THE ROLE OF PRIOR KNOWLEDGE, SITUATIONAL INTEREST, AND CASE STUDY PEDAGOGY IN THE UNDERGRADUATE BIOLOGY CLASSROOM.

Who's Your Daddy? by Ally Hunter

Synopsis: This case study starts with the unique event of a mule giving birth. Then, it follows a farmer as he tries to figure out who sired the foal.

The biology objectives of this case study are to:

1) Compare and contrast the two types of cell division
2) Recognize key differences between mitosis and meiosis
3) Define and explain karyotyping and interpret a karyotype
4) Explain homology and demonstrate how it relates to mule sterility

Lesson Outline:

Group Discussion Activities are in Blue
Instructor stage directions are in italics

Part 1: Early one morning, farmer Dale is out feeding his animals, when he makes an amazing discovery. He enters his best mule Molly's stall and finds a foal by her side. The foal is nursing, and Molly is tending to him like a good mother.

Why is Dale so surprised? *(hear ideas from students; class discussion)*

Show slide:

Meet Molly

Mule: the sterile, hybrid offspring of a donkey and a horse

Prompt students: what is sterile? What does term hybrid mean? *(hear ideas from students)*

Provide Content (review 3 content slides)

Interspecies mating

- Horse: *Equus caballus* 2n=64
- Donkey: *Equus asinus* 2n=62
- Last shared a common ancestor ~2million years ago
- Mules: offspring of a male donkey and female horse
- Hinny: offspring of a male horse and female donkey

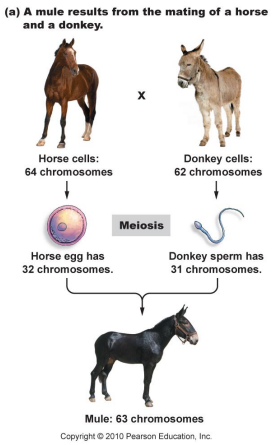


Figure 12-1-Table 12-1

TABLE 12.1 **The Number of Chromosomes Found in Some Familiar Organisms**

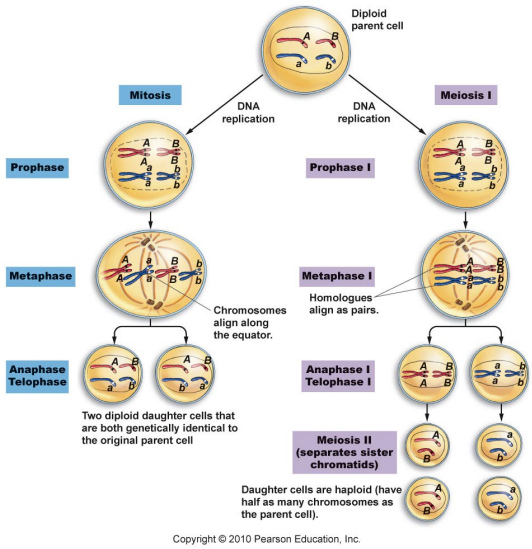
Organism	Number of Different Types of Chromosomes (haploid number *n*)	Diploid Chromosome Number (2*n*)
Humans	23	46
Domestic dog	36	72
Fruit fly	4	8
Chimpanzee	24	48
Bulldog ant	1	2
Garden pea	7	14
Corn (maize)	10	20

SUMMARY TABLE 12.2 **Vocabulary Used to Indicate the Chromosomal Makeup of a Cell**

Term	Definition	Example or Comment
Chromosome	Structure made up of DNA and proteins; carries the cell's hereditary information (genes)	Eukaryotes have linear, threadlike chromosomes; most bacteria and archaea have just one circular chromosome
Sex chromosome	Chromosome associated with an individual's sex	X and Y chromosomes of humans: Males are XY, females XX. Also, Z and W chromosomes of birds and butterflies: Males are ZZ, females ZW.
Autosome	A non-sex chromosome	Chromosomes 1–22 in humans.
Unreplicated chromosome	A chromosome that consists of a single copy (in eukaryotes, a single "thread")	
Replicated chromosome	A chromosome that has been copied; consists of two linear structures joined at the centromere	Centromere
Sister chromatids	The chromosome copies in a replicated chromosome	Sister chromatids
Homologous chromosomes (homologs)	In a diploid organism, chromosomes that are similar in size, shape, and gene content	You have a chromosome 22 from your mother (red) and a chromosome 22 from your father (blue). Homologous chromosomes
Non-sister chromatids	The chromosome copies in homologous chromosomes	Non-sister chromatids
Tetrad	Homologous chromosomes that are joined together	Tetrad
Haploid number	The number of different types of chromosomes in a cell; symbolized *n*	Humans have 23 different types of chromosomes ($n = 23$)
Diploid number	The number of chromosomes present in a diploid cell; symbolized 2*n*	In humans all cells except gametes are diploid and contain 46 chromosomes ($2n = 46$)
Ploidy	The number of each type of chromosome present; equivalent to the number of haploid chromosome sets present	
Haploid	Having one of each type of chromosome (*n*)	Bacteria and archaea are haploid, as are many algae; plant and animal gametes are haploid
Diploid	Having two of each type of chromosome (2*n*)	Most familiar plants and animals are diploid
Polyploid	Having more than two of each type of chromosome; cells may be triploid (3*n*), tetraploid (4*n*), hexaploid (6*n*), and so on	Seedless bananas are triploid; many ferns are tetraploid; bread wheat is hexaploid

Group think and share: provide students with cell division overview. Have them work on questions.

Which type of cell division might be a problem for the mule? Why?



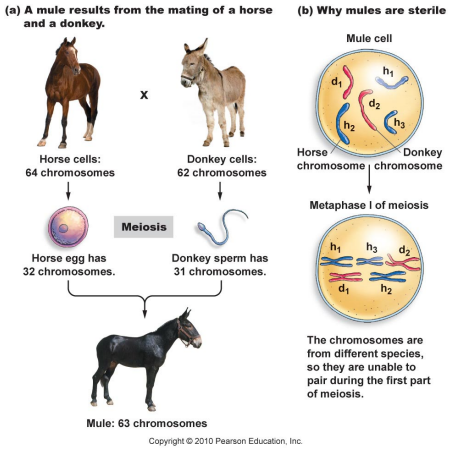
Guide students through shares; have students support arguments with evidence; ask for peers to explain to each other; prompt if stuck "if it were mitosis, would there be mules at all?" Wrap discussion toward focusing on meiosis:

Consider steps of Meiosis. Where could it fail in the mule?

This is a tougher question…walk around and facilitate talks. Direct students toward alignment: prompt "how do chromosomes line up?".

Provide content slide. Conclude Part 1: homologous chromosomes are problematic for a hybrid due to parents being different species.

Why are mules sterile?



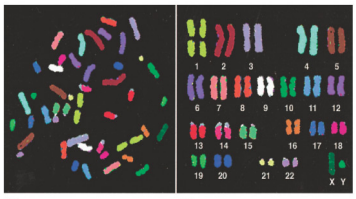
Part 2: Back on the farm, Dale calls the vet:

Get students to volunteer role play:

Dr. Lopez: "Well, I've examined the foal and he is perfect. Never in all my practice, have I been called out for a mule giving birth. I've read reports of this happening, but almost every time, the mother turns out to not be a mule!"
Dale: "Are you suggesting that maybe Molly is not really a mule? Just look at those ears!"
Dr. Lopez: "I know it sounds foolish, but sometimes horses have been known to be mistaken for mules. But, really, they just got unlucky in the ear department. Do you have a karyotype for Molly?"
Dale: "I'm not sure. What is a karyotype?"
Dr. Lopez: "Basically, it is a laboratory report that will tell us if Molly is a mule or not. It would have come from the State Veterinary Lab in Texas."
Dale: "I'll run to the house and get the paper work on Molly."
Dr. Lopez: "Great. In the meantime, I will draw blood from the foal and we will certainly send it to the state lab and have his karyotype done."

Provide content (2 slides)

What is a karyotype?



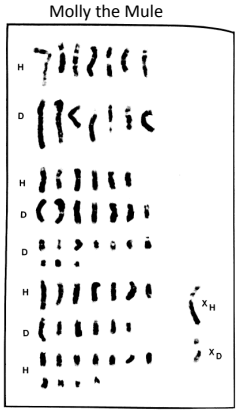
(A) (B)

Chromosomes from metaphase—condensed, replicated

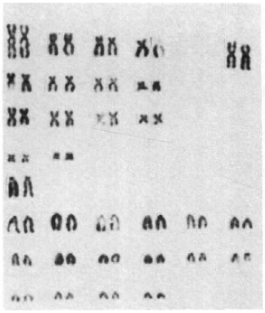
Chromosome painting: each chromosome is probed w/ DNA labeled with a different color

Figure 5-12 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Molly the Mule



Female horse



Group think share: Interpret Molly's karyotype. Is she just a horse? What is different about her karyotype vs. a female horse?

Work toward group conclusion; continue role play:
Dr. Lopez: "Yep, based on this karyotype, Molly is indeed a mule!"
Dale: "So, my next question to you, Dr. Lopez, is Who's the sire of this baby---and WHAT exactly is he?"
Dr. Lopez: "Good question! The karyotype results should give us some insight to what this little critter is. In the meantime, who are the likely suspects in this paternity suit?"

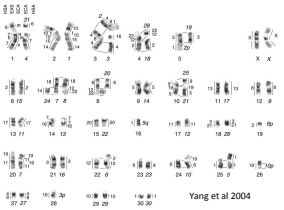
Part 3: Who's the daddy? Problem: Molly has been pastured with many other horses and donkeys. Two are males:

Lightning, a horse

Jake, a donkey

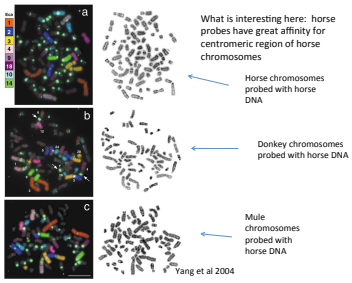
Provide content: (4 slides)

Back to Mule Meiosis…
and the problem of homology



Yang et al 2004

There is some homology between horse and donkey chromosomes. Not a lot, but some.



Yang et al 2004

"affinity hypothesis of chromosomes"

Anderson 1939

- During Meiosis in the mule: perhaps the horse chromosomes stay with the horse and the donkey with the donkey
- Infrequently, yet possibly, a fertile gamete is produced containing a complete set of maternal chromosomes (in this case Molly's mom is a horse)
- Most of the reported hybrid offspring that have been confirmed contain a full set of the mother's maternal chromosomes

How would this look in a mule?

	Female mule 2n=63	Female hinny 2n=63
Male Horse 2n=64	Horse foal 2n=64	Hinny foal 2n=63
Male donkey 2n=62	Mule foal 2n=63	Donkey foal 2n=62

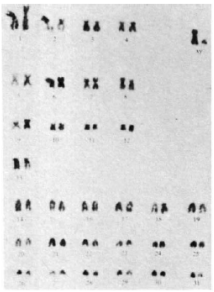
From Zhao et al 2006

In each case, the female passed only her maternal chromosomes to the gamete.

So, the mule passes a set of horse chromosomes.

The hinny passes a set of donkey chromosomes.

Group pair share: Here is the foal's karyotype. Interpret his 2n number, then using the above chart decide: Who's the daddy?!



The mystery foal's karyotype

Hear from students…reach consensus 2n=64…have class vote Lightening or Jake. Then the big reveal:

Who's your daddy?

Mystery Foal:

2n=64
One X, one Y

He is a male horse!

Congratulate class…mystery solved. Then suggest "but wait, we have to name the little guy. Do you guys want to see him? Let's pick a name…

Here's our little mystery foal

Students will point out he looks like a donkey!? Hear from students…

Group think share: Ok, he looks like a mule. He has some donkey attributes. Can you explain this? Brainstorm ideas with your group.

Have groups report out. I've heard some fantastic ideas including thoughts about perhaps being in a "mule" ova (epigenetic) has an impact. Diplomatically hear ideas…steer toward meiotic events.

Group think share: Go back to meiosis. What meiotic event could explain his donkey traits?

Have groups report out. Point to crossing over as an important mechanism of meiosis that adds to genetic variation. Underscore that this is fair hypothesis but has not been tested.

Crossing over happens in Meiosis!

- Although not enough homology to make meiosis go perfectly every time, enough for some crossing over events?

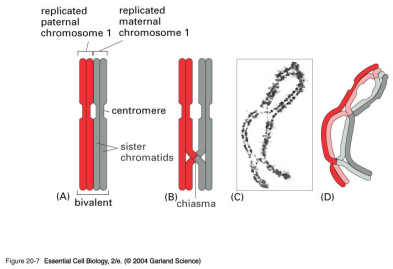


Figure 20-7 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Then you may see this:

Some of Molly's paternal genes (her Donkey father) are showing up in her foal

Some research supports the 'affinity hypothesis' but other research does not

Can't explain the other half of the story: why no fertile male mules?

Complex translocations and poly-valent occurrences could be at work

End of case. Provide students with disclosure that still not enough information to support one hypothesis or another. Point out problems, and other possibilities. However, understanding how meiosis can go wrong (or right in this case) in the mule has helped them thoroughly explore the processes and mechanisms at work. Good job!