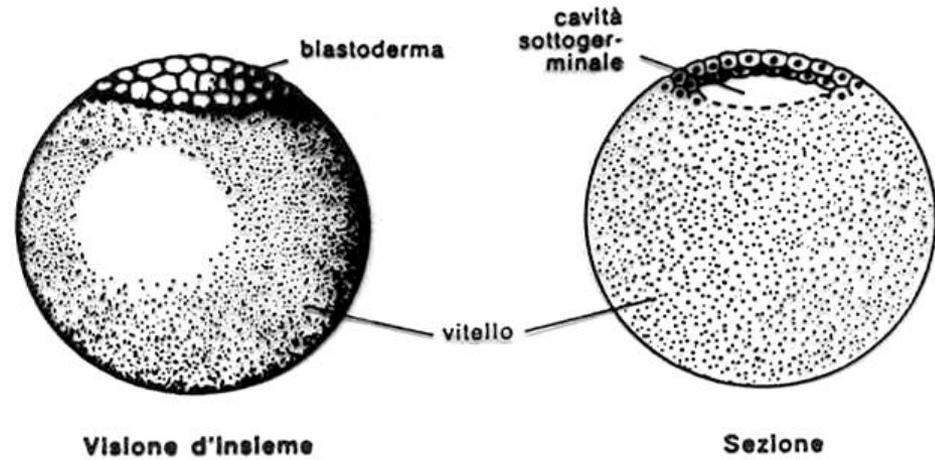


Segmentazione dell'uovo di Anfibi. A e B, primo e secondo solco di divisione; l'estensione dei solchi verso il polo vitellino è ritardata dalla grande quantità di deutoplasma che ostacola la segmentazione. C, il terzo piano di divisione è spostato verso il polo animale. D, E ed F, con il proseguire della segmentazione si formano micromeri al polo animale e macromeri al polo vitellino

## Oloblastica ineguale (Anfibi)

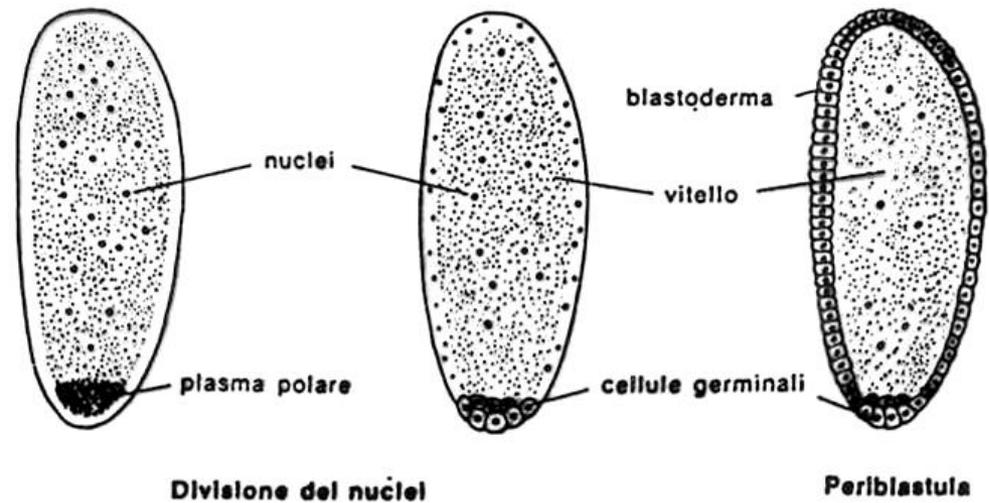


## Meroblastica discoidale (es. Pesci, Rettili, Uccelli)



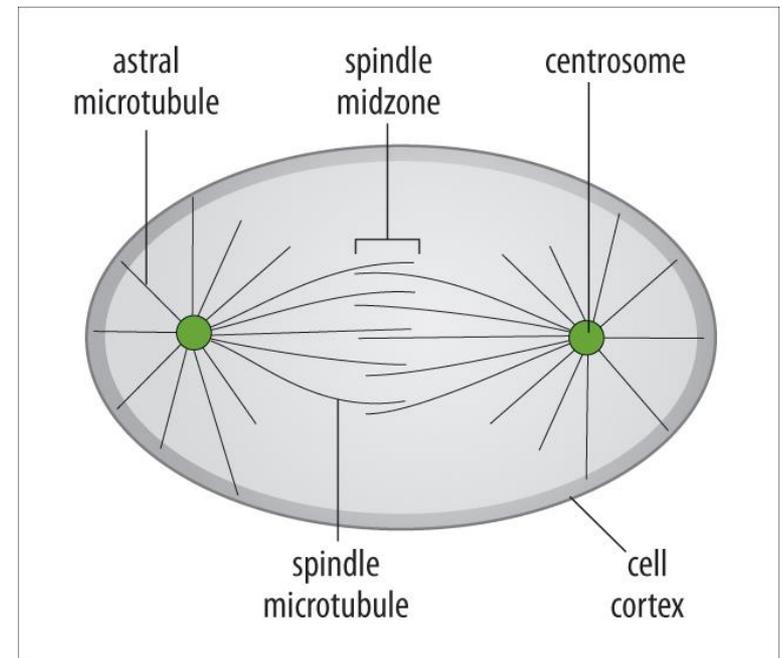
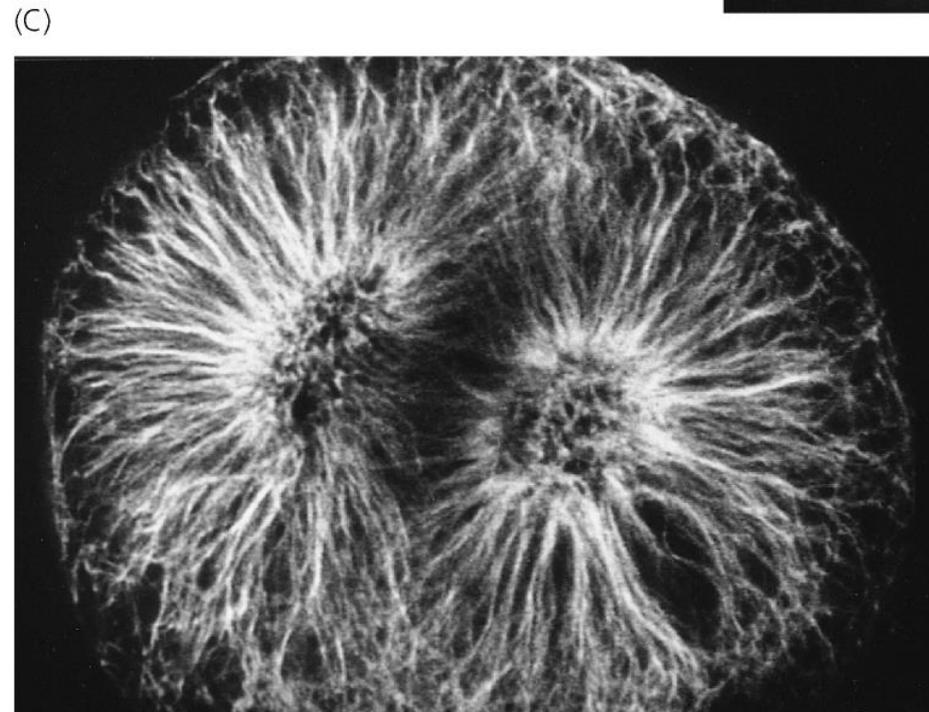
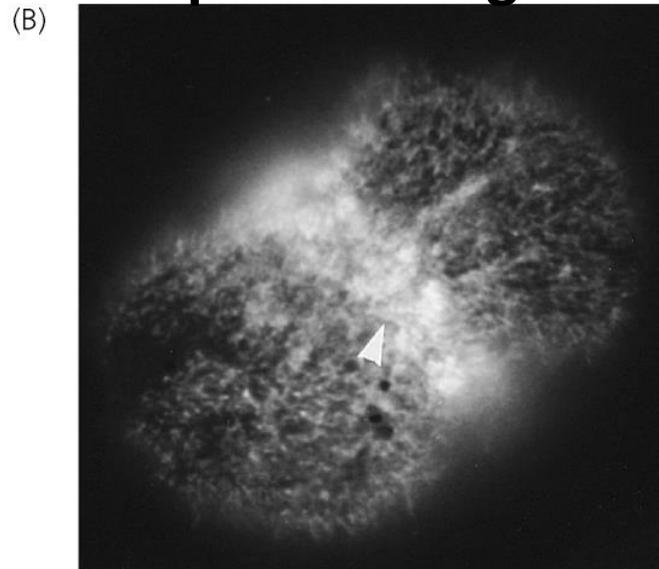
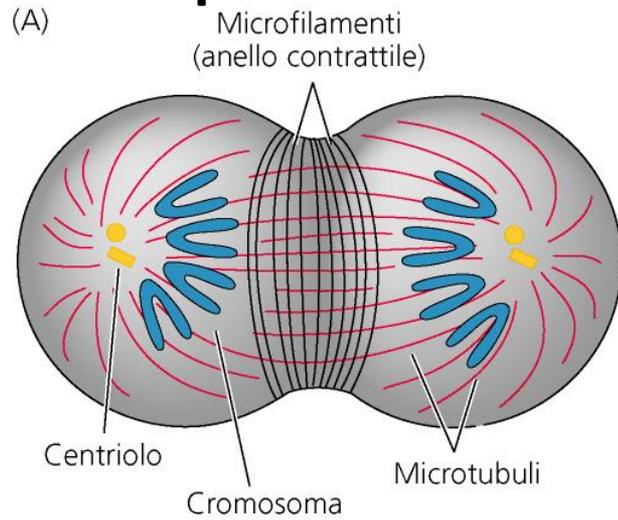
Segmentazione parziale discoidale.

## Meroblastica superficiale (es. Insetti)

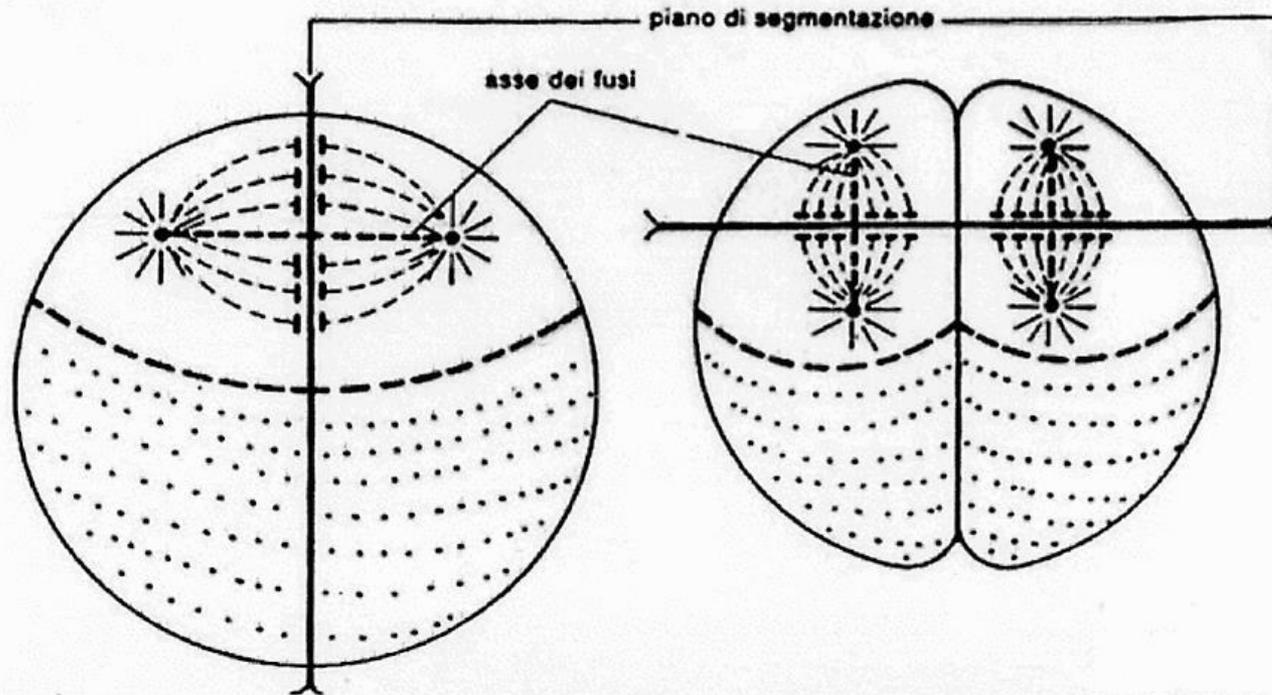


Segmentazione parziale superficiale dell'uovo di Insetti.

# Rapporto tra cariocinesi e citocinesi: importanza del fuso per l'orientamento del piano di segmentazione

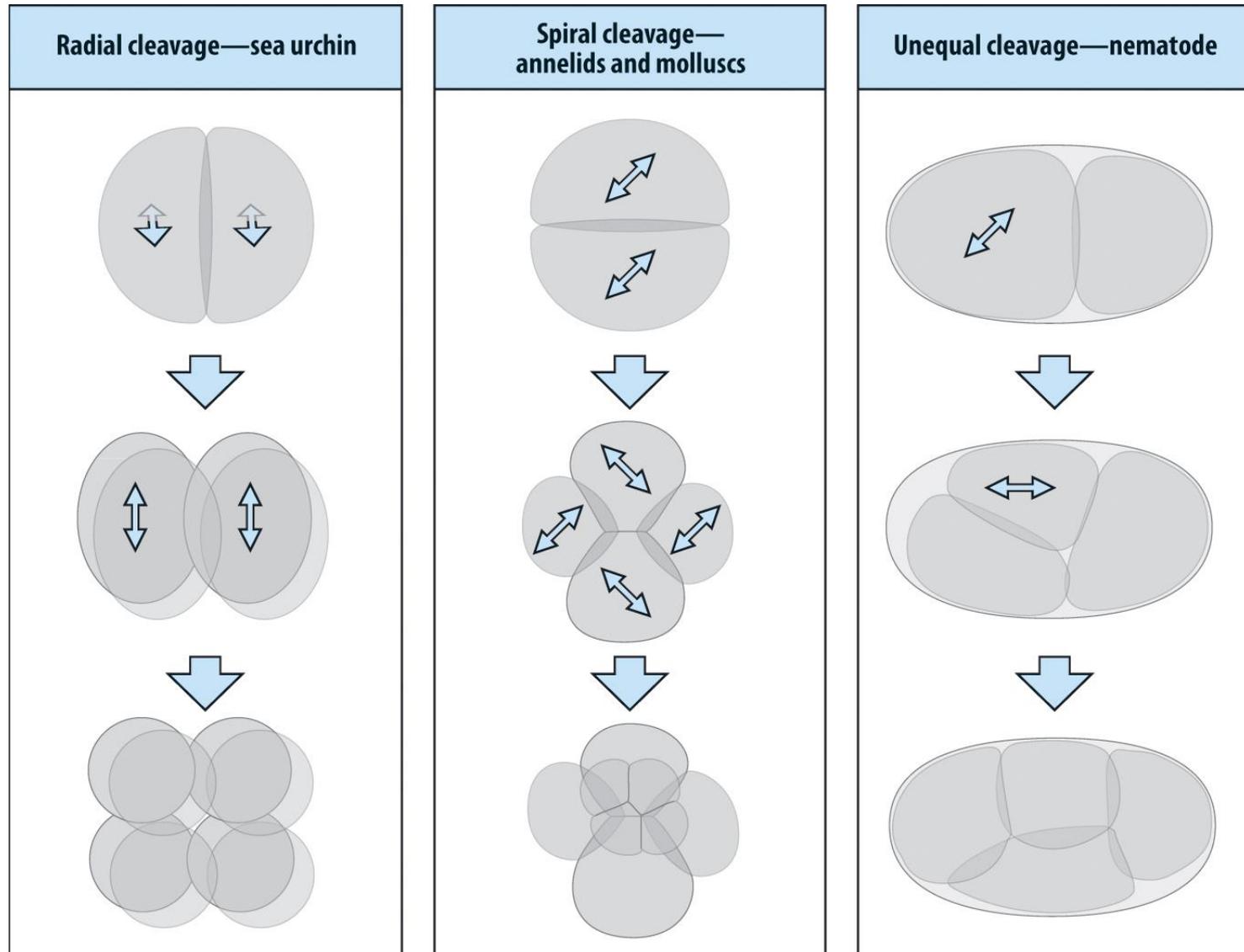


**L'orientamento del fuso mitotico può essere influenzato dalla forma della cellula/distribuzione del tuorlo**



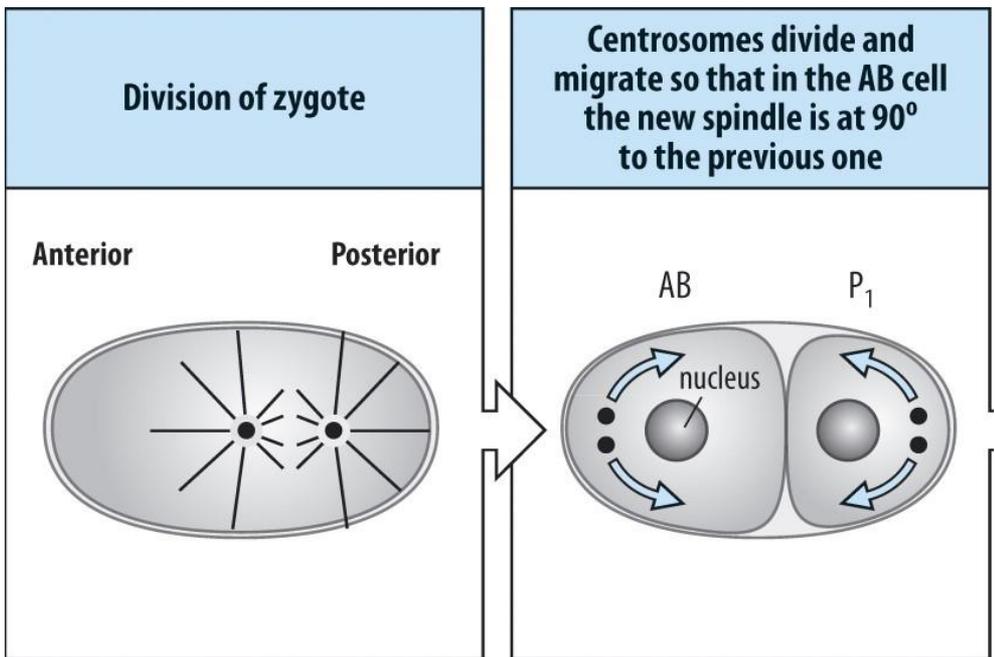
**Legge di Hertwig. I fusi di segmentazione sono disposti secondo la maggior quantità di citoplasma**

**L'orientamento del fuso mitotico può dipendere da altri fattori oltre alla distribuzione del tuorlo, determinando specifiche modalità di segmentazione**

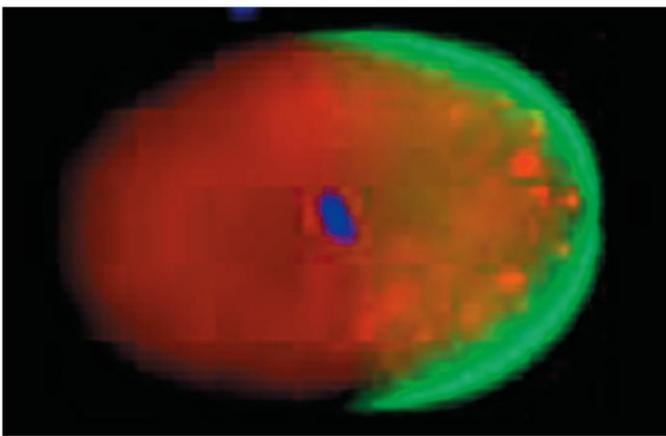


L'orientamento/posizione del fuso mitotico possono essere regolati tramite meccanismi molecolari (es. interazione del fuso con fattori localizzati in modo asimmetrico nella cellula)

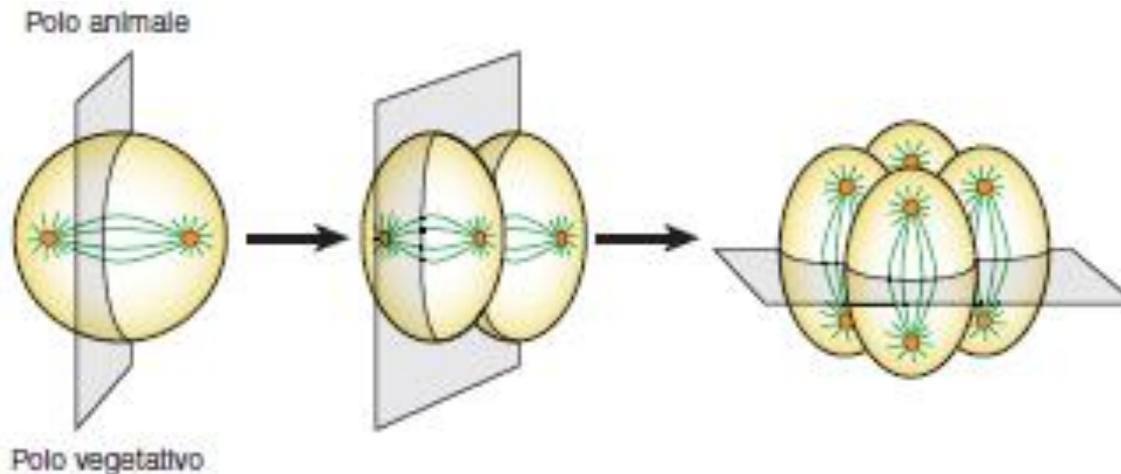
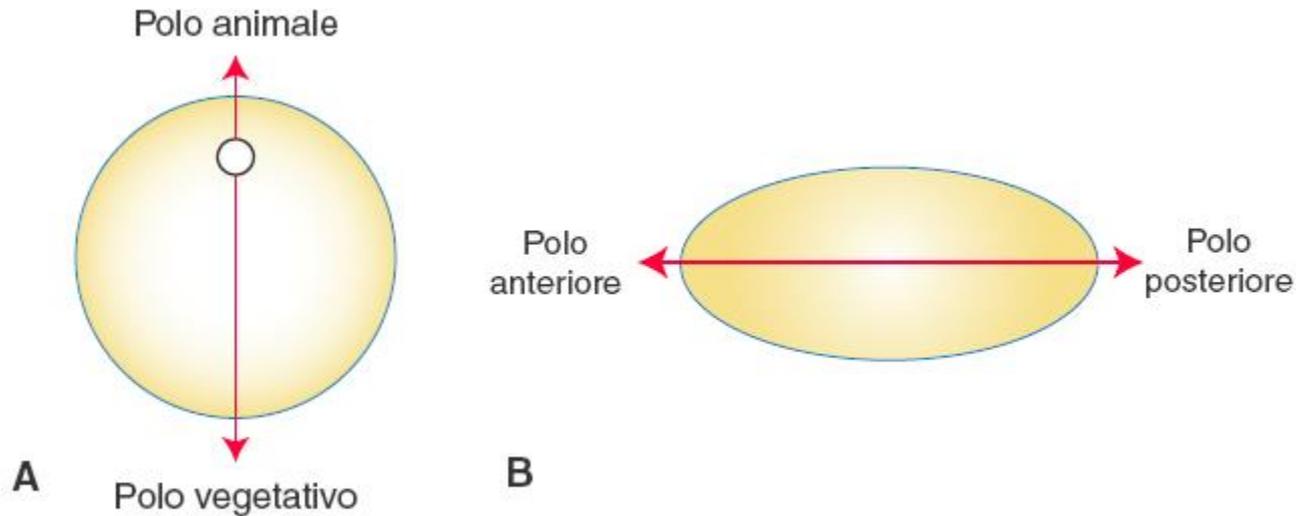
La disposizione del fuso può influenzare sia l'orientamento sia la posizione del piano di divisione cellulare e quindi sia la posizione sia la grandezza delle cellule prodotte (divisione simmetrica o asimmetrica)



(F)



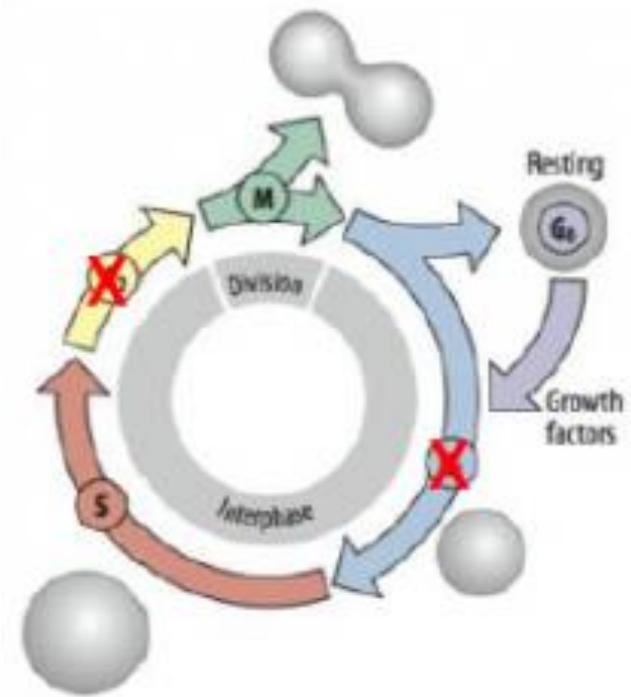
# DIVERSE MODALITA' DI SEGMENTAZIONE DIFFERISCONO IN BASE ALL'ORIENTAMENTO DEI PIANI DI DIVISIONE RISPETTO ALL'ASSE POLARE DELLE UOVA



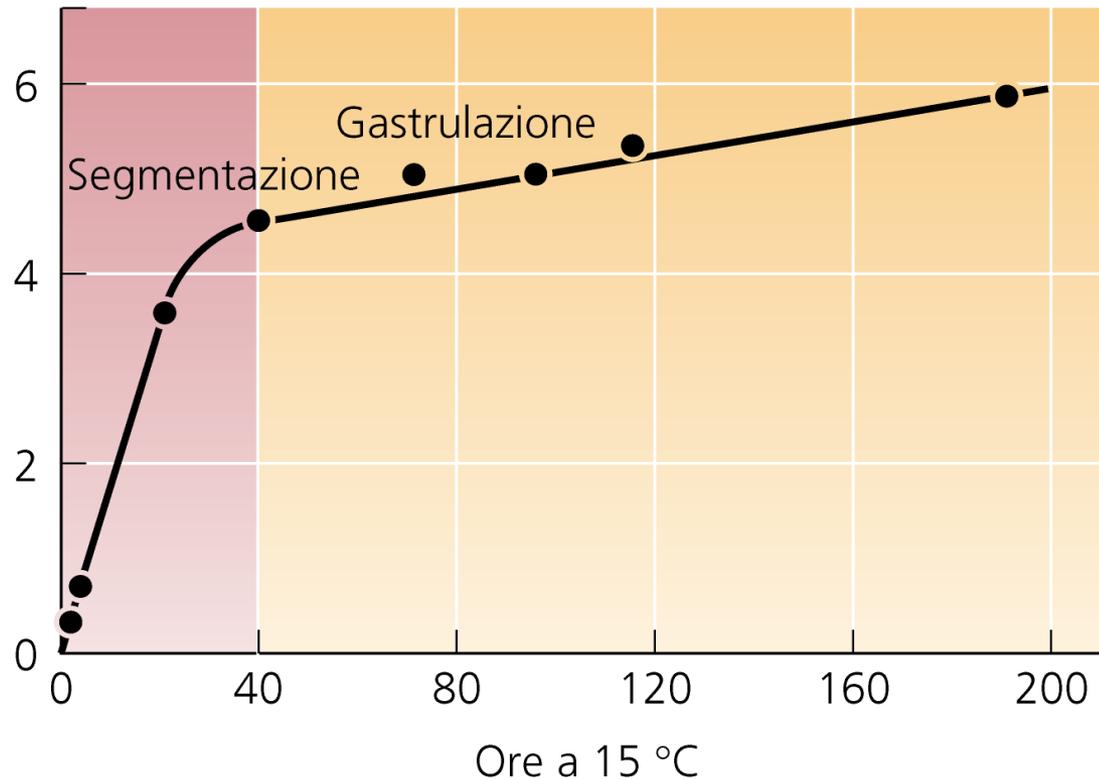
**SEGMENTAZIONE OBLASTICA RADIALE (ES. ECHINDERMI, ANFIBI)**  
Piani di divisione paralleli o perpendicolari all'asse polare

# CARATTERISTICHE DELLA SEGMENTAZIONE

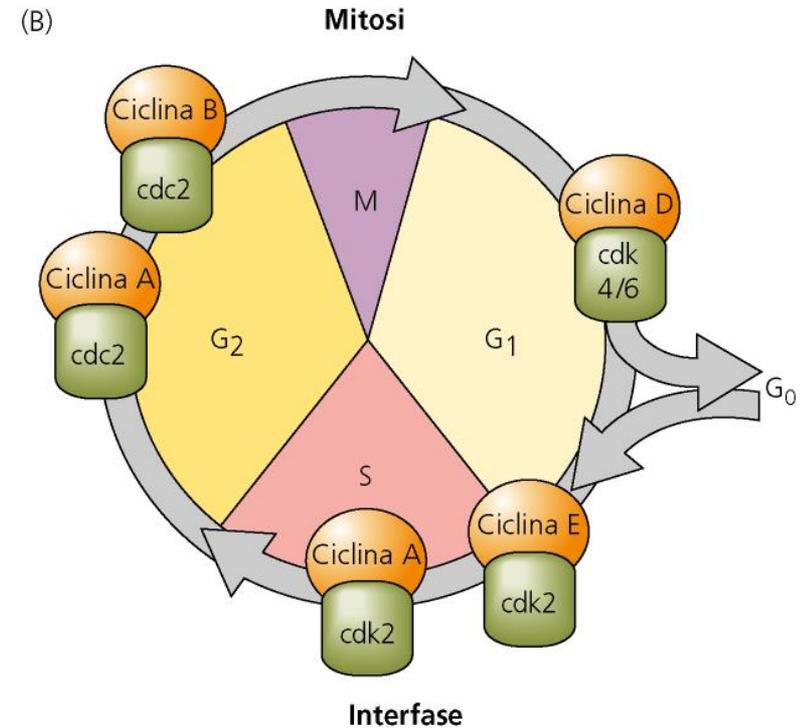
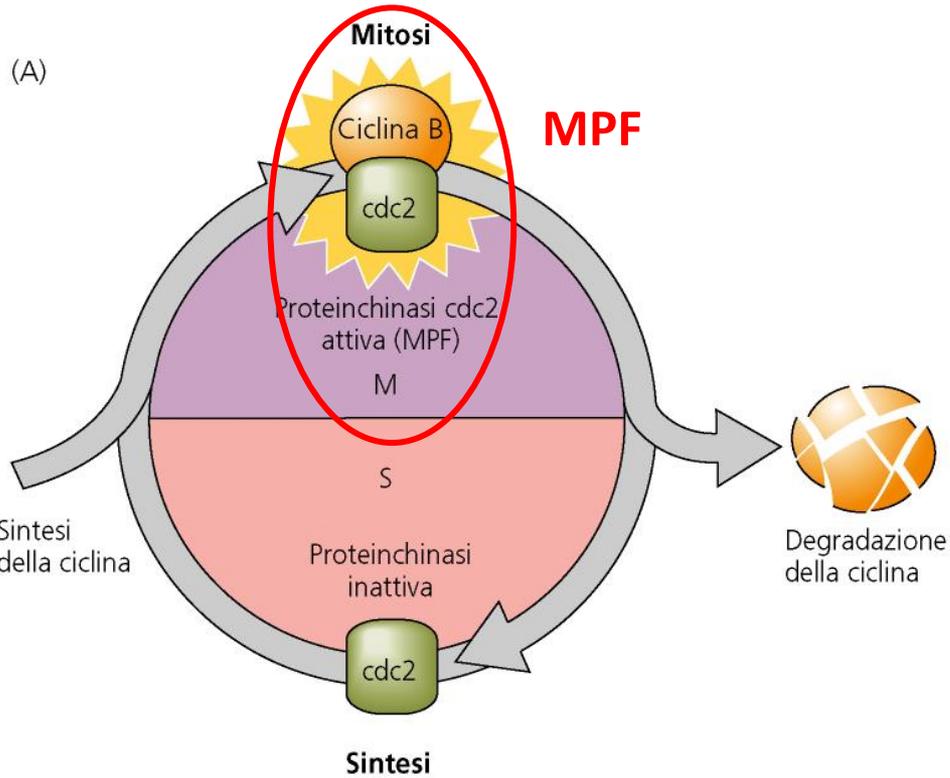
- Pluricellularita'
- Segregazione di determinanti citoplasmatici
- In molti organismi è caratterizzata da divisioni veloci e sincrone
- In questi organismi il ciclo è bifasico  $M \rightarrow S$



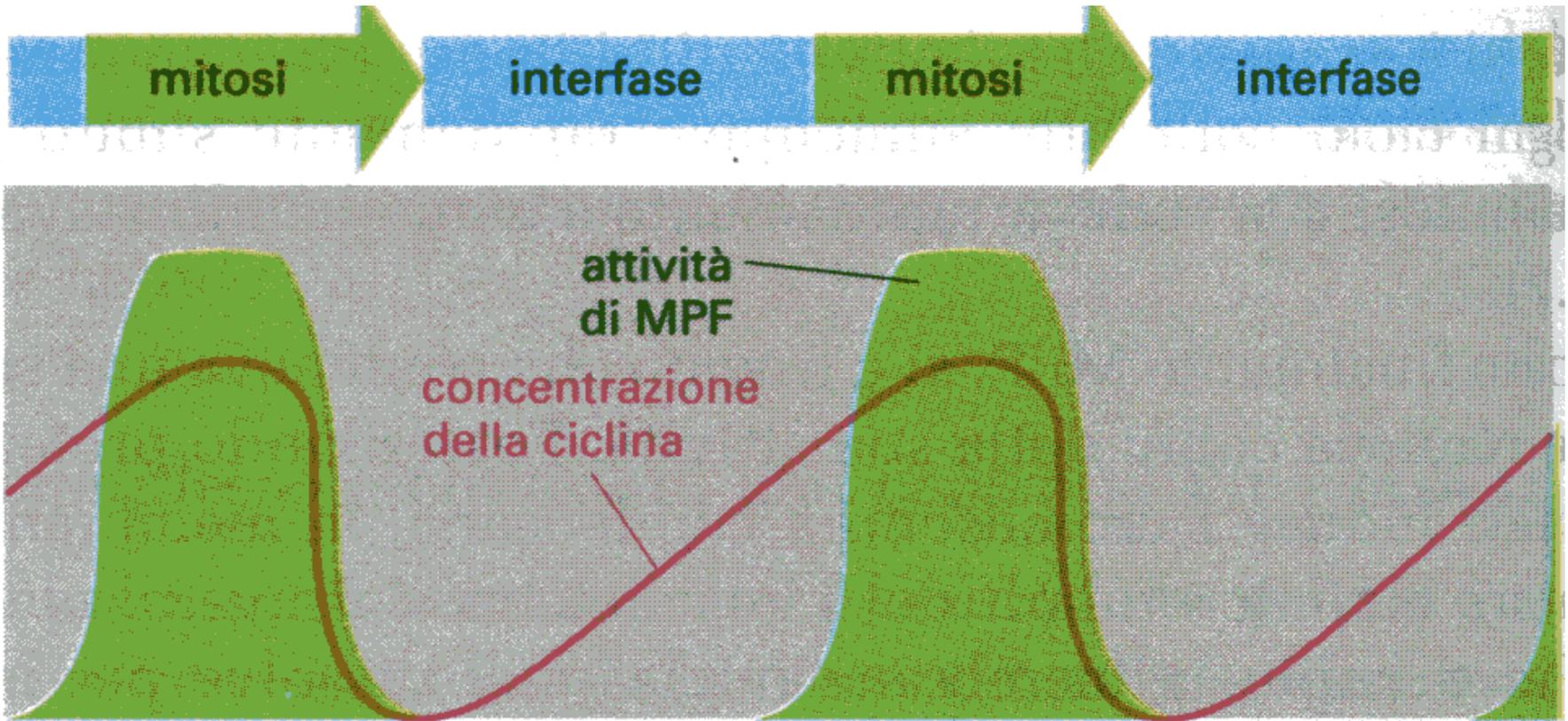
Log<sub>10</sub> del numero di cellule per embrione



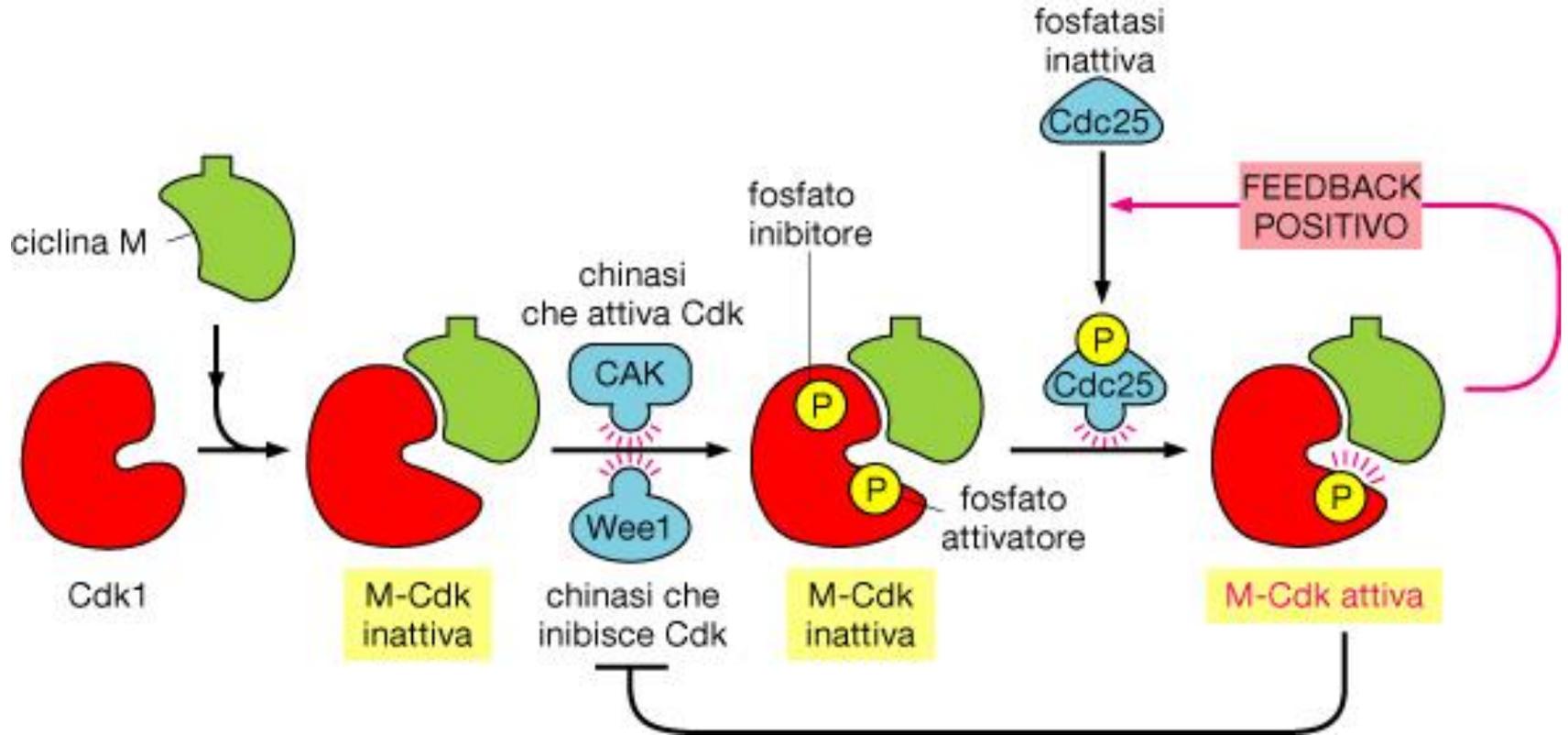
# Cicli bifasici e cicli normali



# Attività di MPF durante la segmentazione



# Regolazione del complesso MPF

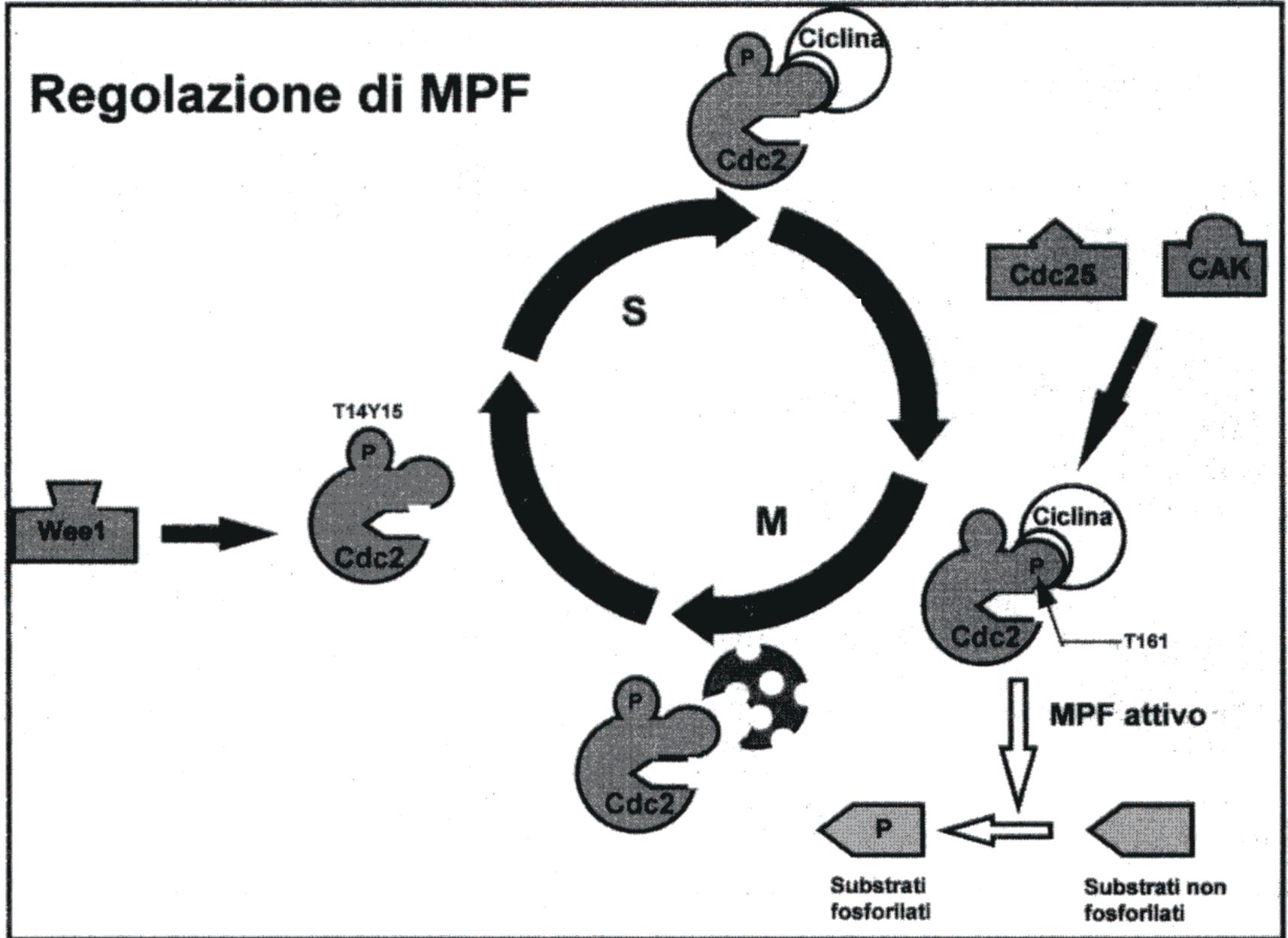


T-14 Fosforilazioni inibitorie  
 Y-15

Chinasi cdc2  $\Rightarrow$  T-161  $\Leftarrow$  cdc25(fosfatasi)  
 Fosforilazione attivatoria

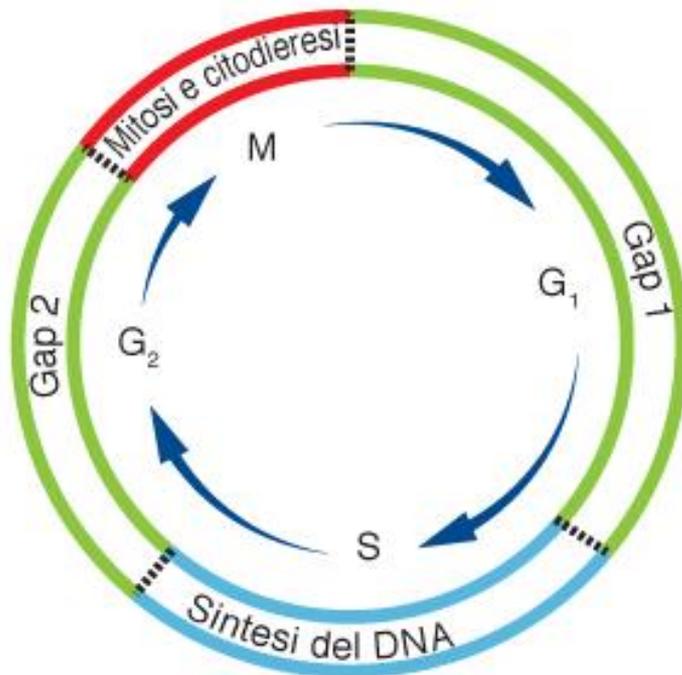
Ciclina B (Cdc13)

# Regolazione di MPF

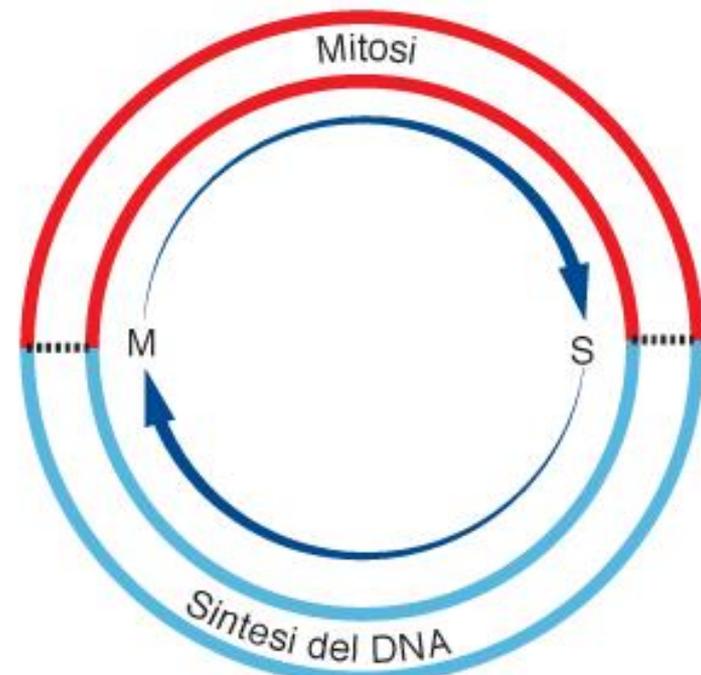


- 1) La ciclina B si accumula in fase S e si degrada dopo l'entrata in M
- 2) Il ciclo bifasico utilizza ciclina materna (mRNA) e proteine regolatrici materne
- 3) Quando si esauriscono le molecole materne si ha l'attivazione del genoma zigotico, il ciclo rallenta e si normalizza (G1 e G2)

**TRANSIZIONE DI MEDIIOBLASTULA**  
(MZT, *Maternal to Zygotic transition*)

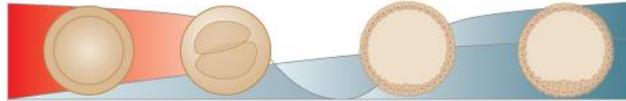


Cellule somatiche



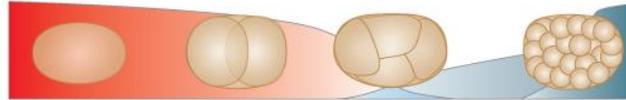
Embrione (prima della MZT)

Riccio di mare (*P. lividus*)



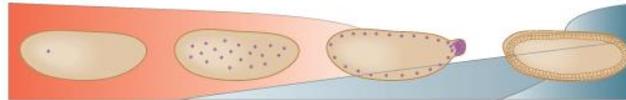
Divisione	1	2	~8	~10
Tempo (ore)	0	2	15	30

Nematode (*C. elegans*)



Divisione	0	1	2	6/7
Tempo (ore)	0	0,7	1,25	3-3,5

Insetto (*D. melanogaster*)



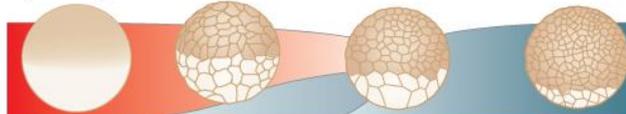
Divisione	0	8	10	14
Tempo (ore)	0	1	1,25	2,5

Pesce Teleosteo (*D. rerio*)



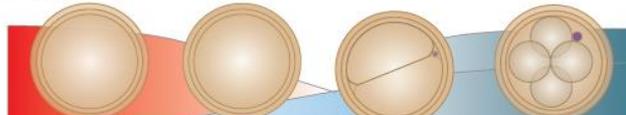
Divisione	0	1	6	10	14
Tempo (ore)	0	0,75	2	2,75	5,25

Anfibio Anuro (*X. laevis*)



Divisione	0	6	13	14
Tempo (ore)	0	4	5	9

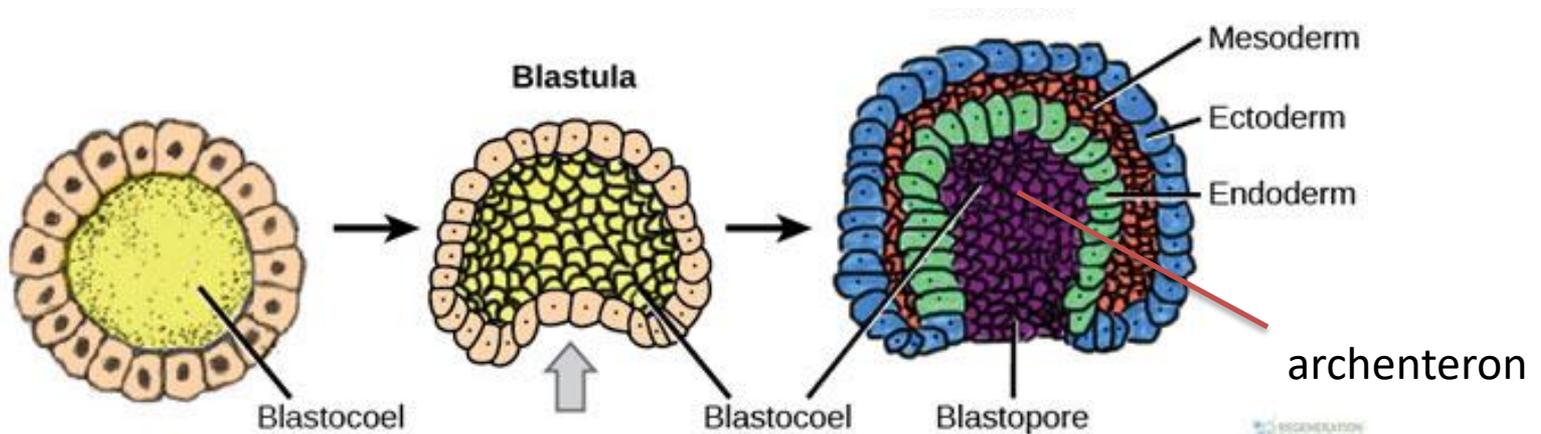
Tofo (*M. musculus*)



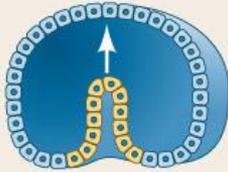
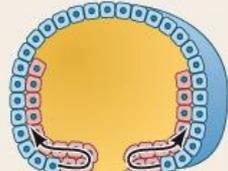
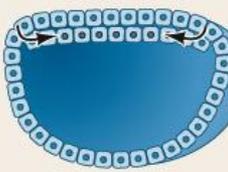
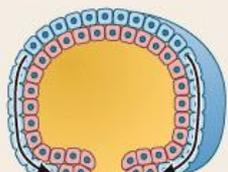
Divisione	0	0	1	2
Tempo (ore)	0	10	22	37

# GASTRULAZIONE

- Movimenti cellulari
- Organizzazione in territori
- Formazione dei tre foglietti embrionali : **Ectoderma**  
**Mesoderma**  
**Endoderma**
- Diminuisce l'attività proliferativa delle cellule
- Scarso accrescimento
- Inizio della trascrizione del DNA zigotico in alcune specie animali
- Sintesi di nuove proteine

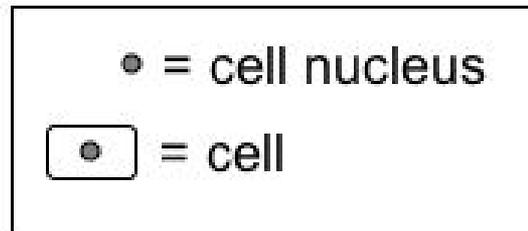
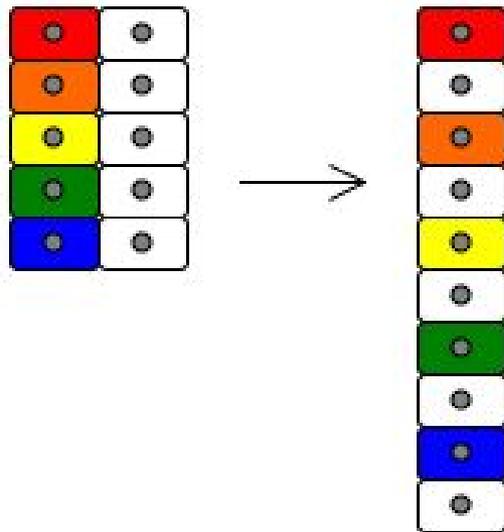


**TABLE 1.1** Types of cell movement during gastrulation<sup>a</sup>

Type of movement	Description	Illustration	Example
Invagination	Infolding of a sheet (epithelium) of cells, much like the indentation of a soft rubber ball when it is poked.		Sea urchin endoderm
Involution	Inward movement of an expanding outer layer so that it spreads over the internal surface of the remaining external cells.		Amphibian mesoderm
Ingression	Migration of individual cells from the surface into the embryo's interior. Individual cells become mesenchymal (i.e., separate from one another) and migrate independently.		Sea urchin mesoderm, <i>Drosophila</i> neuroblasts
Delamination	Splitting of one cellular sheet into two more or less parallel sheets. While on a cellular basis it resembles ingression, the result is the formation of a new (additional) epithelial sheet of cells.		Hypoblast formation in birds and mammals
Epiboly	Movement of epithelial sheets (usually ectodermal cells) spreading as a unit (rather than individually) to enclose deeper layers of the embryo. Can occur by cells dividing, by cells changing their shape, or by several layers of cells intercalating into fewer layers; often, all three mechanisms are used.		Ectoderm formation in sea urchins, tunicates, and amphibians

<sup>a</sup> The gastrulation of any particular organism is an ensemble of several of these movements.

## A: Cellular rearrangement



## B: Cellular migration



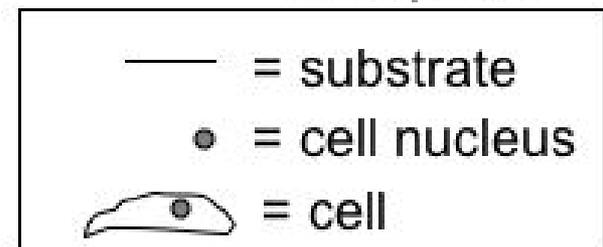
Starting point



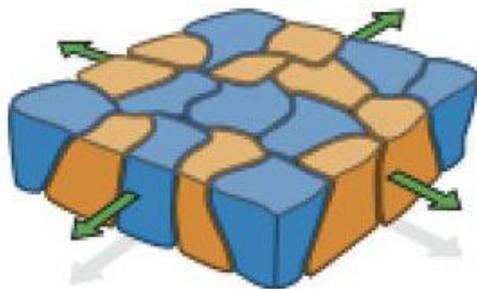
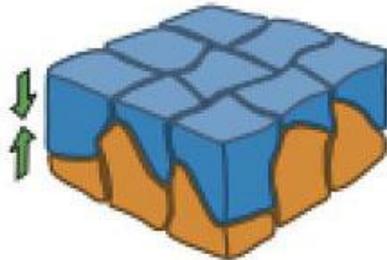
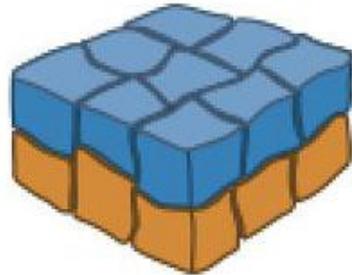
Migration along  
substrate



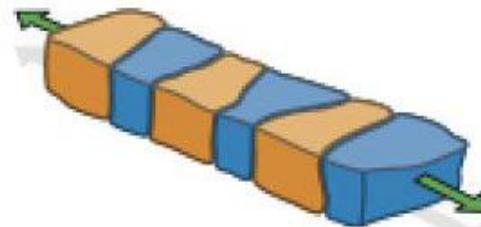
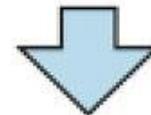
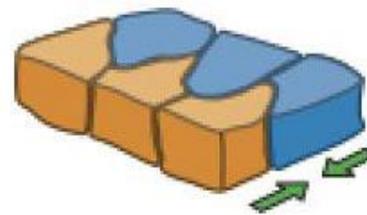
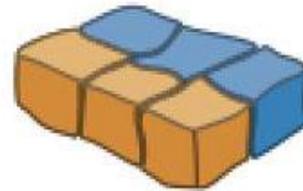
End point



### Radial intercalation



### Medio-lateral intercalation



# GASTRULAZIONE: MOVIMENTI CELLULARI CHE CONDUCONO ALLA DEFINIZIONE DEL PIANO CORPOREO

