NCSE National Center for Science Education

To Lose a Tooth

Overview

To Lose a Tooth is a board game designed primarily for learners ages eight and older. By playing through this evolutionary puzzle, participants will explore how natural selection, sexual selection, gene flow, and isolation result in genetic diversity.

Learning Goals

1. Understand how different methods of evolution interact in a board game setting. Participants should learn that natural selection is far from the only mode of evolution.
2. Think about how adaptation and technology factors into modern health.

Materials

- (48) Wooden jaw pieces
- (72) Wooden teeth (18 grey to represent agenesis)
- (28) Small circular industry tiles
- (4) Large "board game" tiles
- (17) Random effects cards
- (2) dice: 0-5 and D8

Set-up

The game can be played with up to 4 players. If more than 4 people want to play, divide participants into roughly equal teams.

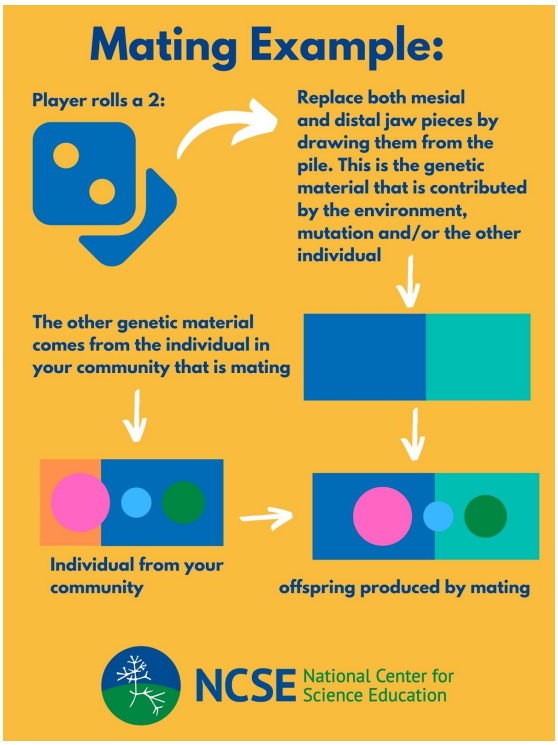
1. Shuffle the random effects cards and place them in a stack in the middle.
2. Deal out 6 jaw tiles and 9 randomly selected teeth to each player.
3. The rest of the jaw pieces should be mixed, and stacked in the center. ~20 or so of the remaining tooth pieces should be placed in a line. These will be the "draw" pile for random mutations.
4. Each team starts out as a hunter-gatherer, with a carrying capacity of 4 individuals (indicated by the CC on the tile). Place the hunter-gatherer (fish) disc on your tile.
5. Currently, each team has 3 individuals, composed of two jaw pieces and 3 tooth pieces. Each team should form their 3 individuals. They should connect two jaw pieces on a side where they share the same width and place three tooth pieces along the jaw with the first molars connected to the central tile.

a. Any grey tooth (fully grey pawn) must be placed in the 3rd molar slot. This is a missing wisdom tooth. If a team draws more than 2 black pegs, have them re-sample and draw again.
b. If a tooth cannot fully fit on the jaw, it is impacted (does not erupt) and should be placed behind the jaw.

Procedure

1. The youngest player goes first. At the beginning of each turn, the player **must do only one** of three things:
    a. **Innovation:** The player may draw an innovation tile from the bag. Once a player has all of the innovation tiles for a particular food production technology, they have adopted that technology. A player must transition between intermediate technologies, even if they already have a more advanced food production technology. If a player already has the maximum number of innovation tiles of that technology, they must replace and redraw. A player *must* transition to the new technology unless the move is between pastoralism and agricultural (in either direction).
    b. **Growth:** If not at carrying capacity, a player may add an additional individual to their society by mating an individual. Roll the dice to determine the amount of genetic material that will be contributed by environment, mutation and the other individual. Results of dice roll are as follows:
        i. Roll 0: Complete duplication of current individual
        ii. Roll 1: Replace the distal jaw piece (the piece furthest from the square tile)
        iii. Roll 2: Replace both mesial and distal jaw pieces
        iv. Roll 3: Replace both jaw pieces and third molar (piece furthest from square tile)
        v. Roll 4: Replace both jaw pieces and second and third molar.
        vi. Roll 5: Replace all 5 pieces.

    However, if a player already has agenesis, they may opt to keep the agenesis, even if they roll higher than a four. The remaining pieces should be duplicated from the individual that is mating.
    c. **Gene Flow:** The player may select an individual to leave their group and join any other group that is not over carrying capacity. That group must send one individual to join the player's group. Roll the D8 to determine which individual. If the individual space is not currently filled, roll until you select an individual.



2. After every player has taken their turn, draw one "random effect" card and follow the instructions. If no teams are impacted, gameplay continues.
3. Repeat step 1, with each team choosing one of the three moves each round.

Definition of Success:

The game ends in one of two ways:

1) Team successfully grows its population to eight people, all of whom survive the random effect of this round.
2) Team is the last one alive.

Modifications and Guiding Questions

Questions for Standard Game

1. What strategy did you use? What worked? What would you change the next time you played?
2. Sometimes each team was playing with a small population size. What were some of the risks with a small population size? (Death is the easy one, but think about genetic diversity too)
3. What do you think would be different if impacted individuals were always removed from the population? What would be different if impaction had no ill effects, as in today?
4. Evolution doesn't just happen by natural selection, it also works through sexual selection, gene flow, and isolation. Can you identify one example of each in the game you played?
5. Why do you think that we replaced jaws before teeth and replaced teeth from the back? (Because environmental factors impact jaws more and the way teeth develop make the third molar the most variable). What do you think this means for agenesis in populations?

Short Form Activity

N.B. This activity is a board game that works well with older groups that will participate in the activity for at least 20 minutes. We have designed a short form activity in case your group is working at a health fair or other place where this is appropriate, but generally we recommend using other NCSE activities for drop-in events.

1. Find the supplemental graphic with the four technology modes and rectangular boxes. Place this at the center of your table.
2. Select approximately half of your jaw and teeth pieces and scatter them on the table.
3. Ask participants about their experience losing teeth. (A mirror can be a great addition to help them count their own teeth). Talk about 6, 12, and 18-year-old molars. Human molars erupt at 6, 12, and 18 years old because of our life history. Most animals grow up much more quickly (like how a human year is seven dog years) and this is reflected in their teeth.
4. Challenge participants to match 2 jaw pieces on your graphic (They are color-coded). Ask them why people who eat different things might have different jaws.

5. Challenge them to put three tooth pieces on each jaw. Ask them what might happen if they put really big teeth on really small jaws (mismatch). Talk about third molar impaction and agenesis.

Advanced Learners

Inhibitory Cascade Patterning:

A fun add-on for older learners is to introduce the Inhibitory Cascade, a general developmental pattern governing relative sizes of teeth. Under this model, molar sizes are typically M1<M2<M3 or M1>M2>M3. In addition, agenesis cannot happen without M1 being the largest tooth.

Further Resources

- https://www.ck12.org/biology/evolution-evidence/lesson/Structural-Evidence-for-Evolution-MS-LS/
- https://www.mayoclinic.org/diseases-conditions/wisdom-teeth/symptoms-causes/syc-20373808?p=1
- https://www.ncbi.nlm.nih.gov/books/NBK279590/
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1963310/
- https://scienceline.org/2007/02/ask-cooper-wisdomteeth/
- https://www.scientificamerican.com/article/human-teeth-likely-shrank-due-to-tool-use/
- https://www.nsf.gov/news/mmg/mmg_disp.jsp?med_id=80266&from=

NGSS Standards

3-LS4-2 Biological Evolution: Unity and Diversity

Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

MS-LS4-5 Biological Evolution: Unity and Diversity

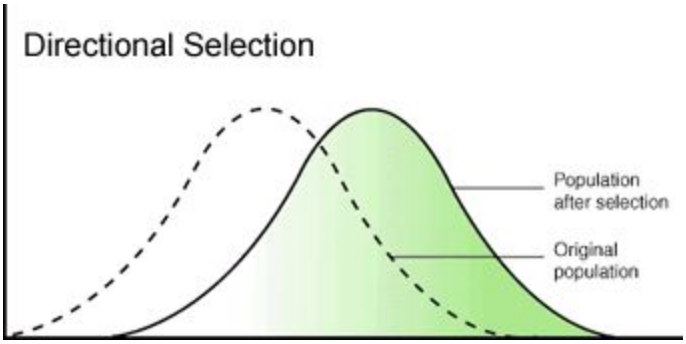
Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

HS-LS4-2 Biological Evolution: Unity and Diversity

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

Associated Vocabulary

- **Agenesis:** The lack of development of wisdom teeth.
- **Common Ancestry/Descent:** Various organisms sharing a common ancestor.
- **Evolution: C**hanges in the heritable characteristics of biological populations over successive generations.
- **Homologous structure:** Structures/genes that are shared between taxa of organisms. Example: Bat wings, primate arms. These structures have a similar function, but are different anatomically.
- **Impaction:** Impaction occurs when the third molars do not have enough room to fully develop.
- **Positive Selection Pressure:** Also known as directional selection. This occurs when an extreme phenotype (observable characteristic) is favored over other phenotypes causing the allele frequency to shift towards the favored phenotype over time.



For instance, if large body size was advantageous for the survival of a particular organism in a given environment, larger organisms would more readily survive and produce offspring who are also large . Eventually, this extreme trait would become more prevalent in this population, as it has been positively selected for.

- **Third Molar (Wisdom Teeth):** One of three molars of the human dentition (arrangement of teeth). The third molars are the only teeth that do not erupt until the late teens to early 20's.
- **Vestigial Organ/Structure:** An organ or structure that was retained from a common ancestor through evolution, that no longer has a function. Example: Tailbone in humans, tonsils, appendix.
- **Vestigiality:** When an organ or a structure has the characteristics of being vestigial, its vestigiality is analyzed.