Inflorescence

A plant molecular biology game
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**Overview:**

You and your friends are biologists seeking to understand how plant cells respond to stress on a molecular level. Compete against your friends to see who can build a flower first. You’ll be faced with abiotic (environmental) and biotic (living) stresses that will challenge your ability to successfully fold and export proteins.

**Play time: 20-40 minutes**

**Components:**

One (1) standard six-sided die  
Four (4) character pieces  
Fifty (50) protein tokens per player. Two hundred (200) total  
Twenty-four (24) stress cards  
Twelve (12) mutation cards  
Six (6) allelopathy cards

**Objective:**

The objective of the game is to build all parts of a flower using folded proteins. To do so, you must fold proteins and export them along the secretory pathway. Proteins folded in the endoplasmic reticulum (ER) move to the Golgi bodies, to the vesicles and eventually out of the cell. The first player to build all parts of their flower wins the game!
**Setup:**

Each player selects a character piece and places it in the “Start” box.

Using the color that matches their character piece, each player puts their ER stress marker just outside of the first (green) rectangle.

The game starts with each player rolling the dice to determine how many of their unfolded proteins are initially in the endoplasmic reticulum. Roll the dice and place that number of proteins in the “unfolded protein” section of the ER. The player with the highest total number of unfolded proteins starts the game.

**Gameplay:**

Each round, the player has a total of five moves available

They can:

- fold a protein from their unfolded protein section
- use an organelle action (see below)
- draw a card

Drawing a card is typically done when there are no proteins available to fold or export, though it can be done at any point in a player’s turn.

*You must maintain proteostasis each turn.* Proteostasis is the balance of folded and unfolded proteins. There can never be more than 7 folded proteins per player in the “folded” section of the ER. Similarly, there can never be more than 5 folded proteins in each the Golgi bodies or the vesicle. They must be moved along the secretory pathway accordingly.

After a player has used all five moves, they must roll the dice and add that many proteins to the unfolded section of the ER.

**Folding an unfolded protein:**

As a move, take one unfolded protein and move it to the folded protein section of the endoplasmic reticulum. When a player achieves five folded proteins, they can be exported (as a group) from the ER using organelle actions (see below). Folded proteins must be moved from the ER to the Golgi bodies, from the Golgi bodies to the vesicle, and from the vesicle to the plasma Membrane. It takes
three actions to export proteins. Once the proteins reach the plasma membrane, the player has achieved the next flower component.

**Organelle actions:**

- Endoplasmic reticulum- export folded proteins from the endoplasmic reticulum to the Golgi body
- Golgi- export folded proteins from the Golgi body to a vesicle
- Vesicle- export proteins from the vesicle to the plasma membrane. Once this action is complete, the next flower component is complete. The protein tokens are removed from the board.

**Card types:**

- Mutations- mutations are changes in DNA that result in a deviation from “normal” cell functions. In the game, mutations are temporary. Mutations can knock down (i.e. reduce) the function of a certain protein or process, as well as completely knockout the function. Conversely, mutations can overexpress (i.e. increase) the function. The mutation card must be played as soon as it is drawn, and it only affects the player who drew the card.
- Allelopathy- these cards can be used against another player to impact their ability to build flower parts.
- Stress- Plants face a variety of biotic (living) and abiotic (environmental) stresses that affect protein folding and overall cell function. The stress card must be played as soon as it is drawn, and it only affects the player who drew the card.

**Endoplasmic reticulum stress and the accumulation of unfolded proteins:**

When too many unfolded proteins accumulate in the cell, endoplasmic reticulum stress takes hold. In the game, ER stress is tracked by a marker. For each player’s seven (7) unfolded proteins in the ER, the stress marker moves forward one. Once it moves forward, it does not move backwards, even if the number of unfolded proteins decreases. When the marker reaches the fifth position, meaning that at one point twenty-five unfolded proteins were present in the cell, programmed cell death (PCD) occurs and the player loses.
Any player that reaches a critical level of ER stress will undergo programmed cell death (PCD). Programmed cell death does just that- it kills the cell in order to save the rest of the plant. If a player reaches PCD, they lose the game.

**Game End Conditions:**

The first player to build every part of their flower wins the game. If no player is able to build the entire flower before running out of cards, the player with the most complete flower wins. Only completed flower parts are considered in this scenario.

**Discussion questions:**

1. Was there a strategy for building your flower the fastest?
2. Was it beneficial or harmful to have lots of unfolded proteins? Why or why not?
3. Why do you think some stresses increase the number of proteins, and other stresses limit the number of proteins?
4. Do you think plants compete amongst each other in nature? Can you think of any specific examples of allelopathy?
5. How do mutations occur in plants? Are all mutations harmful to the plant?

**Credits:**

This game was created by Elizabeth Feldeverd and made possible by the American Society of Plant Biologist (ASPB) Conviron Scholars program.