TEXAS WOMAN'S UNIVERSITY™

Department of Biology

Learning genetics by doing: "making a baby" with playing cards

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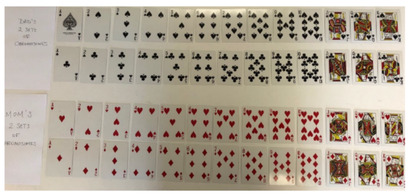
Abstract

Genetics can be a difficult topic to master, especially for non-majors students. For some students, the random yet precise segregation of chromosomes during meiosis and what the different inheritance patterns mean are especially hard to grasp. To help students understand these basic genetic concepts, we developed an in-class activity to connect genetics concepts with students' lived experiences. Using a deck of playing cards with the cards representing chromosomes, teams of students practice applying inheritance patterns learned in class to "make a baby". The students are given background: each card represents a chromosome. The two black suits are the dad's chromosomes. The two red suits are the mom's chromosomes. Students are instructed to perform meiosis: after laying out cards in order by suit, one student in the group makes the "sperm" chromosome set by selecting one card each of clubs or spades, randomly mixing clubs and spades. In a similar way, another student makes the "oocyte" chromosome set from heart and diamond cards. The group performs "fertilization" by lining up the two sets of cards, the "sperm" ace with the "oocyte" ace, etc. They confirm no aneuploidies (they need 2 aces- one black, one red. 2 two's, etc.). After students have successfully "made a baby", the instructor makes available a table with the genotypes associated with each chromosome and the inheritance pattern. Real human traits that generally follow autosomal recessive (straight hair line), dominant (widow's peak, Huntington disease), sex-linked (gender), incomplete (cancer susceptibility), and polygenic (eye color) inheritance patterns are provided for the students to work through. The students' goal is, as a group, to interpret the genotype and phenotypes of their "baby" based on the randomly selected card chromosomes their "baby" has. They fill in a paragraph describing their baby's traits based on the genotype and the given inheritance patterns, and each student provides an individual analysis/defense of their conclusions. This activity has been refined over four semesters with two different instructors. A high percent of students provided positive responses when asked if this activity helped them understand the patterns of inheritance and if this activity was enjoyable.

This activity is adaptable to one's favorite inheritance patterns, traits, and diploid, sexually reproducing, multi-chromosomal organism. Practically, it is fairly inexpensive, doable in 50 minutes, scaleable to fairly large classes (with help from teaching assistant(s)), provides an opportunity to assess core objectives of teamwork and critical thinking, and is a mostly enjoyable learning process for both students and instructor.

Make mom and dad's karyotype

1. Please pick up a worksheet and sign a photo release form.
2. Make a group of 2 or 3 people.
3. If it hasn't been done already, please order the stack of cards nearest you in 4 rows: spades, clubs, hearts, and diamonds, from ace to king. *This one deck of cards will be used by two groups.*

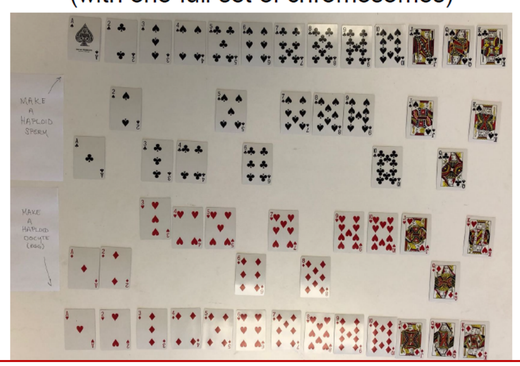


4. Decide who gets to make the "sperm" and who gets to make the "egg".

Create sperm and egg

Perform meiosis!

randomly take "chromosomes" (cards)
to make haploid sperm and egg
(with one full set of chromosomes)

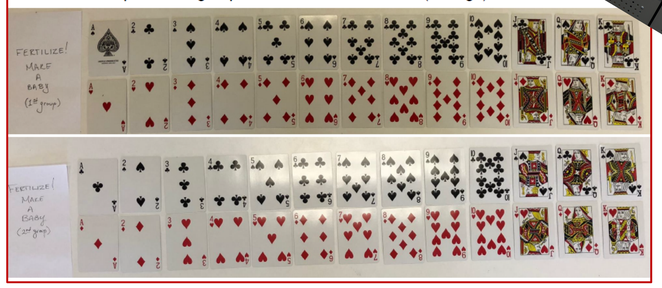


Fertilize to make a baby

Fertilize!

Put the sperm and egg together to make a diploid "baby"!
Match their chromosome pairs
to confirm your baby will survive
and to see what traits your baby has.

Here's an example of two groups' "babies" from one deck (siblings).



Determine your baby's genotype and phenotype

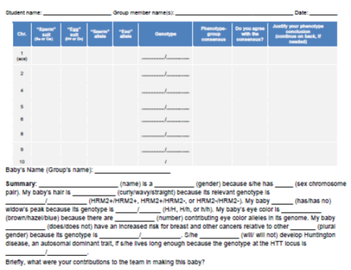
Discover what traits your baby has by figuring out its genotype

Please take a copy of this chart for your group, if needed.
At the end of class, some groups can read the paragraph they wrote about their baby and we can see how the parents' traits segregated in their offspring!

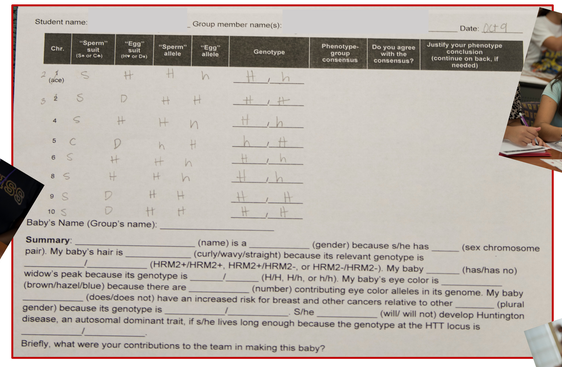
Chromosome	Character	trait	gene	Trait allele	Inheritance	Paternal (dad's) genotype (spade + club) Spade	Club	Maternal (mom's) genotype (heart + diamond) Heart	Diamond	Notes
2	Hair line shape	Widow's peak	H	H is dominant for the widow's peak h is recessive (straight hair line)	autosomal dominant (peak) autosomal recessive (straight)	H	h	h	H	
3	Cancer susceptibility	Early onset breast and ovarian cancer susceptibility	BRCA1	BRCA1(-)	incomplete	BRCA1(+)	BRCA1(-)	BRCA1(+)	BRCA1(+)	55 to 65 percent of women who inherit a harmful *BRCA1* mutation will develop breast cancer by age 70 years
4	Eye color	Brown eye	OCA2	OCA2(-) is non-contributing	polygenic	OCA2(-)	OCA2(+)	OCA2 (-)	OCA2(-)	5-6 + alleles = brown 3-4 + alleles = hazel 0-2 + alleles= blue
5	Hair type	Curly hair	HRM2	HRM2+	incomplete	HRM2+	HRM2-	HRM2+	HRM2-	+/+ = curly +/- = wavy -/- = straight
6	Eye color	Brown eye	EYCL1	EYCL1(-) is non-contributing	polygenic	EYCL1(+)	EYCL1(-)	EYCL1(+)	EYCL1(+)	
8	Huntington disease	Huntington disease	HTT	HTT(-)	autosomal dominant	HTT(+)	HTT(+)	HTT (-)	HTT(+)	This trait appears (usually) later in life
9	Eye color	Brown eye	MC1R	MC1R(-) is non-contributing	polygenic	MC1R(+)	MC1R(-)	MC1R(-)	MC1R(+)	
10	gender				Sex-linked	X	Y	X	X	sex chromosomes determine male/female

Discover what traits your baby has by figuring out its genotype

Work as a group.
Each student turns in their own worksheet at the end of class.
We'll do the first one together.



Examples of a common mistake and a correctly completed sheet



Student name: _____ Group member name(s): _____ Date: Oct 9

Chr.	"Sperm" suit (S+ or C+)	"Egg" suit (H+ or D+)	"Sperm" allele	"Egg" allele	Genotype	Phenotype-group consensus	Do you agree with the consensus?	Justify your phenotype conclusion (continue on back, if needed)
2 (ace)	S	H	H	h	H , h			
3	S	D	H	H	H , H			
4	S	H	H	h	H , h			
5	C	D	h	h	h , h			
6	S	H	H	h	H , h			
8	S	H	H	h	H , h			
9	S	D	H	H	H , H			
10	S	D	H	H	H , H			

Baby's Name (Group's name): _____

Summary: _____ (name) is a _____ (gender) because s/he has _____ (sex chromosome pair). My baby's hair is _____ (curly/wavy/straight) because its relevant genotype is _____ / _____ (HRM2+/HRM2+, HRM2+/HRM2-, or HRM2-/HRM2-). My baby _____ (has/has no) widow's peak because its genotype is _____ / _____ (H/H, H/h, or h/h). My baby's eye color is _____ (brown/hazel/blue) because there are _____ (number) contributing eye color alleles in its genome. My baby _____ (does/does not) have an increased risk for breast and other cancers relative to other _____ (plural gender) because its genotype is _____ / _____. S/he _____ (will/ will not) develop Huntington disease, an autosomal dominant trait, if s/he lives long enough because the genotype at the HTT locus is _____ / _____.

Briefly, what were your contributions to the team in making this baby?

Student name _____ Group members' names _____ Date 3/2/16

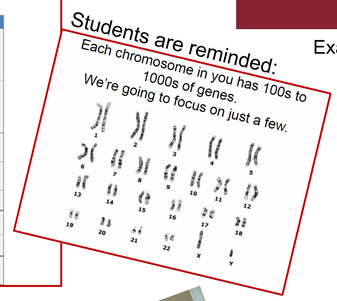
Chr.	"Sperm" suit (S+ or C+)	"Egg" suit (H+ or D+)	"Sperm" allele	"Egg" allele	Genotype	Phenotype-group consensus	Do you agree with the consensus?	Justify your phenotype conclusion (continue on back, if needed)
2	C	D	h	H	h , H	widow's peak	yes	Because one chromosome that is necessary to have that trait
3	C	D	BRCA(-)	BRCA(+)	BRCA(-), BRCA(+)	cancer susceptibility	yes	Sperm had BRCA(-) trait so the offspring is cancer susceptible
4	S	H	OCA2(-)	OCA2(-)	OCA2(-), OCA2(-)	Blue eyes	yes	Only 2 alleles were positive causing blue eyes
5	C	D	HRM2(-)	HRM2(-)	HRM2(-), HRM2(-)	Straight hair	yes	Straight hair is the recessive trait which is HRM2(-) which both sperm and ovum have.
6	S	H	EYCL1(+)	EYCL1(+)	EYCL1(+), EYCL1(+)	Blue eyes	yes	Only 2 alleles were positive causing blue eyes.
8	C	D	HTT(+)	HTT(+)	HTT(+), HTT(+)	no Huntington Disease	yes	HTT(+) needs to be present to inherit the disease.
9	C	H	MC1R(-)	MC1R(-)	MC1R(-), MC1R(-)	Blue eyes	yes	Only 2 alleles were positive for blue eyes.
10	S	H	X	X	X , X	female	yes	Two X chromosomes results in a female

Baby's Name (Group's name): Bob (Big Old Potato)

Summary: BOB (name) is a female (gender) because s/he has XX (sex chromosome pair). My baby's hair is straight (curly/wavy/straight) because its relevant genotype is HRM2(-) / HRM2(-) (HRM2+/HRM2+, HRM2+/HRM2-, or HRM2-/HRM2-). My baby has (has/has no) widow's peak because its genotype is H / h (H/H, H/h, or h/h). My baby's eye color is blue (brown/hazel/blue) because there are 2 (number) contributing eye color alleles in its genome. My baby does (does/does not) have an increased risk for breast and other cancers relative to other females (plural gender) because its genotype is BRCA(-) / BRCA(-). S/he will not (will/ will not) develop Huntington disease, an autosomal dominant trait, if s/he lives long enough because the genotype at the HTT locus is HTT(+) / HTT(+).

Briefly, what were your contributions to the team in making this baby?
1. Set up the Counts and read the information from the chart. ☺ This was fun.
I was there when the baby was born!!

Assessment



Example of feedback in one course, assessed in class using a Likert-type scale and free response (n=50):

- "The 'making a baby with cards' inheritance patterns activity helped me understand the patterns of inheritance."
  - 84% agreed or strongly agreed
  - 2% disagreed or strongly disagreed
- "The "making a baby with cards" inheritance patterns activity was enjoyable."
  - 82% agreed or strongly agreed
  - 2% disagreed or strongly disagreed
- The most common free-response answer to the question, "What have been the best aspects of this course's lecture portion?", mentioned the interactive, hands-on activities, which included this activity.

This activity can be used for core assessment

As a condition for belonging to the core curriculum, all public university core courses are required by Texas to participate in core assessment. This activity can be used to assess the following objectives for a non-majors biology course:

- critical thinking skills
- empirical and quantitative skills, and
- teamwork.

Future

- Use an online learning management system form for submission.
  - reduces the possibility of loss of student assessments
  - facilitates grade entry
- Use multiple choice for most entries (this will prevent common mistakes).