Penobscot Estuary Community Modeling Workshop
ABM Draft Osmoregulation Function
August 6th, 2025

# Osmoregulation Function

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# Relevant Background Information

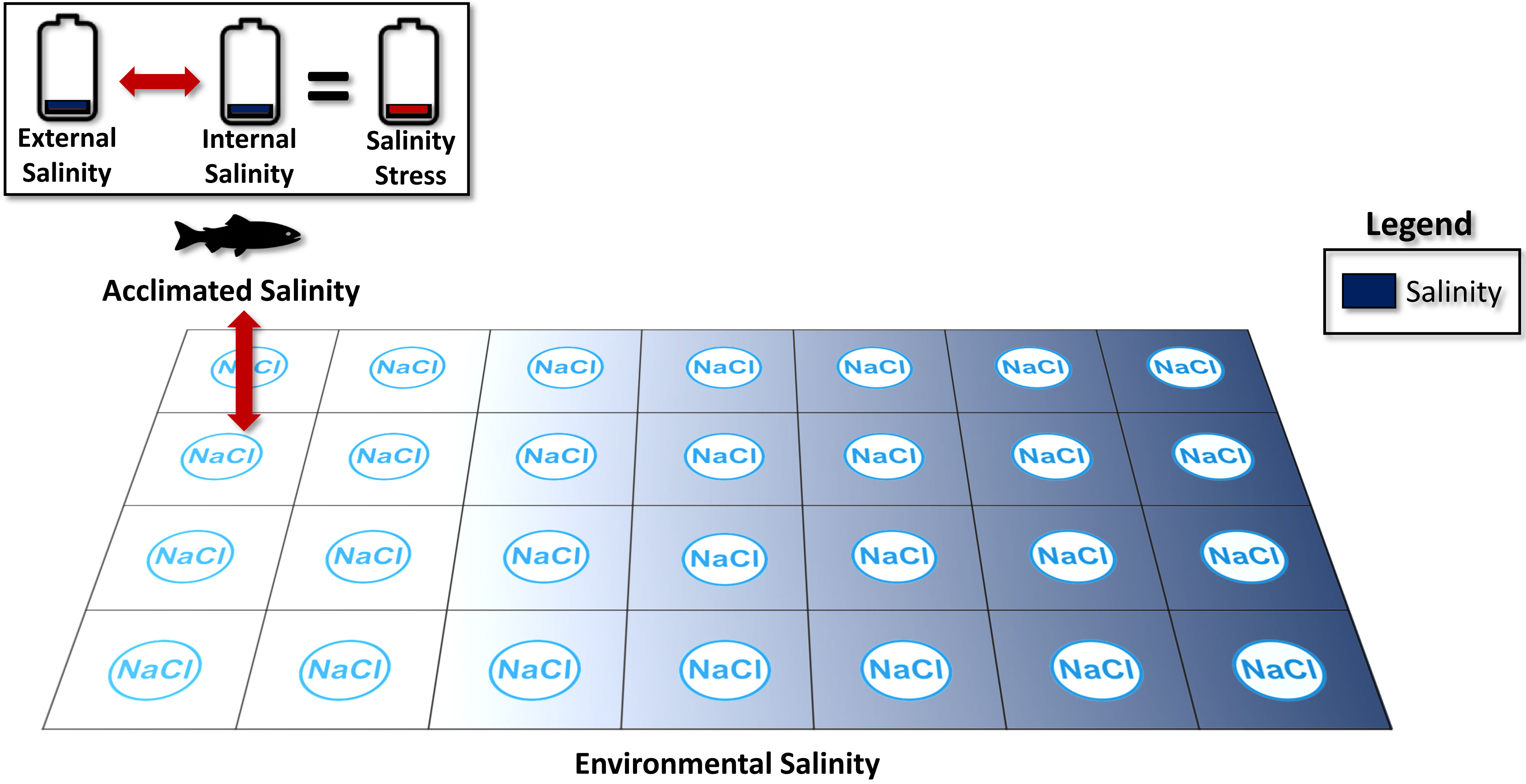
| Term | Definition |
| --- | --- |
| **Osmoregulation** | How fish keep the right balance of salt and water inside their bodies, even when the water around them changes. |
| **Gills** | Organs that allow fish to breathe and also help control the salt and water balance in their bodies. |
| **Chloride Cells** | Special cells in the gills that help fish adjust to salty or fresh water by moving salt in or out of their bodies. |
| **Homeostasis** | The ability of fish to keep their internal conditions stable and healthy, even when the environment changes. |

# Model Objectives

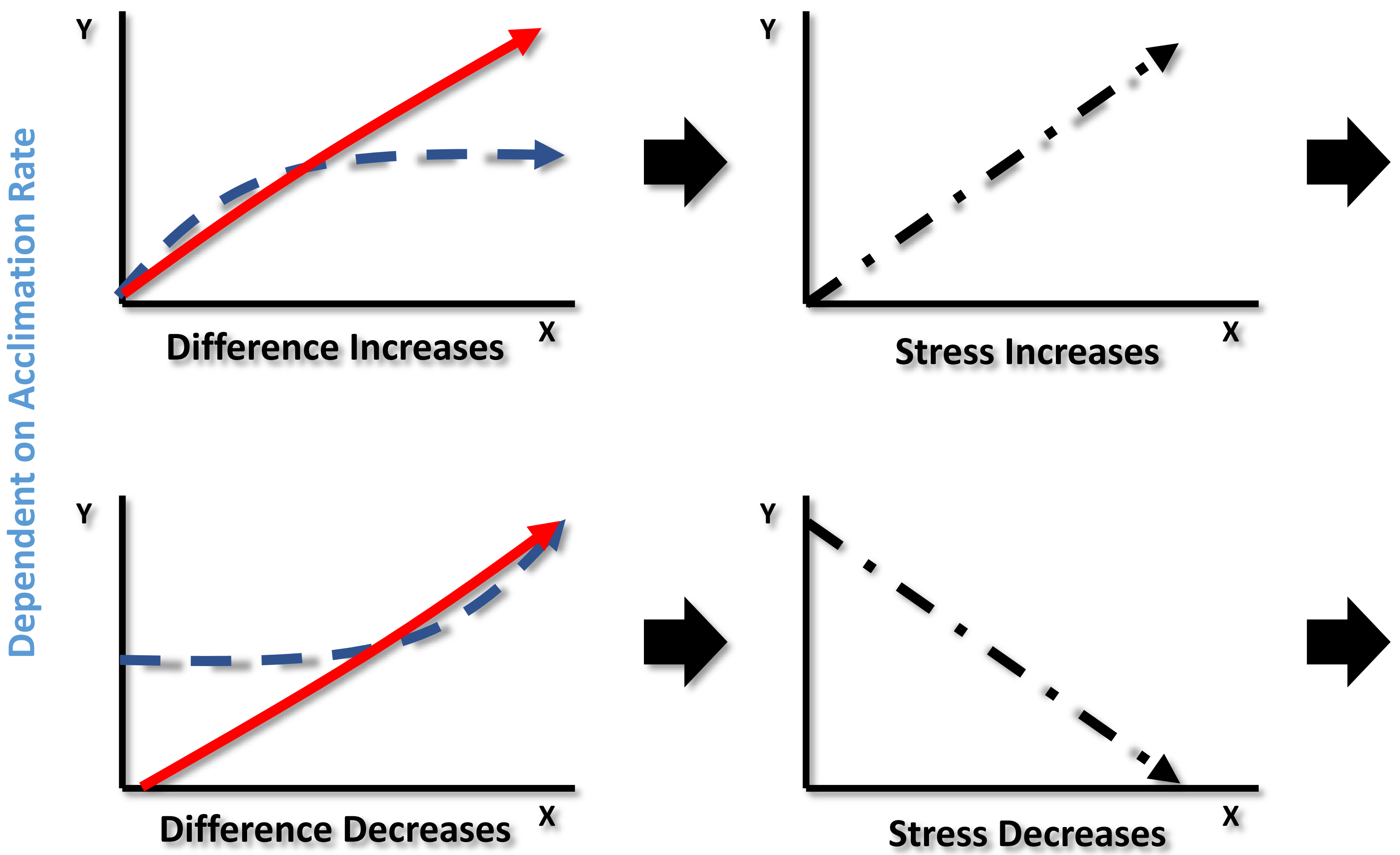
**Purpose:** Simulates stress and energy use as fish adapt to changing salinity.

**Objectives:**

1. **Quantify Salinity Stress** by calculating the difference between environmental salinity and internal salinity.
2. **Regulate Chloride Cell Density** to maintain homeostasis by adjusting cell expression in response to stress.
3. **Estimate Energy Costs** associated with chloride cell creation, maintenance, and decay to track the metabolic trade-offs of osmoregulation.




When environmental salinity differs from a fish’s internal balance, the fish experiences stress and must use energy to maintain homeostasis.




## Ecological Implication

**Individual osmoregulation processes cannot keep up with maintaining balance of salt in the fish and salinity stress increases.**

**Fish is maintaining balance and salinity stress decreases.**

**Acclimated Salinity**
**Environmental Salinity**

Stress increases when environmental salinity doesn't match the fish's acclimated salinity.

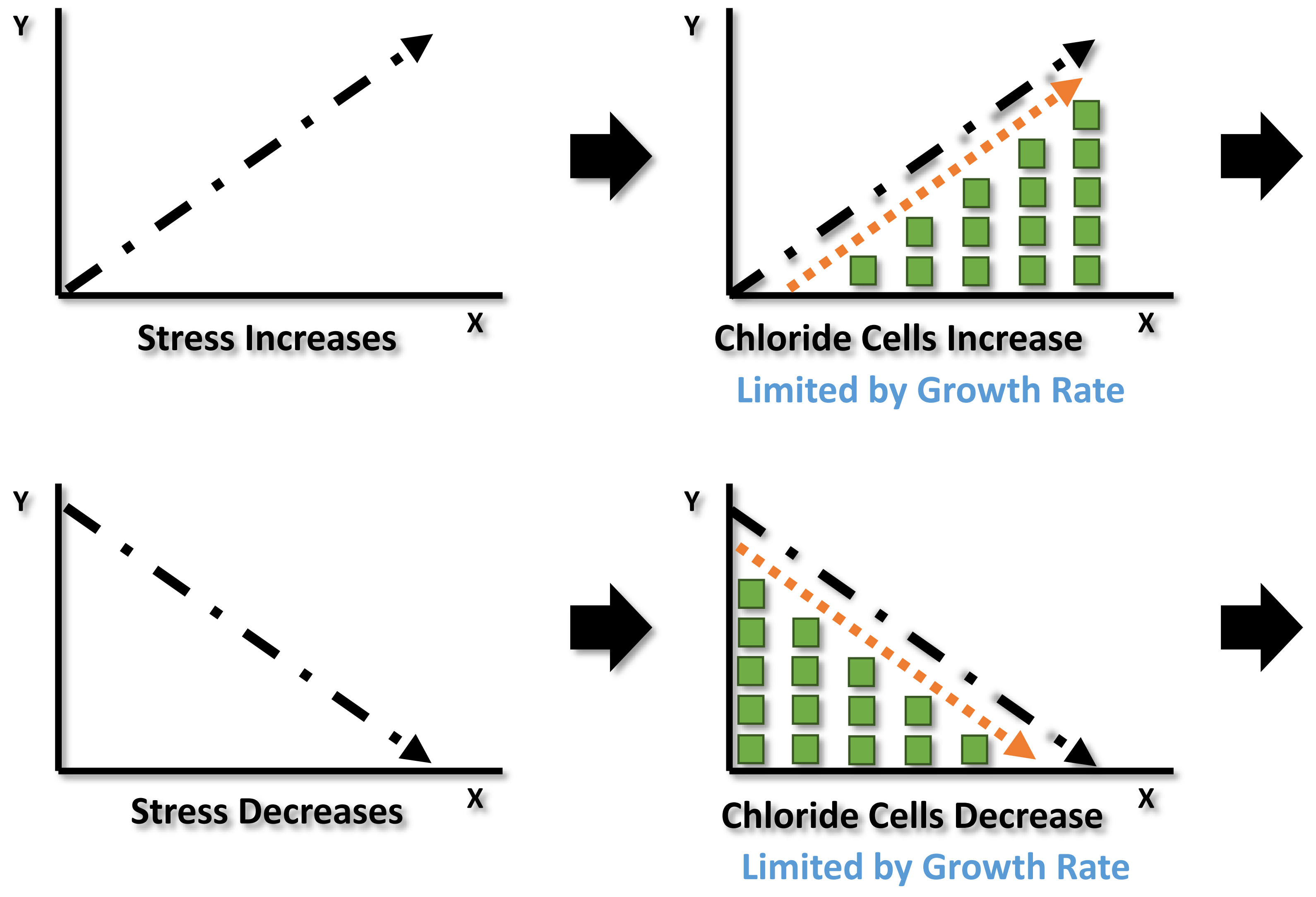
# Calculate Patch Stress

Tracks the highest level of stress experienced in a patch.

If Current **Stress** <= **Patch-Stress**
No Change

If Current **Stress** > **Patch-Stress**
Update **Patch-Stress** to Current **Stress**

Each patch records the highest stress fish have experienced there, helping identify zones of peak physiological challenge.

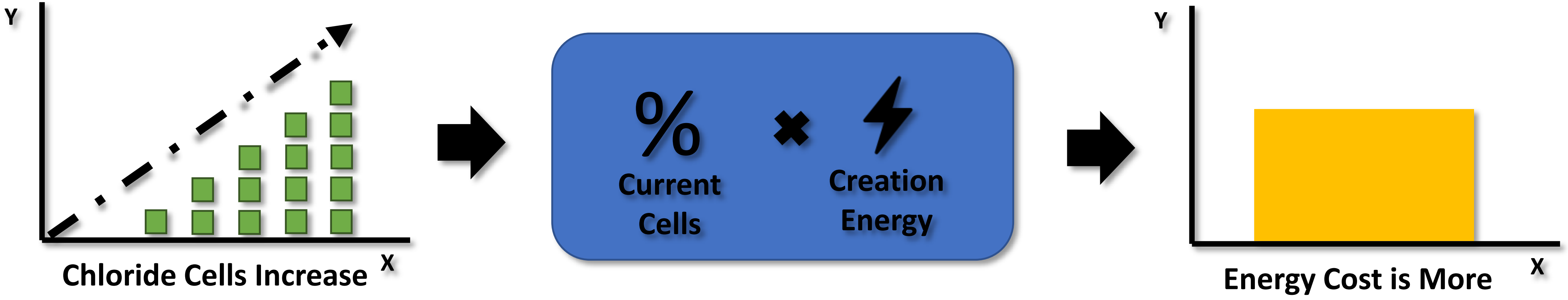



## Ecological Implication

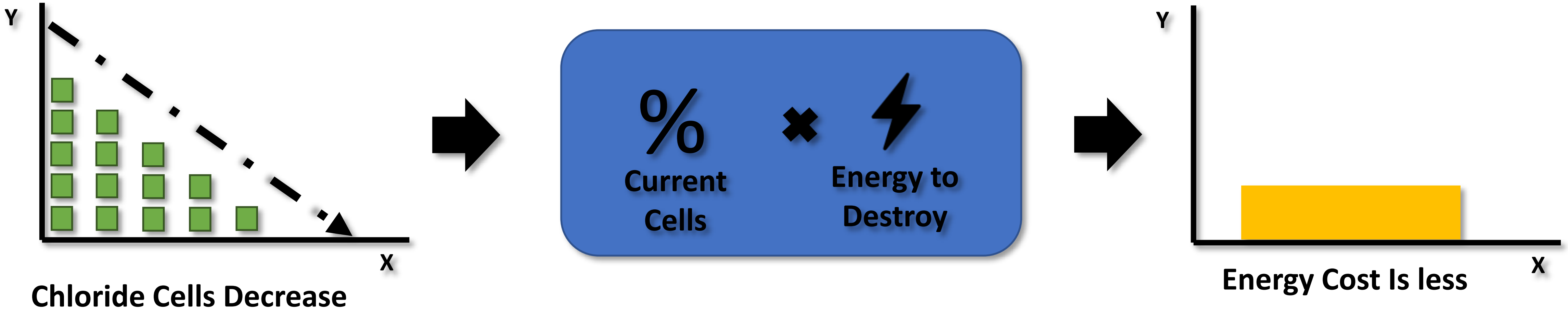
**Stress initializes the creation of new chloride cells to keep up with osmoregulation and maintain homeostasis, limited by a fish's cell growth rate.**

**Fish can remove excess chloride cells that are not needed to maintain balance.**


As stress increases, fish build more chloride cells to regulate salinity. When stress decreases, fish reduce unneeded cells to conserve energy.




Stress initializes the creation of new chloride cells which costs lots of energy



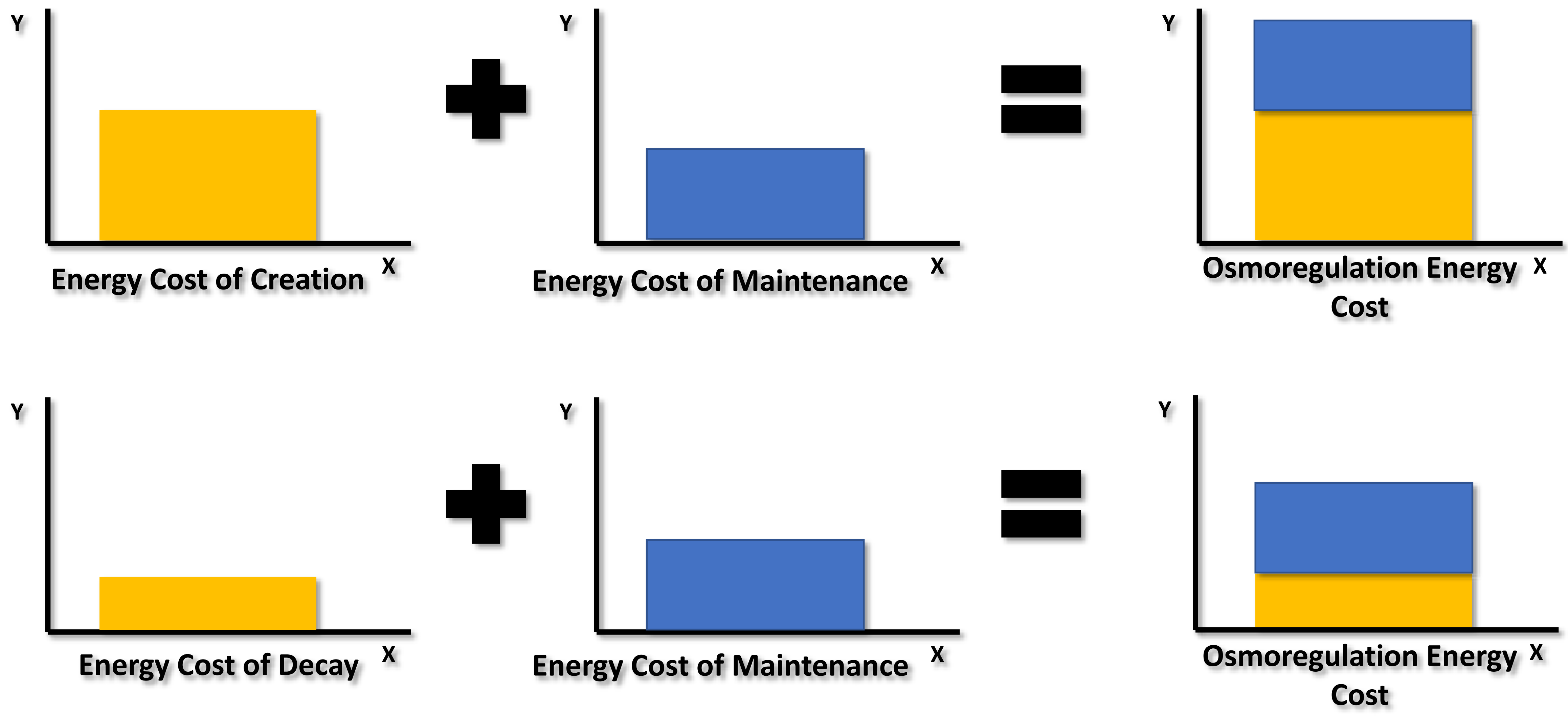

Fish can remove excess chloride cells that are not needed, but this still uses some energy.

Creating new chloride cells requires more energy than removing excess ones, but both processes contribute to the overall cost of osmoregulation.

# Cell Maintenance Energy

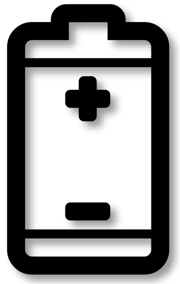

**Maintenance Energy:** amount of energy a fish must use to keep its existing chloride cells functioning properly, even when no new cells are being created or removed.

Even without new cell growth or removal, fish must spend energy to maintain their existing chloride cells and keep them functioning.




Total osmoregulation cost is the sum of energy used to create, destroy, and maintain chloride cells.

# Total Energy Balance



Current Energy Levels

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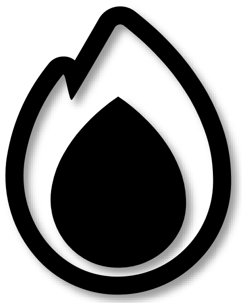

Energy Cost of Osmoregulation

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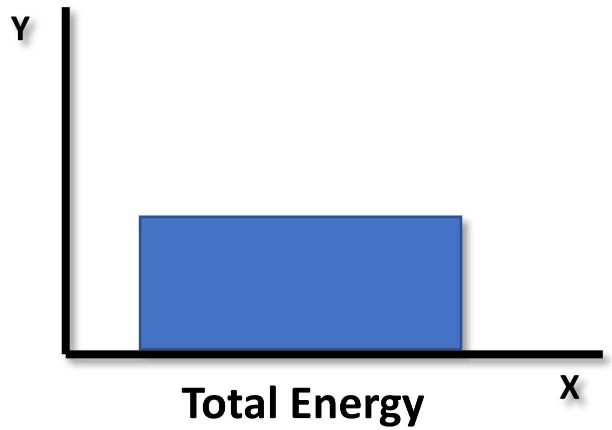
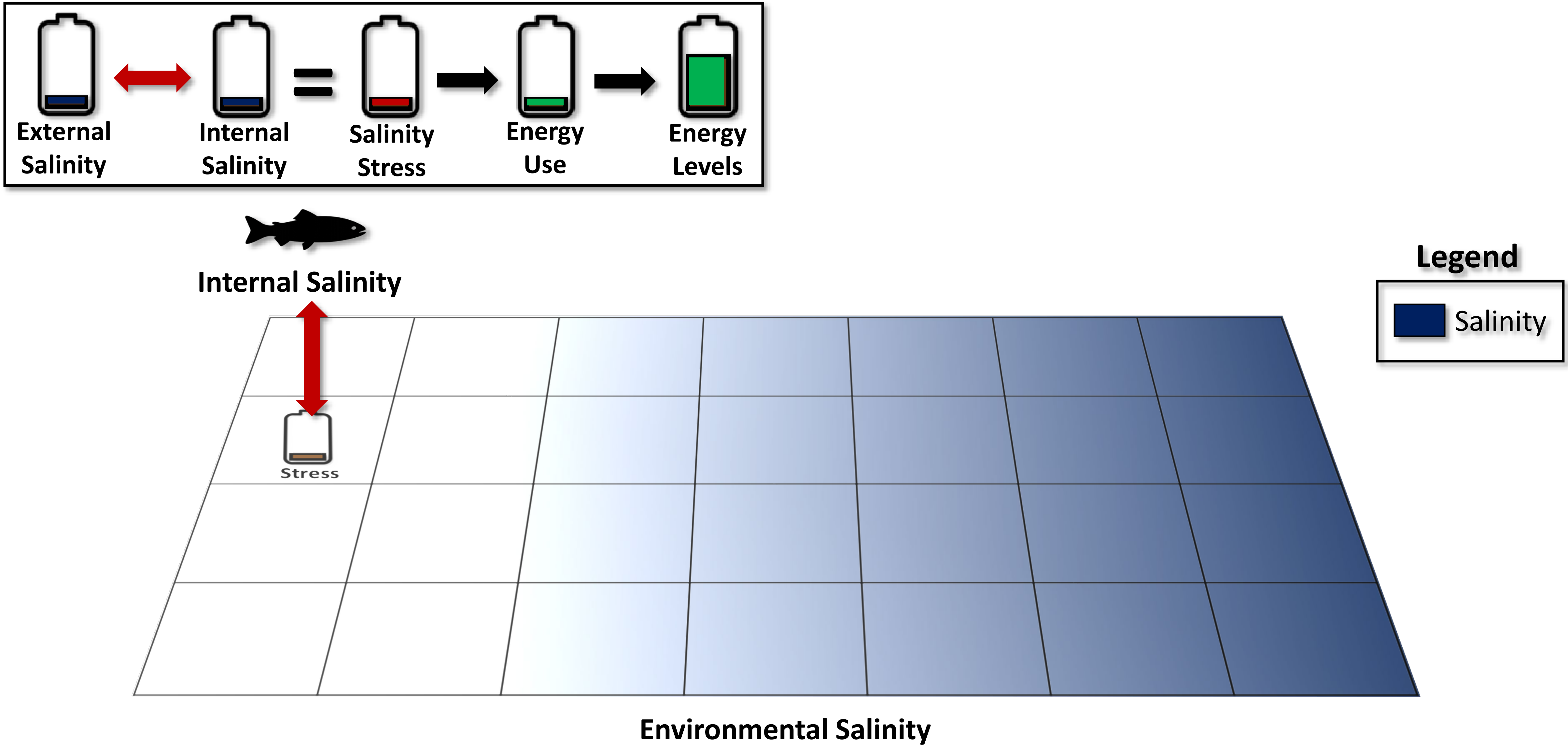
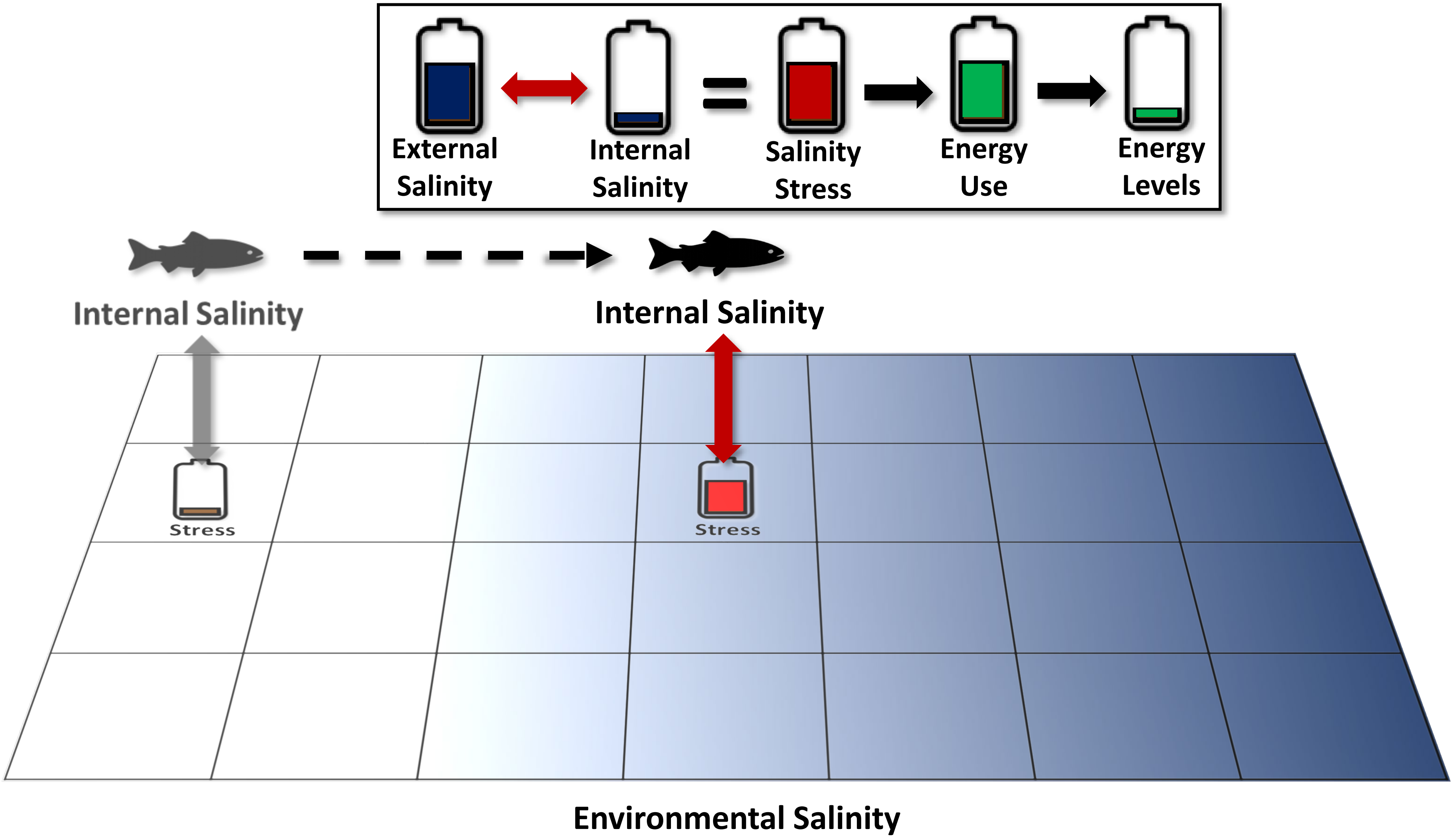



**Total Energy:** amount of energy a fish has left to complete migration.

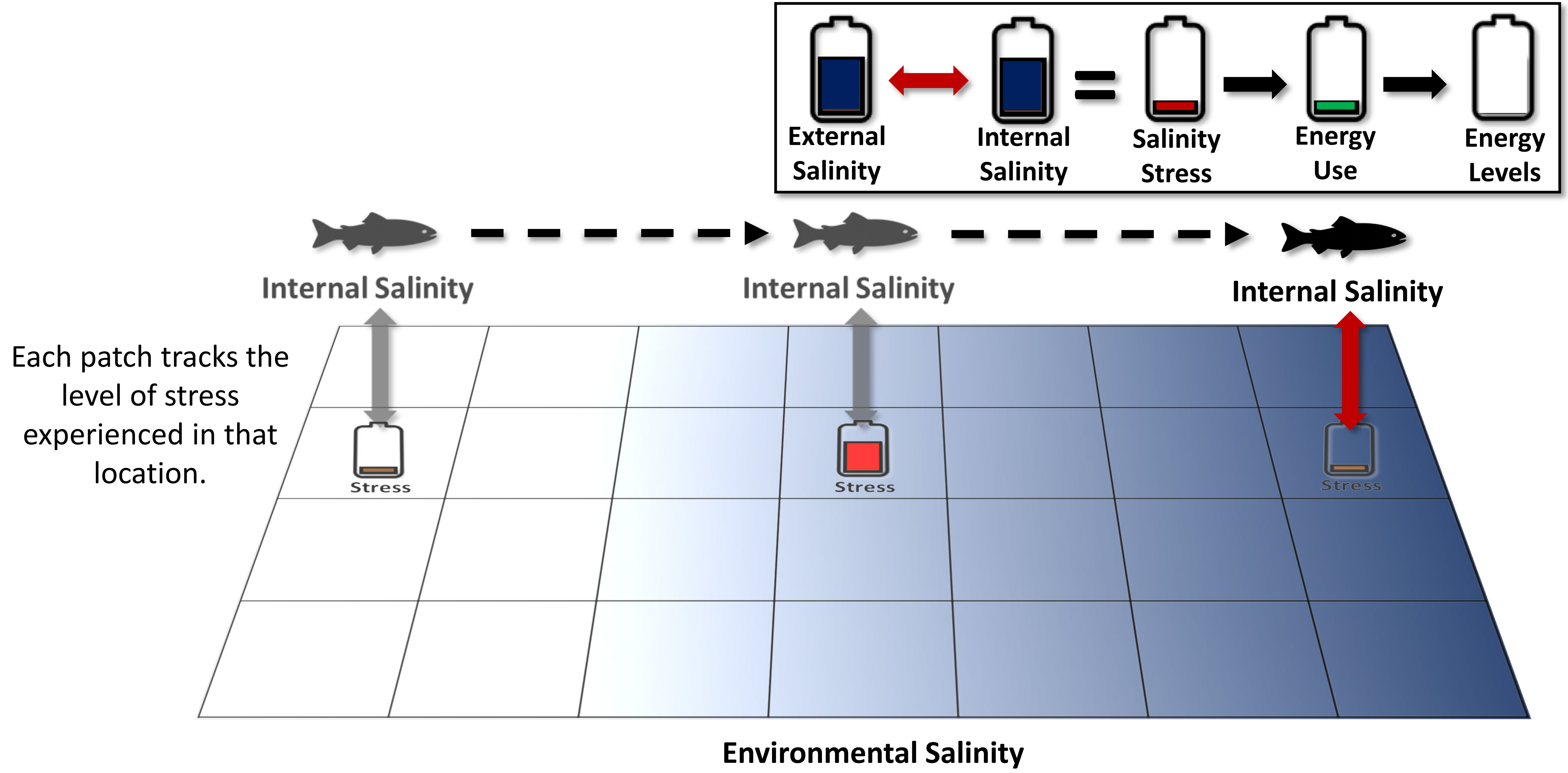
A fish's total energy budget depends on how much it starts with minus what's spent on osmoregulation.




When internal and environmental salinity are similar, fish experience low stress and expend less energy.




Differences between internal and environmental salinity create stress, requiring fish to spend energy to maintain balance.




Energy loss increases along migration routes as fish navigate salinity changes, with the highest stress in transitional zones.

# Individual-Specific Traits

| Trait Type | Generalization |
|---|---|
| **Salinity Acclimation Rate** | Higher for larger, older fish; species-dependent |
| **Cell Growth/Decay Rate** | Slower in larger, older fish |
| **Creation Energy** | Higher for large/old fish or energetically expensive species |
| **Decay Energy** | Lower than creation but still influenced by size and age. |

Individual traits such as size, age, and species affect how fish regulate salinity. These differences influence stress levels, energy use, and overall osmoregulatory cost.

# Outputs of Interest

| Type | Variable | What It Tells Us |
|---|---|---|
| **Temporal** | Salinity-Stress | Shows how hard a fish is working to maintain internal balance as salinity changes. Higher stress means more physiological strain, and higher energy cost. |
| | Energy | Tracks how much energy a fish is using over time to regulate its salt balance. |
| **Spatial** | Patch-Stress | Identifies locations where fish experience the highest salinity stress, which may reduce their ability to stay healthy. |
| | Patch-Energy | Maps where fish are using the most energy to stay balanced, especially in areas with fluctuating salinity. |

Outputs highlight stress hotspots and periods of high energy demand that may limit fish survival or guide restoration priorities.

# Discussion Prompts

1. **Accuracy & Realism**

- Do the steps feel realistic based on your knowledge or experience?
- Does it make sense that fish would use more energy to manage salinity stress in certain areas or times?

2. **Missing Variables, Traits, or Parameters**

- Are there other traits that might affect how well a fish regulates salinity (like stress, body condition, or energy reserves, individual acclimation ability)?
- Are there environmental factors or variables missing (e.g. temperature, precipitation) impacting a fishing ability to manage stress?

3. **Outputs of Interest**

- Which outputs from the osmoregulation function would help us better understand how salinity affects fish, or help guide management and restoration decisions (e.g. stress zones, osmoregulation energy expenditure)?
- Are time-based outputs (like how fish expend energy over time) more useful, or location-based outputs (like where fish are expending the most energy)?