

# MCDB 4650 Developmental Biology Spring 2021

## Exam #1

are you currently in physically located in Boulder (or surrounding parts of) Colorado (→)

- yes, in colorado in colorado but away
- from Boulder & the University
- no, outside of colorado

type in the time you started the exam (↓)

time exam started

if you have no idea how to answer a question - you can write "no idea" in the text box and proceed to the next question. That will get you 1 point.

Timer ^

00:00

**Q1A (4 points)** Genome diminution is a genetic change since the genome is altered. Propose a model that would lead to the loss of specific genomic regions in specific cell types. You can draw a schematic if you want (not required), but indicate how specificity is achieved (that is, how specific genomic regions are lost or retained).

what exactly is your molecular model for the process



**Q1B (4 points)** In most organisms, cellular differentiation is essentially irreversible and involves a number of epigenetic (rather than genetic) changes. What epigenetic changes would be particularly difficult to reverse and why? Include drawing if you want (not required)

what exactly is your molecular model for the process



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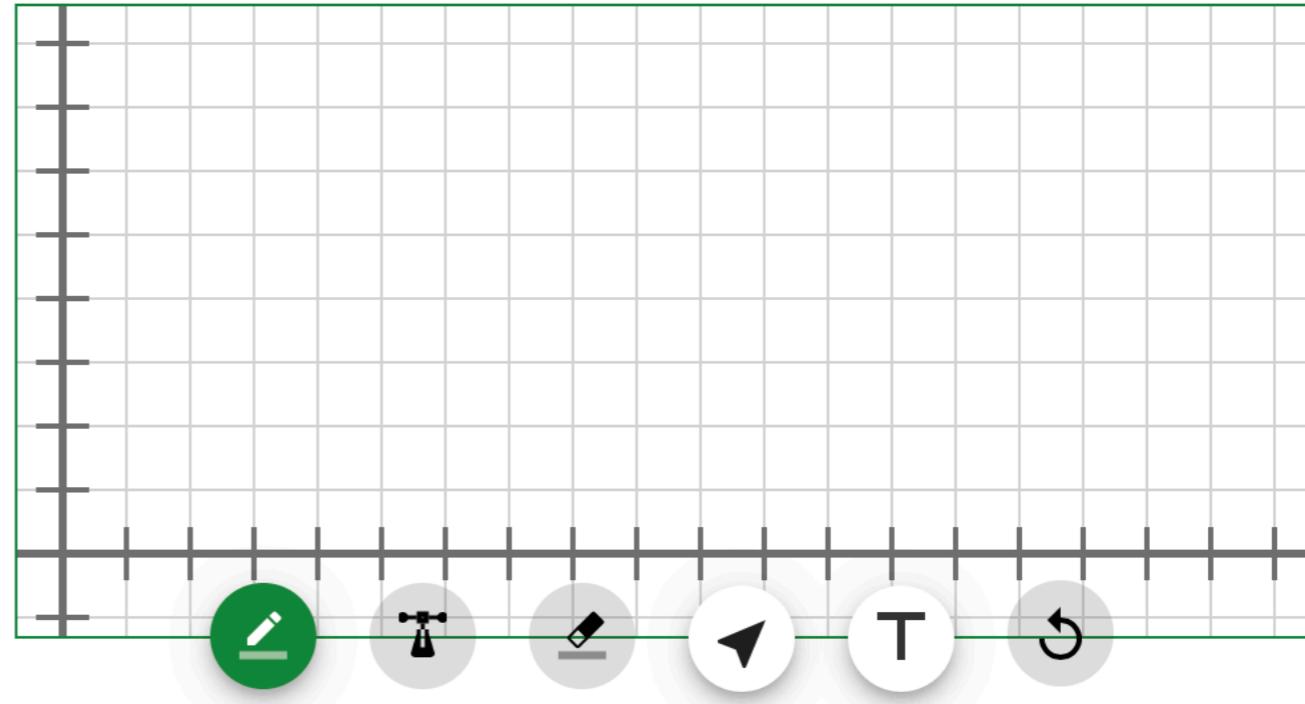
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**Question 1C (3 points)** You are asked to predict whether nuclear replacement experiments, such as those carried out by John Gurdon in Xenopus (in which the nuclei of fertilized eggs were replaced by nuclei from various differentiated cells, producing normal adults) would work in Ascaris (which uses genome diminution). Explain your thinking (↓).

explain

**Question 1D (4 points)** Predict how the efficiency of nuclear (replacement) transplantation (Y-axis: % normal embryos) will change based on the age of the embryo (X-axis: from fertilized egg to swimming tadpole). Describe the factors that influence (and complicate) your prediction (↓).

explain



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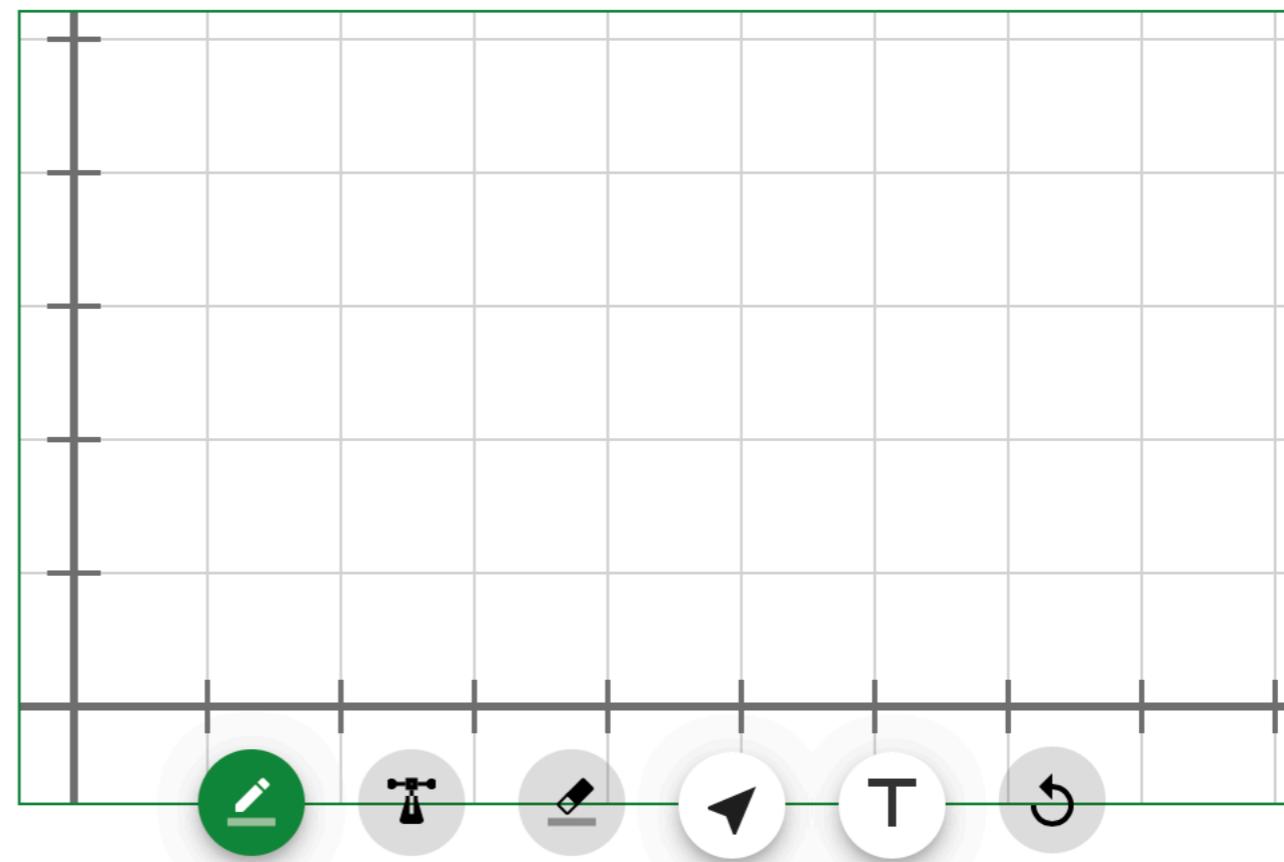
**Q2A (5 points)** You are studying a system in which a secreted signal molecule (the ligand) binds to and activates a receptor protein kinase that, when active, phosphorylates the SQUISH protein.

Assume that increased levels of P-SQUISH lead to changes in gene expression. What factors will determine whether a specific level of signal molecule will lead to altered gene expression?

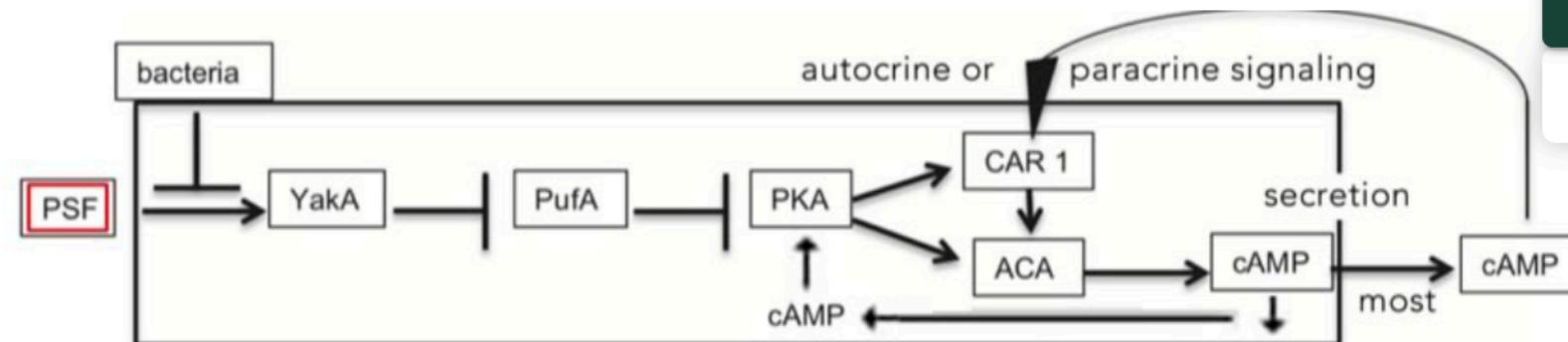
explain

**Q2B (5 points)** Now assume that P-SQUISH has a second activity, it increases the rate of receptor degradation. Assume a ligand concentration sufficient to produce a detectable increase in P-SQUISH, compare the behavior of the system WITHOUT the P-SQUISH receptor effect (blue) with one with the P-SQUISH receptor effect (red) as a function of time. How will the final steady state levels of P-SQUISH compare in the two scenarios? Explain why.

explain



**Q3** The unicellular–multicellular transition seen in slime molds (and a number of other organisms) is regulated by multiple "threshold" type signaling responses.



**3A (6 points)** What distinguishes a threshold response from a standard sigmoidal response & why are thresholds used to control such processes?

explain

**3B (3 points)** What factors are likely to be most critical when individual Dictyostelium cells decide to cooperate?

explain

**3C (3 points)** Predict the effect, over time, on the frequency of cheaters in a population of Dicty if the environment was hospitable over long periods of time.

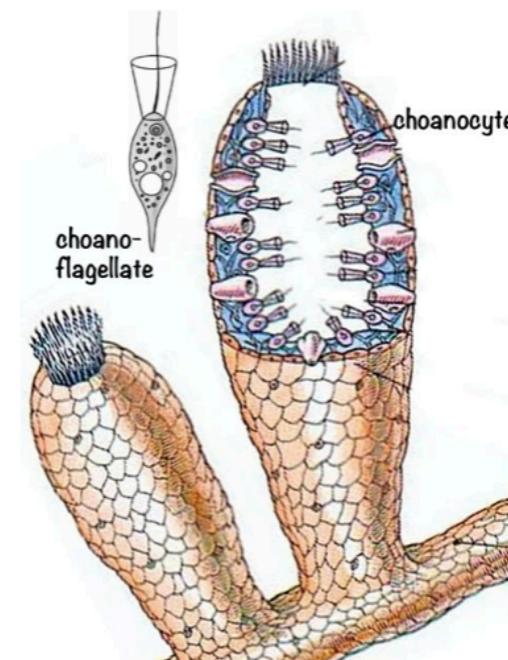
explain

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**Q4A (4 points)** When constructing a plausible model for the common ancestor of metazoans describe the types of observable features that you would think are most useful?

explain



**Q4B (4 points)** Describe the types of data you would use to unambiguously identify a HOX cluster in a newly identified organism. You can use a drawing if you want.

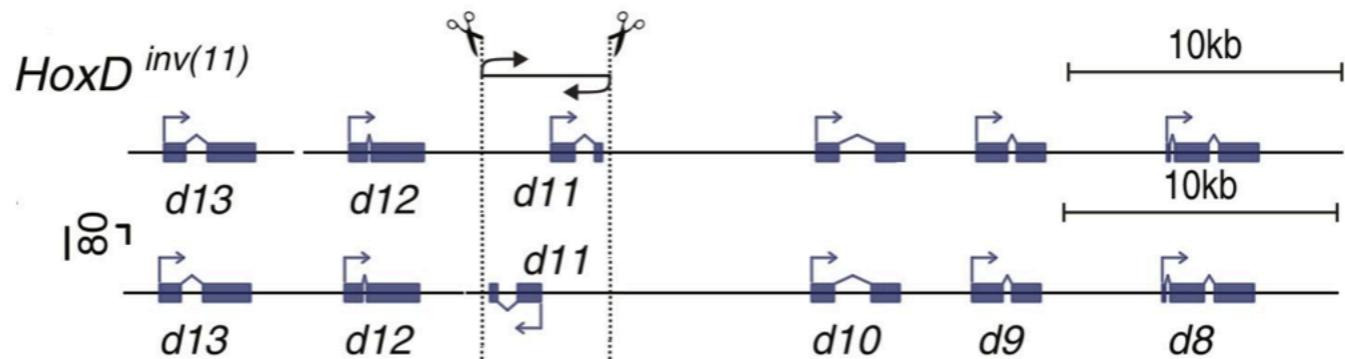
what exactly is your molecular model for the process



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**Q4C (4 points)** You flip the orientation of one of the genes in a HOX cluster and observe that neither developmental timing or expression domain of the gene are altered - what could you conclude about the regulatory elements that control the expression of the flipped gene?



what exactly is your molecular model for the process

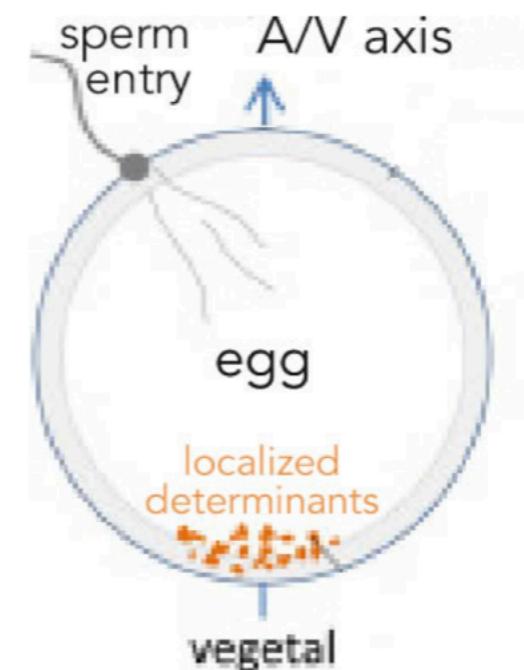
**Q5A (6 points)** In Xenopus the oocyte (and egg) are asymmetric along the animal vegetal axis.

One example of this asymmetry is the distribution of cytoplasmic RNAs, some RNAs are concentrated in the animal hemisphere, different RNAs in the vegetal. Propose a model, and the processes involved, that could lead to such asymmetries in what is large, but single cell.

explain

**Q5B (4 points)** After fertilization the cortex moves with respect to the egg's inner region, which orients to the Earth's gravitational field. UV illumination of egg's vegetal region inhibits cortical rotation, leading to ventralized embryos. It is possible to rescue normal axis formation by placing UV-treated fertilized eggs in an artificial gravitational field, i.e. a centrifuge, so that the inner region moves with respect to the cortex.

What do such experiments tell us about how the dorsal-ventral axis arises?



explain

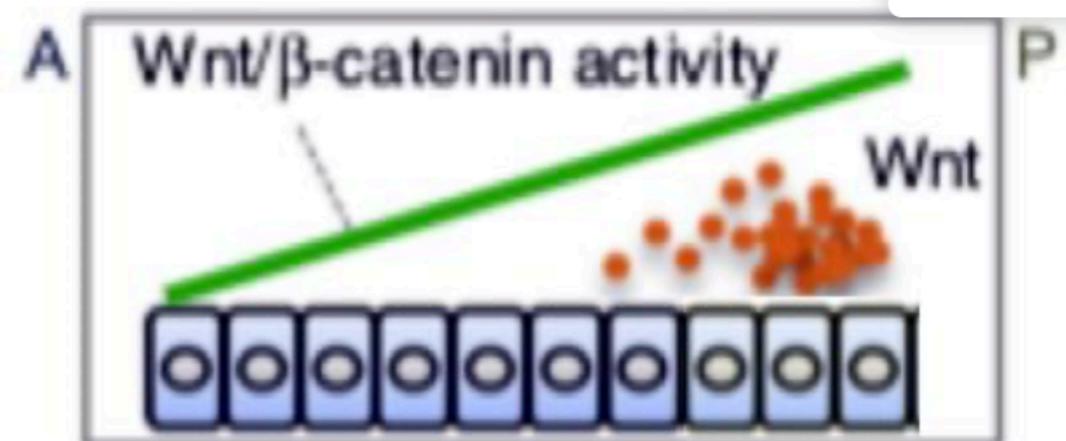
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**Q6 (6 points)** In the zebrafish dorsal organizer, there are "eccentric" cells that fail to accumulate nuclear  $\beta$ -catenin and cells outside of the organizer region that do display nuclear  $\beta$ -catenin. Nuclear  $\beta$ -catenin interacts with, and influences the activities of transcription factors.

Both types of "eccentric" cells are induced to undergo apoptosis.

Propose a model by which such eccentric cells could be recognized and describe what might happen if they are not removed..



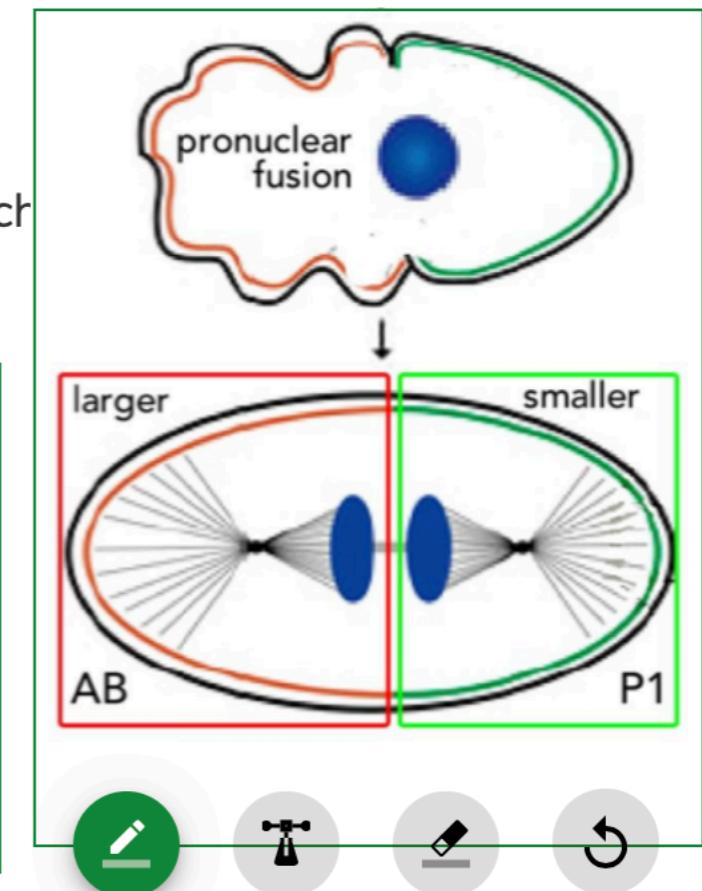
explain here

**Question 7A (4 points)** Explain how the specific features of *C. elegans* development make it a uniquely powerful system in which to study the regulation of programmed cell death.

explain here

**Question 7B (4 points)** The first division in the *C. elegans* embryo is asymmetric. Predict what would happen to spindle position and subsequent development if you used a laser beam to cut the connection between the spindle and posterior pole (which would normally produce the future P1 cell) (↓). Draw the position of laser cut (→)

explain here



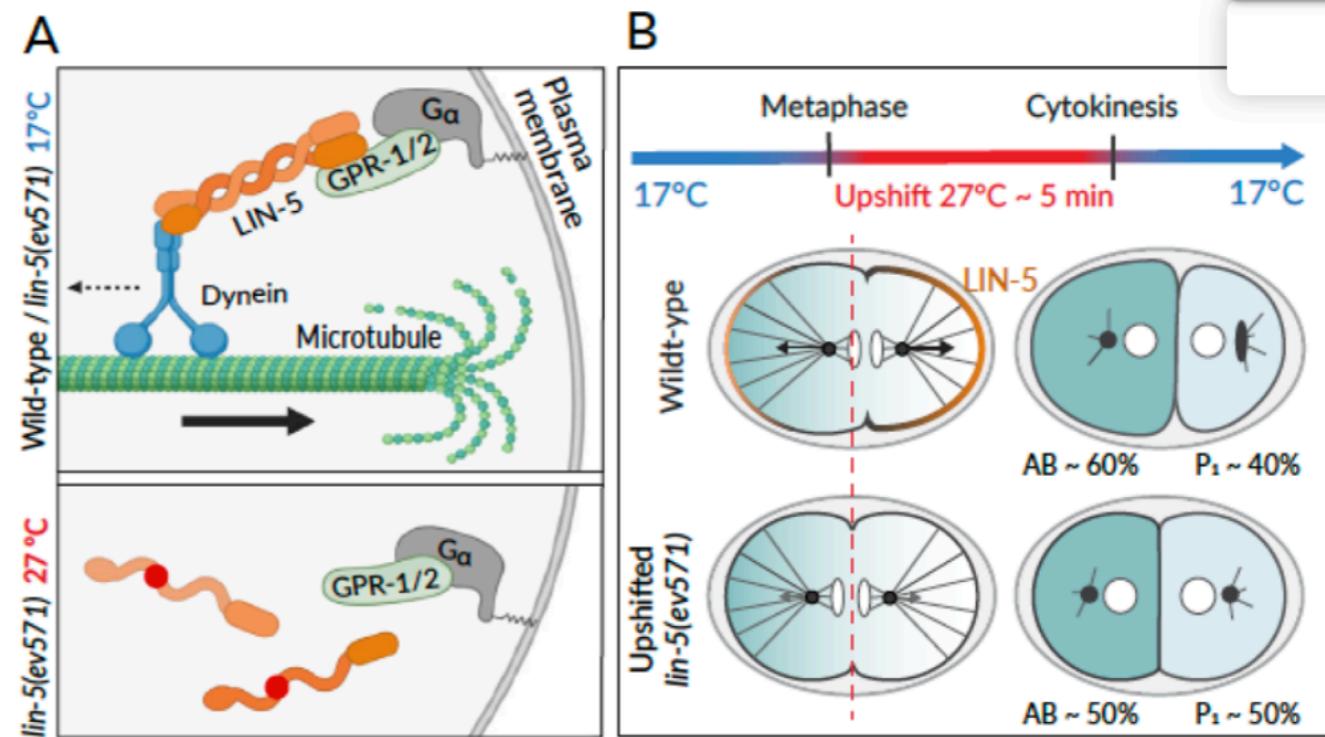
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**Question 7C (4 points)** In this study, a temperature sensitive mutant of *lin-5*, which encodes a protein that connects the posterior cortex to dynein motors) was used.

First what is meant by restrictive and permissive temperatures of a mutation and how do they influence the gene product ( $\downarrow$ ).

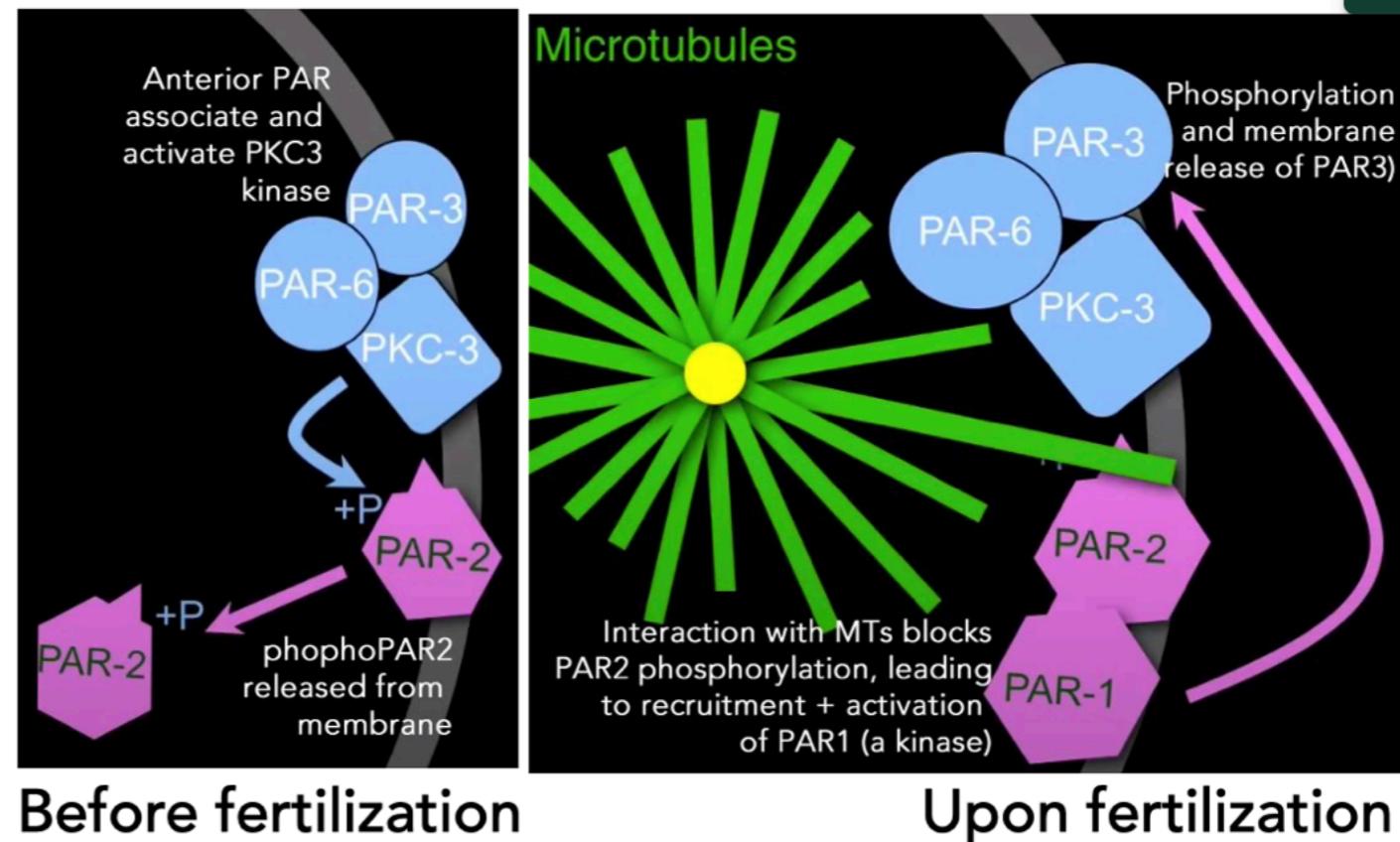
explain here



and then explain why, at the restrictive temperature, the spindle moves to the center of the embryo ( $\downarrow$ ).

explain here

**Question 7D (4 points)** In the unfertilized *C. elegans* egg, the PAR3 complex is localized around the cortex and inhibits PAR2 binding to the cortex. Sperm entry leads to spindle microtubule stabilization and membrane localization of the PAR2/PAR1 complex, which inhibits PAR3 localization; the result leads regional asymmetries of PAR3 and PAR2 proteins. Predict what would happen if the egg did not contain a functional PAR1 protein and explain why (↓).



explain here

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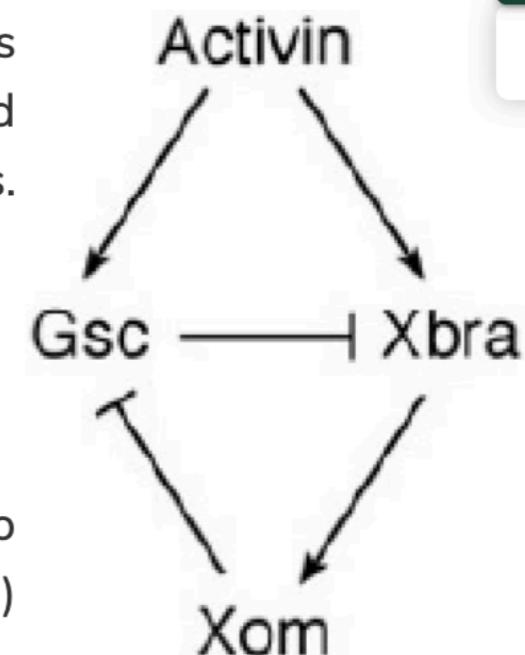
**Q8 (6 points):** In this system, activin activates the expression of *Gsc* and *Xbra* ( $\rightarrow$ ).

Saka & Smith modeled this gene network based on estimates of the various parameters involved, including synthesis rates, half-lives, and the affinities of the *Gsc*, *Xbra*, and *Xom* proteins for their DNA target sites.

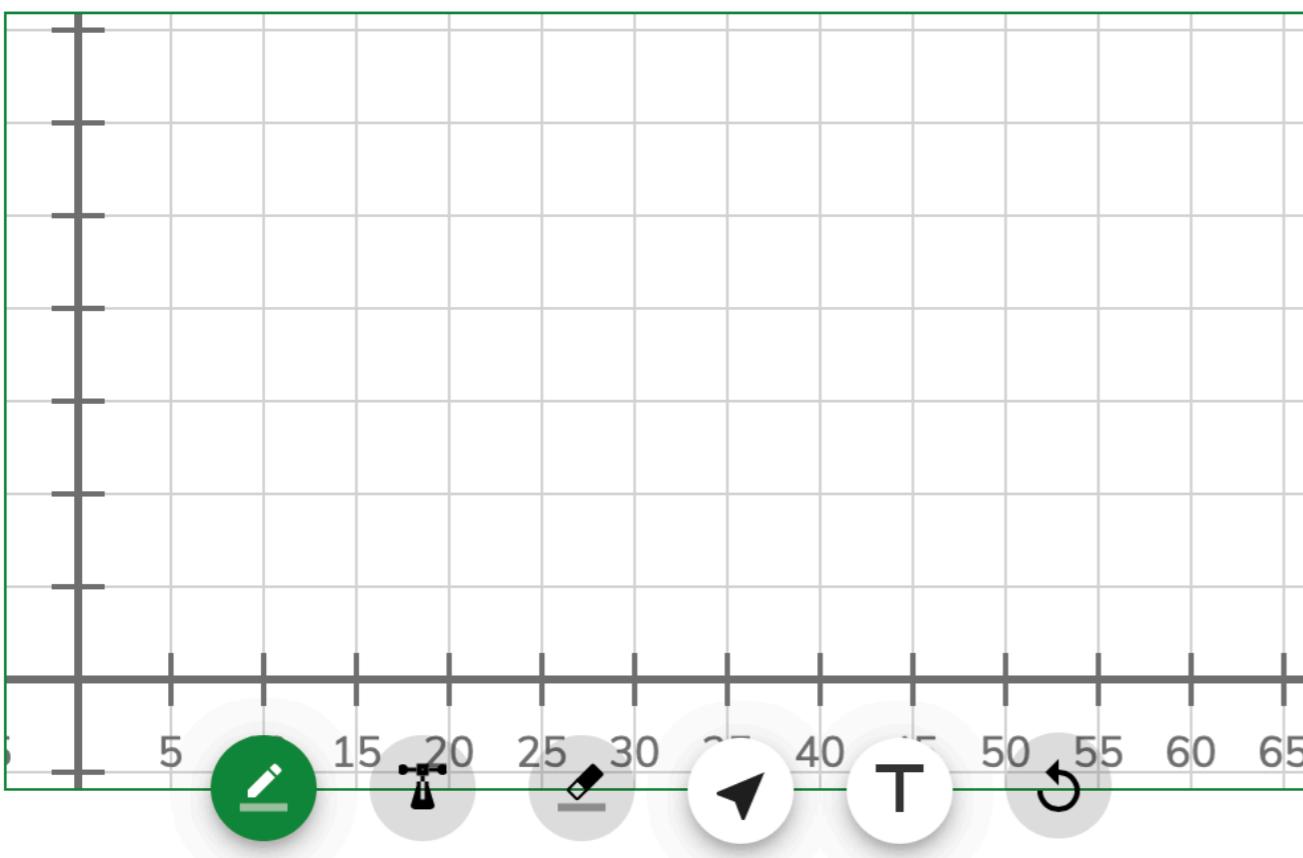
Assume that activin activates *Gsc* and *Xbra* expression equally, but that the movement of *Gsc* into the nucleus is faster than that of *Xbra* & *Xom*,

A: Predict ( $\downarrow$ ) the level of *Gsc* protein as a function of time (activin is added at time 10 and remains in the system)

B: Predict (in a different color) How will the response change if *Gsc* also negatively regulates the activin receptor? describe your assumptions ( $\downarrow$ )



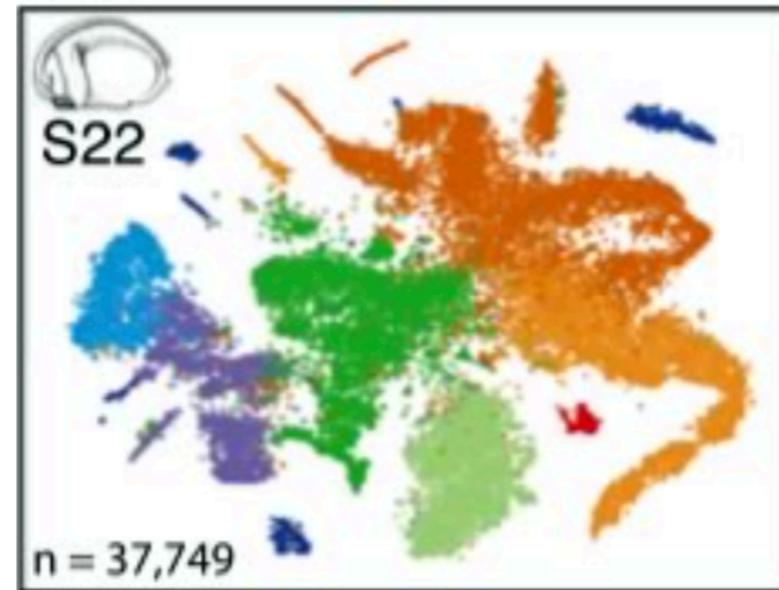
explain here



**Q9 (5 points):** When we consider complex data sets, such as those associated with single cell RNA SEQ analyses of developing embryos, the results are often analyzed by using principle component analysis so that the observations can be displayed in meaningful ways.

In this case from Briggs et al (2018), the analysis of tens of thousands of cells from a stage 22 *Xenopus* embryo is displayed in terms of cell types (→).

**Q:** What does it mean, in molecular terms, that all of the cells of a certain type do not map to a single X,Y coordinate? (→)



- Pluripotent blastula
- Germline
- Non-neural ectoderm
- Placodal
- Specialized epidermis
- Neural
- Neural crest
- Marginal zone
- Dorsal mesoderm
- Vent/lat/int. mesoderm
- Endoderm

explain here