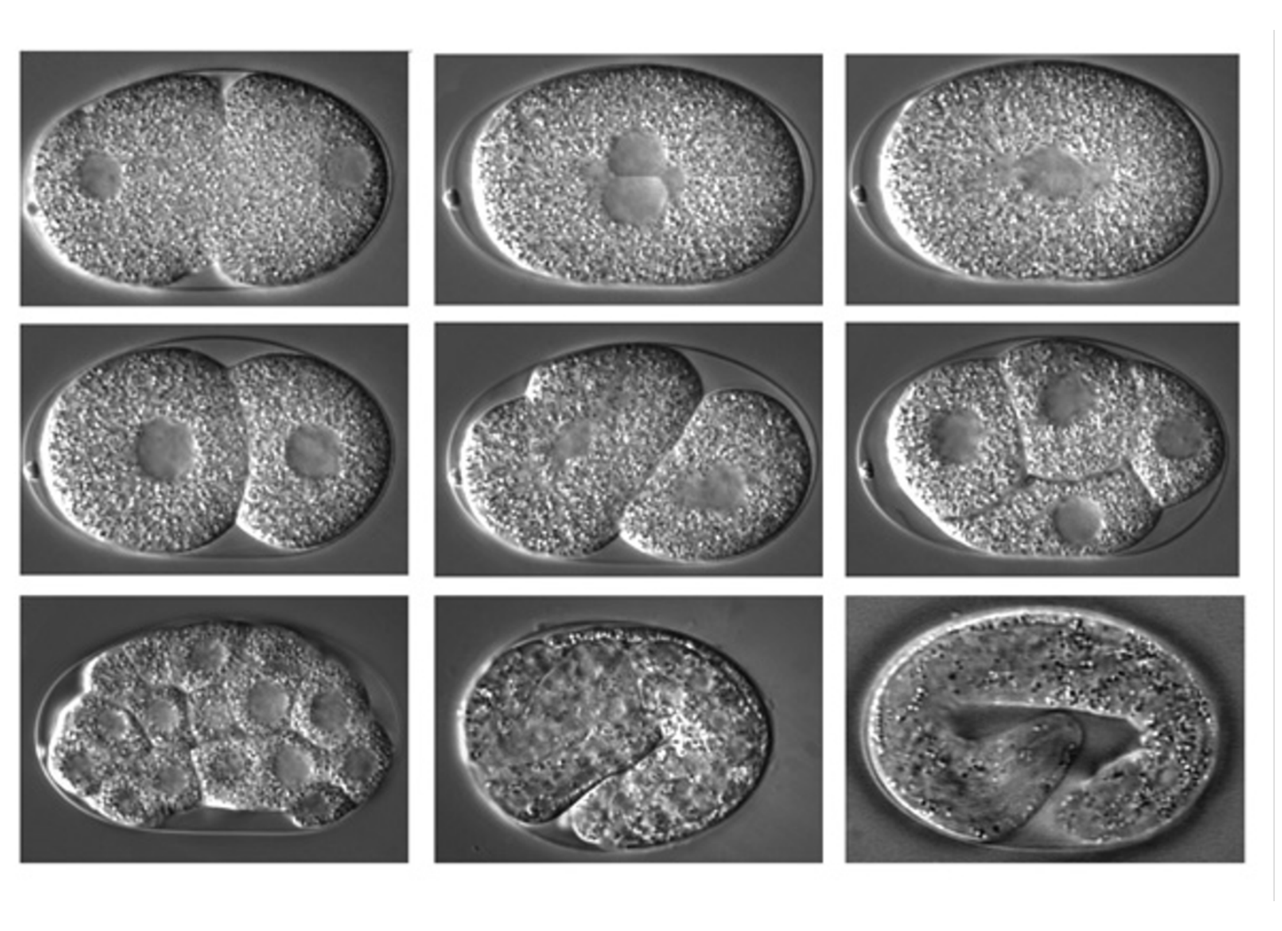
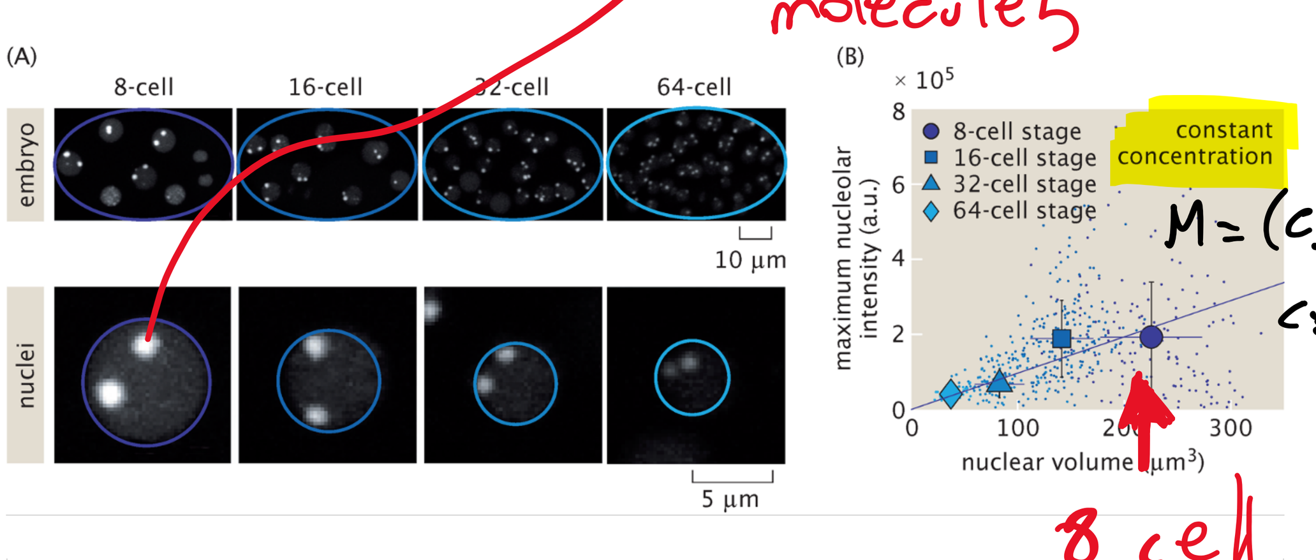
In-class Lecture 3 - Scaling, Part I

Wednesday, January 19, 2022 3:51 PM

Scaling of nucleolar size with nucleus volume in the C. elegans embryo

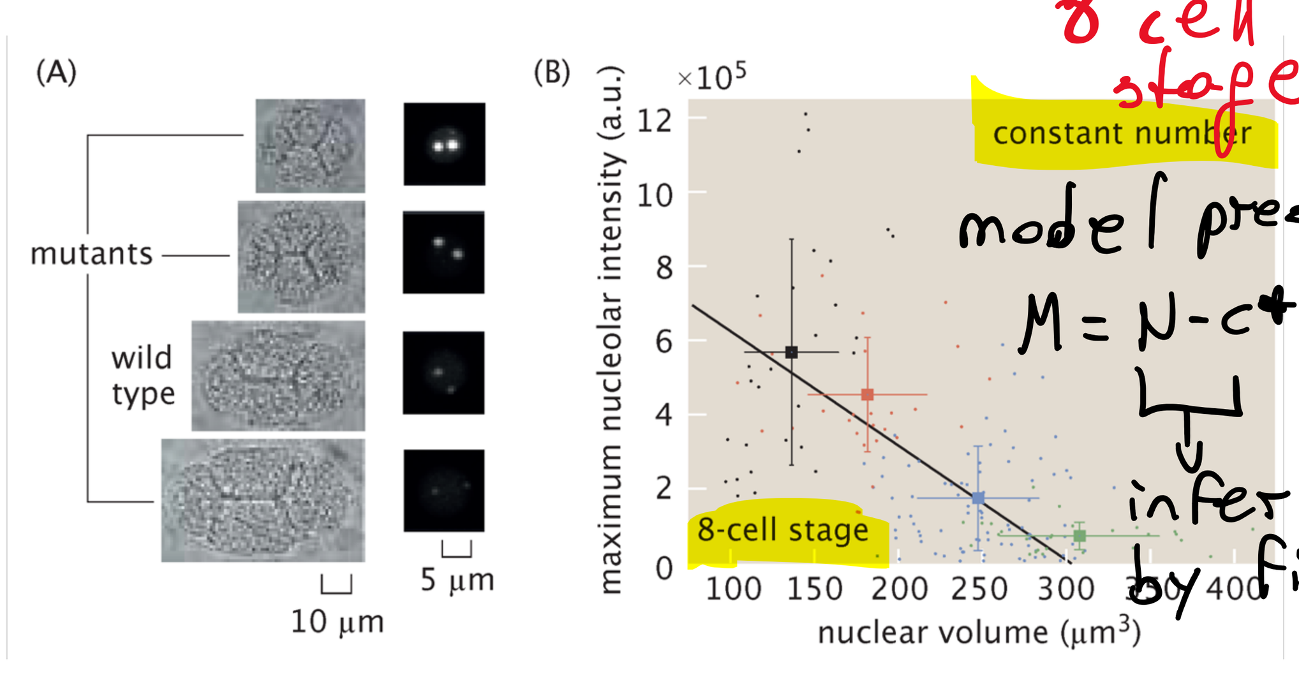


Experiment: labeled FIB-1 molecules

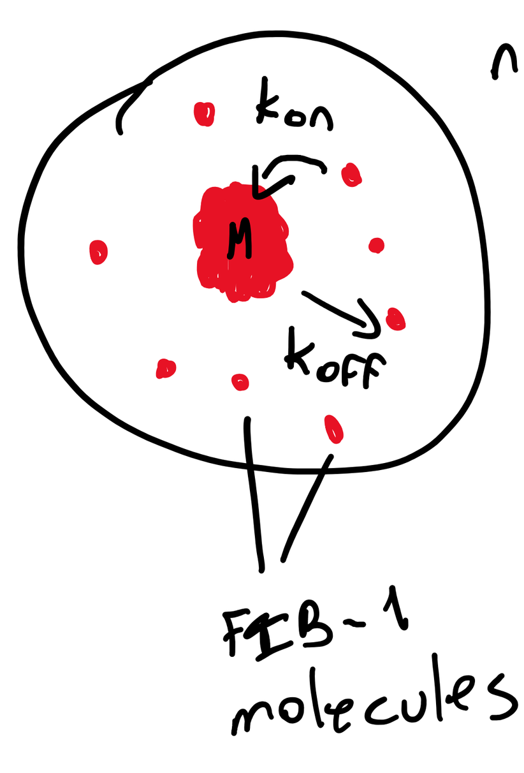


$M = (c_{tot} - c_*)V$

8 cell stage



model pred. $M = N - c_* V$ → infer by fitting



nucleus of volume V

N = total # of FIB-1 molecules

M = # of FIB-1 molecules in nucleolus

k_{on} = rate of incorporation of FIB-1 molecules per molecule

$[k_{on}] = \frac{1}{\text{time}} \frac{1}{\text{concentration}}$

Rate of FIB-1 incorporation $= k_{on} \cdot$ concentration of free FIB-1 molecules

$= k_{on} \cdot \frac{N-M}{V}$

Rate of separation of FIB-1 molecules $= k_{off}$

↳ Caution: there might be other models for k_{off} that account for the amount of FIB-1 already in the nucleolus (M)

$M(t+\Delta t) = M(t)$ + # incorporated − # left nucleolus

(Δt: small time interval)

$M(t+\Delta t) = M(t) + k_{on}\frac{N-M}{V} \cdot \Delta t - k_{off}\Delta t$

(arrival) (depart)

⇓ first difference eqn.

$$\frac{M(t+\Delta t) - M(t)}{\Delta t} = k_{on}\frac{N-M}{V} - k_{off}$$

this is just $\frac{dM}{dt}$

Assume steady-state

$M(t+\Delta t) = M(t)$

⇓

$k_{on}\frac{N-M}{V} - k_{off} = 0$

$N - M = k_{off}\frac{V}{k_{on}}$

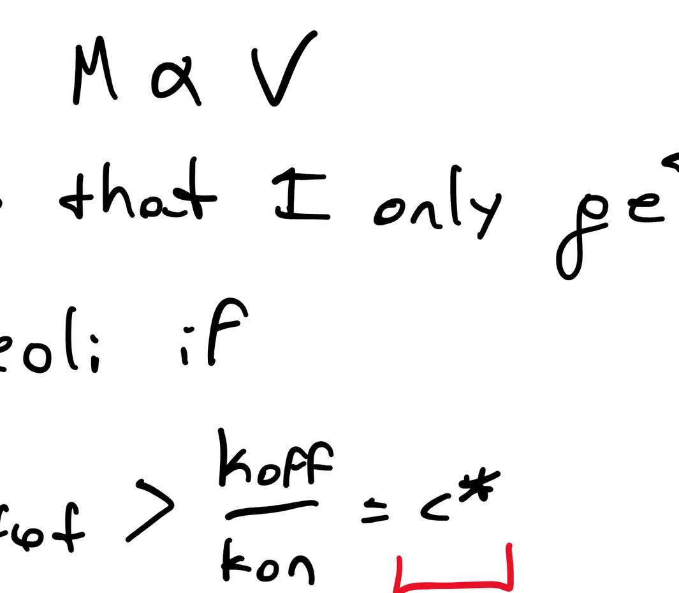
$N - k_{off}\frac{V}{k_{on}} = M$

$$M = \left(\frac{N}{V} - \frac{k_{off}}{k_{on}}\right)V$$

($\frac{k_{off}}{k_{on}}$: units of conc; $\frac{N}{V}$: concentration of FIB-1 in the cell $= c_{tot}$)

$M = \left(c_{tot} - \frac{k_{off}}{k_{on}}\right)V$

(const.)



⇒ @ fixed conc.

$M \propto V$

Note that I only get nucleoli if

$c_{tot} > \frac{k_{off}}{k_{on}} = c^*$ (critical concentration)

What about the constant number exp.? Here N is held fixed.

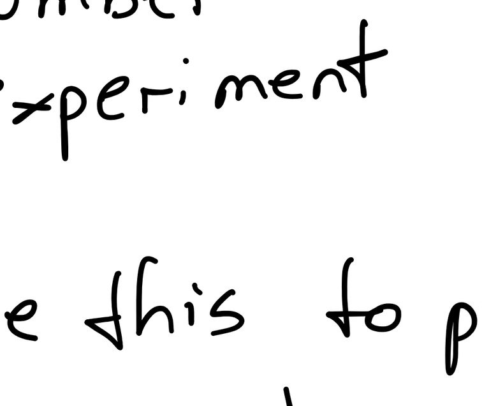
$M = \left(\frac{N}{V} - c_*\right)V$

$M = N - c_* V$

⇓

for const. number

$M = b - a \cdot V$



We fit to get from fixed number experiment ⇒ N: total #, c_*: critical concentration

Use this to predict outcome of fixed conc. exp.

$M = (c_{tot} - c_*)V$

$c_{tot} = \left.\frac{N}{V}\right|_{8\text{ cell stage}}$