- 1. In this problem, abc.defgh, ijkl,mnop, and qrstuv.wx represent three normal chromosomes in a diploid organism. The dot in the sequence represents the centromere. Only the constitution of the aberrant chromosome of each homologous pair is given:
 - a) abcfg.deh
 - b) abgfc.deh
 - c) abjkc.defgh, il.mnop
 - d) abkjc.defgh, il.mnop
 - e) ars.defgh, ijbc.mnop, qkltuv.wx
 - f) abcbc.defgh
 - g) abcdef.gh
 - h) ac.defgh, abc.defgh
 - i) abc.dba, hgfec.defgh

For each of the above:

A) What is the name of each type of change?

B) Show the pachytene configuration in an F_1 if homologous parts pair?

- **2.** A plant is heterozygous for a given pair of genes, *D* and *d* (d = dwarf). The chromosome carrying *D* also carries a duplication (*Dp*). The duplication reduces the ability of the pollen carrying *Dp* to compete by 90%. Also, there is 20% recombination between *Dp* and *D*, *d*. What are the expected kinds and frequencies of:
 - a) the different kinds of gametes?
 - b) the different kinds of zygotes when crossed with a *dd* normal \bigcirc ?
 - c) the different kinds of zygotes when crossed with a *dd* normal 3?

3. Contrast the chromosome and chromatid breakage-fusion-bridge cycles in relation to their initiation (origin).

- **4.** Investigations of gene sequences on a particular chromosome show the presence of the following three arrangements:
 - a) ABCDEFGHIJ
 - b) ABCHGFIDEJ
 - c) ABCHGFEDIJ

Explain the possible evolutionary relationships between these arrangements.

5. Show how an inverse repeat can be used to create a deficiency.

6. Microscopical examination of anaphase I in pollen mother cells reveals the presence of a ≈ 4. In 20% of these cells, one chiasma is present in the interstitial segment. Alternate disjunction occurs in all cells with a frequency of 75%. ¿What percentage of the pollen formed will be viable?

7. The following is from:

Lukaszewski, A.J. 1995. Chromatid and chromosome type breakage-fusion-bridge cycles in wheat (*Triticum aestivum* L.). Genetics 140:1069-1085.

In this case, the author was able to obtain an inverted repeat in a wheat chromosome via the use of a breakage-fusion-bridge cycle. Fill in the missing steps (max number of steps = 4):



8. ABC DEFGH represents a normal chromosome in a diploid organism, with the dot in the sequence reprensenting the centromere. You have detected a second individual with the following sequence: ABGFC DEH.

A) What is the name of this cytological phenomenon?

B) Draw the sequence of events that would lead to the modified gene sequence found in the second individual.

C) Draw the pachytene configuration you would expect if you crossed the two individuals together.

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9. The following diagrams are from McClintock's 1931 and 1932 publications. They represent pachytene configurations for chromosome pairs which have undergone some sort of structural reconfiguration. For each one, identify the structural reconfiguration which has occurred:

Note: the large circles in c and e are the nucleolus.

10. The following is from: The following is from:

Padha, L., S. Sareen, R. Mangotra, and A.K. Koul. 1998. Genetic diversity among Plantagos. XXXIII. *Plantago ovata* Forsk. Caryologia 51:149-158.

The authors also took dry seeds, and exposed them to γ -rays from ⁶⁰Co at various doses. The authors then looked at meiosis in the progeny. An example may be seen in figure C.

A. Describe what is going on in figure C.



Fig. A. A somatic cell squash and karyotype of *Plantago* ovata. Bar = $10 \mu m$.





- Fig. B. Diplotene.Fig.B. Also explain whether or not the gametes will be viable, and why.fro
- C. Finally, what accounts for the differences in configuration seen between figure C and figure D?

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Fig. D. Another pollen mother cell from a plant from an irradiated seed.

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11. The following is from:

Wang S-Q and D Zhang. 2007. Chromosomal [...] in *Paeonia intermedia* (Paeoniaceae). Plant Science 172: 380-392.

Photo D is Anaphase I.

A) Explain what is going on in photo E. What are the arrows point at? What will be the result after Telo II?

B) Top photo (D/E): If you assume both photos come from the same plant, what would have had to happen in D to prevent it from looking like E?

C) Bottom photo (D/G): What is being depicted in these cells? Explain the phenomena leading up to the observations in D and G. (ie, what would have been seen at AnaI and the reasons for it?).



P. intermedia. http://plants.chebucto.biz/f leurs/F0570.JPG



Anaphase I in two cells of peony.



Anaphase II in 2 cells of peony.

12. The following is from:

Nishikawa K, T Mori, N Takami and Y Furuta. 1974. Mapping of progressive necrosis genes, *Ne1* and *Ne2* of common wheat by the telocentric method. Japan J Breed 24: 6:277-281.



Ne1 is on chromosome 5B, while *Ne2* is on 2B, and lead to tissue death (necrosis) in the presence of each other.

In this paper, the authors crossed a 2B monoditelosomic line of bread wheat (2n=6x=41 + 1Telosome), heterozygous for the *Ne2* locus, and crossed to a pasta wheat that was homozygous recessive for the gene (2n=4x=28). Data are as follows:

35 intact chromosomes		34 intact +	Totals	
normal	necrotic	normal	necrotic	
198	22	15	160	395

What is the distance between Ne2 and the centromere?

13. The following is from:

Wang S-Q, D Zhang and J Pan. 2008. Chromosomal (...) heterozygosity in *Paeonia decomposita* (Peaoniaceae). Caryologia 61:128-134.



http://www.hillkeep.ca/images/IMGP5011x .jpg

Peonies are popular ornamental plants due to their showy flowers. In this case, the authors found a plant with altered meiosis and studied it. The photos below depict some of their findings:

The figures depict Ana I. For each of the figures D - F, describe:

A) What the arrows are pointing at?

t

B) The types of crossovers that led to these configurations



C) The expected chromosomal configuration at Ana II.

D) The fertility of the resulting gametes.

14. The following is from:

Cuadrado A, R Acevedo, S Moreno Diaz de la Espina, N Jouve and C de la Torre. 2004. Genome remodelling in three modern *S. officianuarum* x *S. spontaneum* sugarcane cultivars. J Expt Bot 55:847-854.

Sugarcane is a hybrid between the two species in the title. In this case, the authors used a genome-specific probe to distinguish between the chromosomes. As seen in the photo, a pair of non-homologous chromosomes from the different parents have exchanged ends.



A) What will be the meiotic configuration of these two pairs at pachytene? (Name it or draw it)

- B) What possible configurations will this lead to at Met I?
- C) What will be the fertility of the resulting gametes for each configuration in B)?

15. The following is from:

Talukdar. 2010. (...) in grasspea (Lathyrus sativus L.): (...). Journal of Heredity 101: 169-176.



- A = 7II + 1B. The other photos do not have B chromosomes
- A. Explain the phenomena seen in B & C.

B. The configuration shown in B was seen in 1229 out of 2150 Pollen Mother Cells, and the configuration of photo C was seen in the remainder. What % of the pollen is expected to be fertile?

16. The following is from:

Khan et al., 2010. Relevance of unilateral and bilateral sexual polyploidization in relation to intergenomic recombination and introgression in Lilium species hybrids. Theor Appl Genet 171:157-173.

In this paper, the authors crossed different genotypes of Longiflorum lilies crossed to Asiatic lilies. These F1 plants were then backcrossed reciprocally to Asiatic lilies. Due to the presence of 2n gametes, the progeny were triploid. They then used GISH to look for recombination between the Longiflorum and Asiatic genomes. An



example is pointed out by arrowheads in the adjacent figure.

On average, there were 7.8/36 recombinant chromosomes when the F1 was the female; and 2.3/36 when used as a male. The authors conclude that, "These differences amongst the rate of recombination between male and female parents are in accordance with the findings of Lagercrantz and Lydiate (1995) and Labonne et al. (2007) who found that there is an increase in the rate of recombination during female meiosis as compared to male meiosis in *Brassica nigra* and *Tunera krapovickasii* × *T. subulata* interspecific hybrid, respectively."

Here are some representative data. Data on left use the F1 as female; those on right use F1 as male.

Genotypes	Parents		No. of	Genotypes	Parents		No. of
	Female	Male	recombinant chromosomes		Female	Male	recombinant chromosomes
044525-1	041556	Mont Blanc	2	044595-1	Pollyanna	041519	5
044539-1	041558	Pollyanna	2	044595-4	Pollyanna	041519	0
044571-1	041557	Mont Blanc	3	044601-1	Mont Blanc	041502	3
062035-1	041560	061092	6	044601-2	Mont Blanc	041502	6
062035 2	041560	061002	0	044601-3	Mont Blanc	041502	1
002055-2	041300	001092	6	044601-4	Mont Blanc	041502	2
062071-1	041560	061091	12	044601-5	Mont Blanc	041502	1
062071-2	041560	061091	14	044601-6	Mont Blanc	041502	3
062074-1	041560	061085	14	044601-7	Mont Blanc	041502	3
062074-3	041560	061085	19	044601-8	Mont Blanc	041502	3
062074 4	041560	061005	12	044638-1	Vivaldi	041502	2
002074-4	041300	001085	14	044638-2	Vivaldi	041502	2
				044638-3	Vivaldi	041502	4

1. Do you agree with the assessment that there is a difference in recombination rate between male and female meiosis? Explain your answer.

2. Are you convinced they are looking at recombination between homoeologues as opposed to translocations? Explain your answer. What test or observation would you want to make to know for certain?

Chromosome Reconfigurations, Page 15

1. The following is from:

Wu et al. 2012. Cytogenetic characterization of **induced tetraploids** in medicinal plant (*Platycodon grandiflorus*). Caryologia 5:182-186.

A) What is the arrow pointing at?



B) Provide an interpretative drawing of what the arrow is pointing out.

C.) The configuration by the arrowhead can disjoin in 3 possible ways. Name each way and describe the result from each disjunction.

D.) Assume the configuration by the arrowhead was going to result in double reduction. Explain and give the probability for all the steps need to get double reduction.

E.) List 3 ways whereby tetraploids can be induced from a diploid plant

18. The following is also from:

Chester et al. 2012. Extensive chromosomal variation in a recently formed natural allopolyploid species, *Tragopogon miscellus* (Asteraceae). PNAS 109 :1176–1181

A) Compare and contrast GISH with FISH



B) Many *T. miscellus* individuals exhibited translocations, as seen above. These almost always involved homeologs. Give a plausible hypothesis to explain why translocations are more common between homoelogs than non-homoelogs or non homologs.

Chromosome Reconfigurations, Page 17

19. The following is from: Scaldaferro, Gabriele, Seijo et al., 2014. Efficiency of cytogenetic methods in detecting a chromosome rearrangement induced by < > in a cultivated chili pepper line (*Capsicum baccatum* var. pendulum – Solanaceae). International Journal of < > Biology, 90(1): 104–112.

The objective was to study structural mutations in cayenne chili peppers. To that end, they studied the chromosome behavior of two genotypes, seen below:

A) What stage of cell division is shown in these figures?





- B When cell B is finished dividing, how many pollen grains will be sterile? Why?
- C) How can the phenomenon in B) be created?

D) After meiosis is over, what percent of the resulting spores will be fertile? Why

Extra Credit: Sketch out how the chromosomes involved in the IV configuration are interacting. In other words, diagram how a configuration like this is held together.—

20. The following is from:

Easterling KA, NJ Pitra, RJ Jones, LG Lopes, JR Aquino, D Zhang, PD Mattews, and HW Bass. 2018. 3D molecular cytology of hop (*Humulus lupulus*) meiotic chromosomes

reveal.... Front. Plant Sci., 01 November 2018 | https://doi.org/10.3389/fpls.2018.01501

Hops have been cultivated by vegetative propagation for the past 1300 years. During this time, perhaps mutations have accumulated that affect fertility. In this study, the authors were trying to determine what lowers fertility, and found several causes. One of them is seen in figures I and L. Telomeres are labeled by FISH.

- A) What is the term for the cluster of telomeres seen in F?
- B) For I, state the stage of division seen and draw or explain why the 2 chromosome sets are connected. What is the diagnostic feature that informs the stage of division?
- C) For L, state the stage of division seen and draw or explain why 2 of the chromosome sets are connected. What is the diagnostic feature that informs the stage of division?





21. The following is from:

https://www.ck12.org/biology/mutation/lesson/Mutation-Types-BIO/

The figure shows 5 different types of chromosomal reconfigurations. Name all 5, by writing the name of each rearrangement in the space provided on top of each figure:



Chromosome Reconfigurations, Page 20

22. The following is from: Ahirwar R & RC Verma. 2016. Ethyl methane sulphonate (EMS) induced translocation and inversion heterozygote in *Allium cepa* L. Cytologia 81: 149-153. Describe the chromosomal rearrangements and crossovers that lead to the following photos:



A-Bridge + fragment @ Ana I



B-2 Bridges + 2 fragments @ Ana I



C-Bridge + fragment @ Anall

23 The following is from:

Liu B, X Tao & Q Dou. 2022. Meiotic chromosomal abnormality detected in a heterozygote of *Elymus nutans.* Frontiers in Plant Science, 13: 895437.

The authors were looking at meiosis on an allohexaploid, 2n=6x=42, and found the following at Ana I. There are two phenomena that give this configuration at Ana I. Name these, and describe additional observations that need to be made to distinguish between the two.



24. The following is from <u>https://www.federalregister.gov/documents/2020/10/09/2020-</u> 19669/pesticides-exemptions-of-certain-plant-incorporated-protectants-pips-derived-from-newertechnologies

The past administration asked all federal agencies to update their regulations for biotechnology. The last agency to respond was the EPA, whose role is to regulate pesticides. As such, it does not want altered plants to produce metabolites at levels that may be toxic. EPA's main concern is that changes to chromosomes may alter gene expression levels.

EPA published its proposed rules on Oct 9 of last year. The public had 60 days to respond, so responses were due Dec 8 of last year. In all, 8120 comments were submitted. The EPA must now respond to these comments before it can settle on the final regulations.

Federal rule-making is not a popularity contest. Likewise, it is not a vote. Thus, comments like 'I support' or 'I am against' do not count. Likewise, comments along the lines of 'I believe' or 'in my opinion' do not count either. *Instead, comments are supposed to be literature reviews, citing papers from the refereed literature that explain how the science on the topic supports or does not support the proposed rule.*

As mentioned in class, people are starting to use gene-editing to induce chromosomal changes deletions, inversions, and translocations. The EPA has decided not to allow such a use for editing in its proposed rule, and states:

Although EPA recognizes that large-scale changes like translocations may be considered genetic variants, changes that affect the structure of chromosomes can affect many genes along the chromosome and are likely to disrupt or change the substances made by those genes. Insufficient information is available to allow the Agency to *a priori* conclude which structural changes would result in novel exposures, and therefore which changes may or may not result in unreasonable adverse effects. Thus, at this time, the Agency is unable to make a generic risk assessment on the consequences of chromosomal structural modifications and is not proposing an exemption that would allow for changes such as chromosomal inversions, translocations, or rearrangements.

For this exam, prepare comments on the above paragraph. You will need to find papers in the refereed literature that you can use to justify your support or lack thereof for the proposed rule banning changes in chromosomal structure. Thus, the review should focus on the historical uses and the ensuing safety (or lack thereof) issues of structural variants in domestication and breeding. Concise arguments and clear points are helpful.

Limit your comments to a *maximum* of 1 page + additional pages for references. Use Plant Physiology format for the reference.