Maintenance of Constancy of the Internal Environment during Fish Migration Between Fresh and Seawater

Group 4:
Kuan Yi Xian, Jeeann
Lee Tien Ming
Lee Tze Chuen
Lee Wan-Jean
Lee Yee Tjin

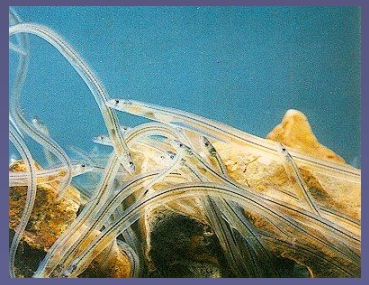
Migration

Seasonal movement of complete populations of animals to a more favourable environment

Migratory Fish

Diadromous

- **Catadromous**: sea → freshwater (breed)
- **Anadromous**: freshwater → sea (breed)
- **Amphidromous**: sea ⇔ freshwater (non-breeding)



Potadromous

- wholly freshwater

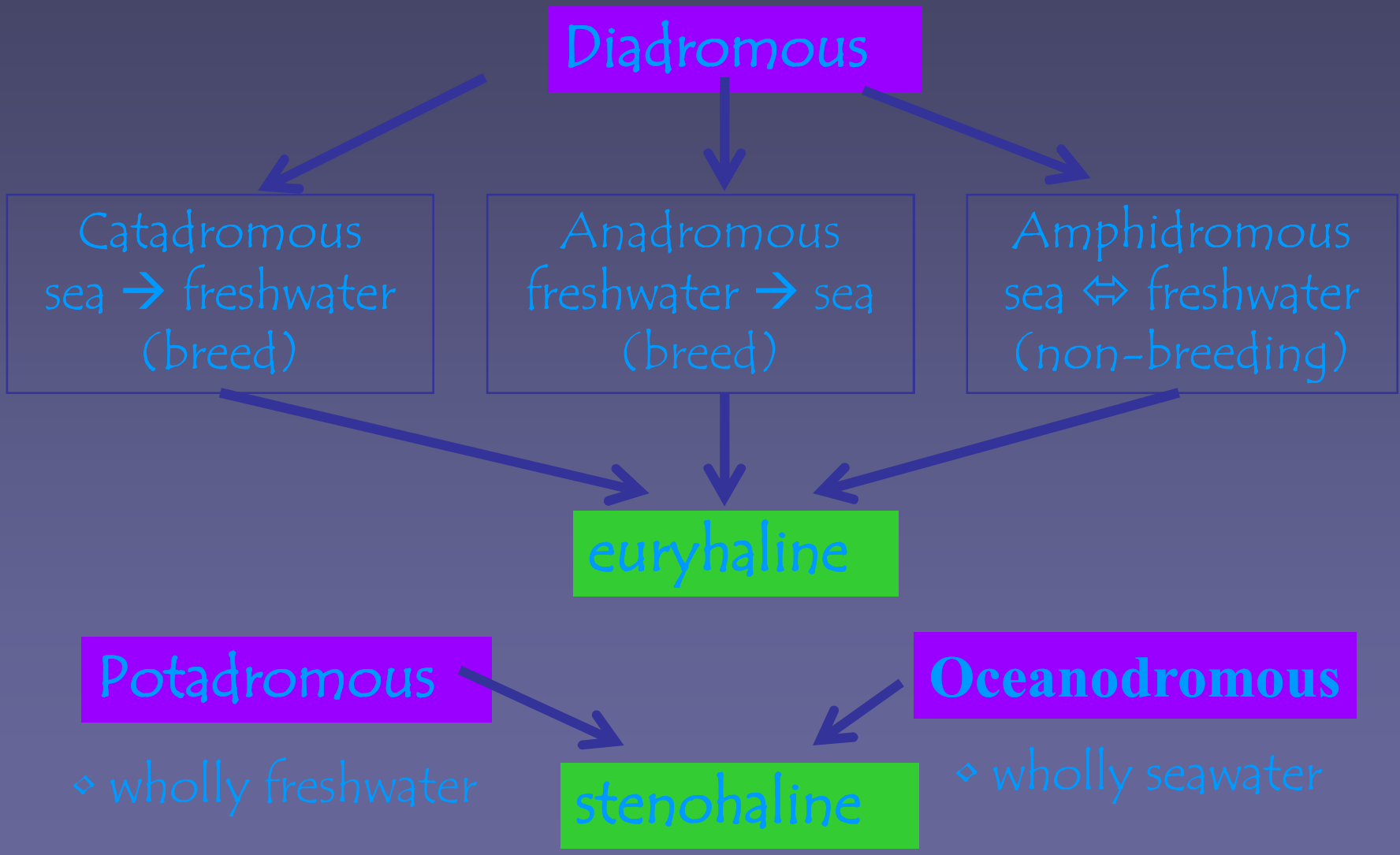
Oceanodromous

- wholly seawater

Salinity Tolerance

- **Euryhaline animals**
  - aquatic animals that can withstand large variations in salinity of their environment
- **Stenohaline**
  - animals that can only survive within a limited range of salinity

Fish Migration & Salinity Tolerance



Osmoregulation in fish

- Problems arising from differences in salinity
- Impact on the physiology of the fish
  - body fluid
  - body volume
- Possible mechanisms for osmoregulation
  - kidney
  - gut
  - gills
  - hormones

Differences between Freshwater & Saltwater

1) Salinity

- Saltwater has a high amount of dissolved monovalent ions like Na^+, Cl^- and divalent ions.

- Freshwater has a lower amount of ions.

Ion	Soft lake water[a]	River water[b]	Hard river water[c]	Saline water[d]	Dead Sea[e]
Sodium	0.17	0.39	6.13	640	1955
Magnesium	0.15	0.21	0.66	6	2028
Calcium	0.22	0.52	5.01	32	481
Potassium	–	0.04	0.11	16	219
Chloride	0.03	0.23	13.44	630	7112
Sulfate	0.09	0.21	1.40	54	5.3
Bicarbonate	0.43	1.11	1.39	3	3.7

[a] Lake Nipissing, Ontario.
[b] Mean composition of North American rivers.
[c] Tuscarawas River, Ohio.
[d] Bad Water, Death Valley, California.
[e] Dead Sea, Israel. This water also contains 74 mmol per kg H_2O of bromide.

Differences between Freshwater & Saltwater

2) Temperature

- The temperature of the water body is effected by its size.

- most freshwater environments have smaller body and thus have higher temperature.

- Temperature is also effected by the amount of ions in the water.

Differences between Freshwater & Saltwater

3) Stability

- Seawater VS Freshwater
  - Seawater more stable than freshwater as freshwater environments are subjected to more changes than seawater environments.
- Swamp-water VS Freshwater
  - Freshwater more than swamp-water as swamp-water environment conditions fluctuate more frequently than freshwater environments.

Differences between Freshwater & Saltwater

4) pH

- pH in seawater is slightly more alkaline due to the presence of mono-ions like Mg^{+}, Ca^{2+}, etc.

- pH of freshwater environs are highly variable due to runoff from rain, etc.

Problems of Fish Migration

In aquatic survivability, 2 factors must be maintained in narrow limits:

- Bodily Solutes (amount of ions)
- Volume of Fish (water volume)

Problems of Fish Migration

- Teleost plasma concentrations are 30% to that of seawater.

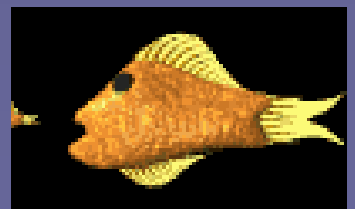
- Fish migrating between saltwater and freshwater environments encounter extreme osmotic pressures which is deadly unless controlled.

- 2 types of migrations
  - Anadromous migration
  - Catadromous migration

Problems of Fish Migration

Anadromous Migrations (Freshwater to Saltwater)

- Fish enters a more hyper-osmotic environment than it's own internal environment.
- Water loss through urine and permeable gills.
- Consumption of hyper-tonic water and food increases internal salt content.



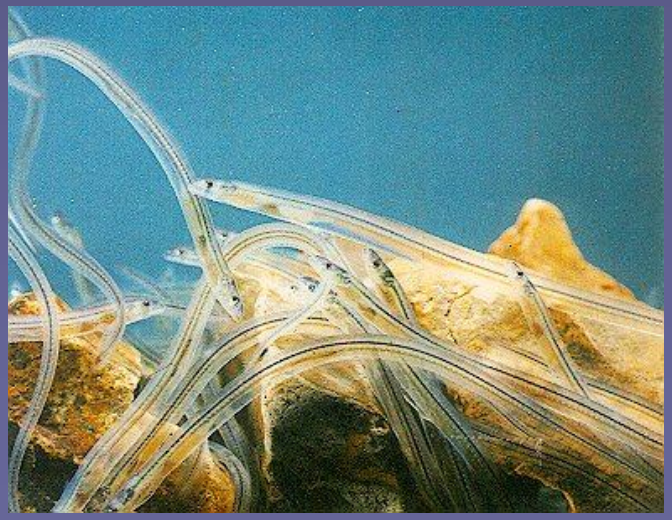
Problems of Fish Migration

- Fish volume decreases, osmotic balance and metabolism disturbed.

Problems of Fish Migration

Catadromous Migrations (Saltwater to Freshwater)

- Fish enters a more hypo-osmotic environment than it's own internal environment.
- Water gain through permeable gills and drinking.



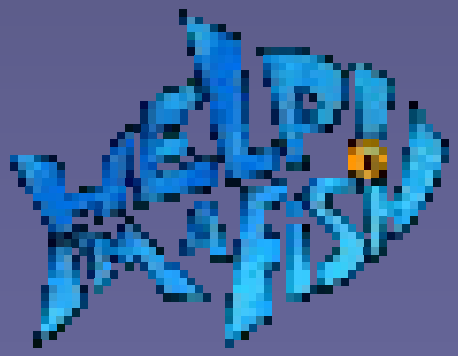
European eel,
Anguilla Anguilla

Problems of Fish Migration

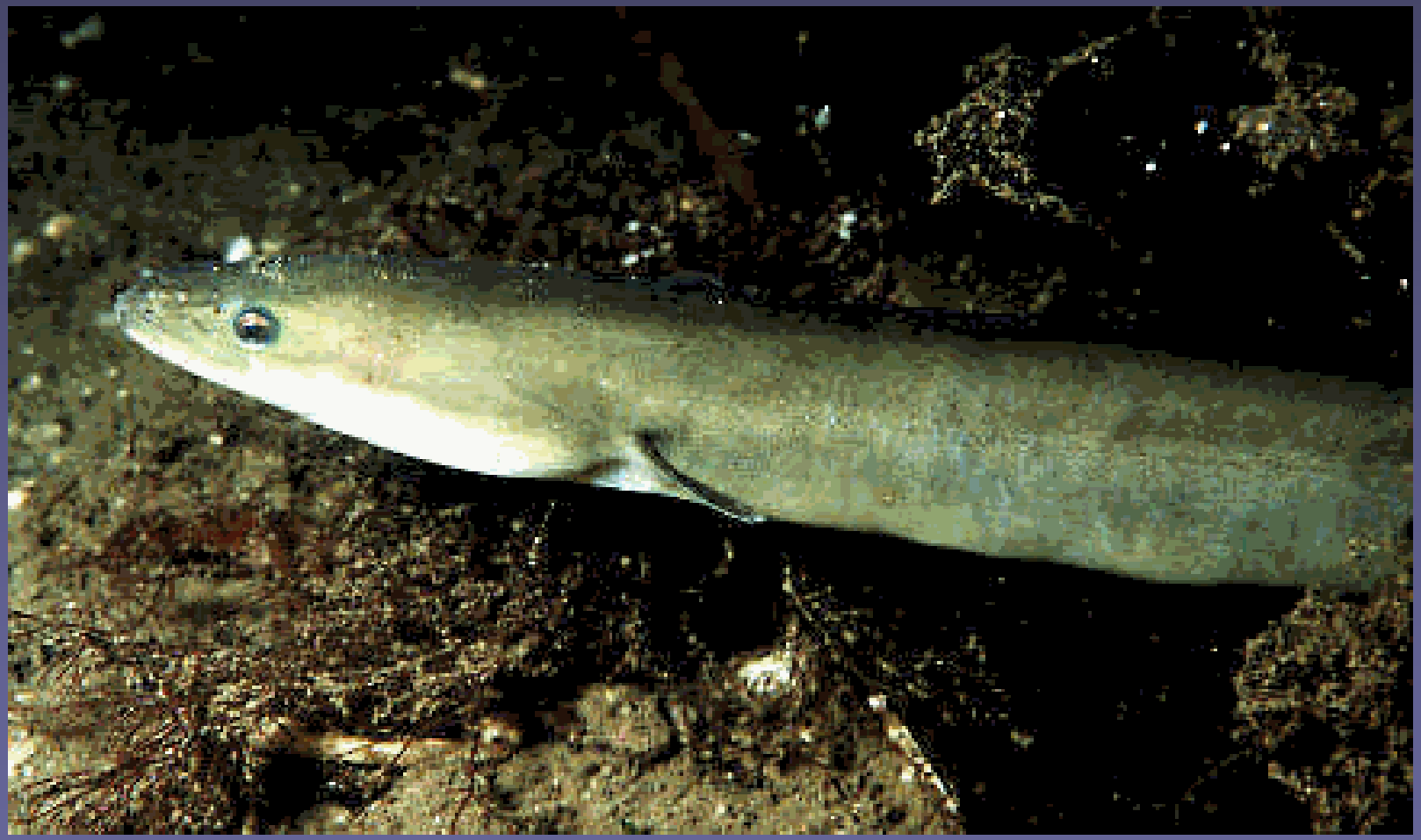
- Fish volume increases, osmotic balance and metabolism disturbed.

Problems of Fish Migration

- Other than pressures from salinity, fluctuation in pH and temperature of the new environment might also disturb the fish's metabolisms, leading to dire effects.



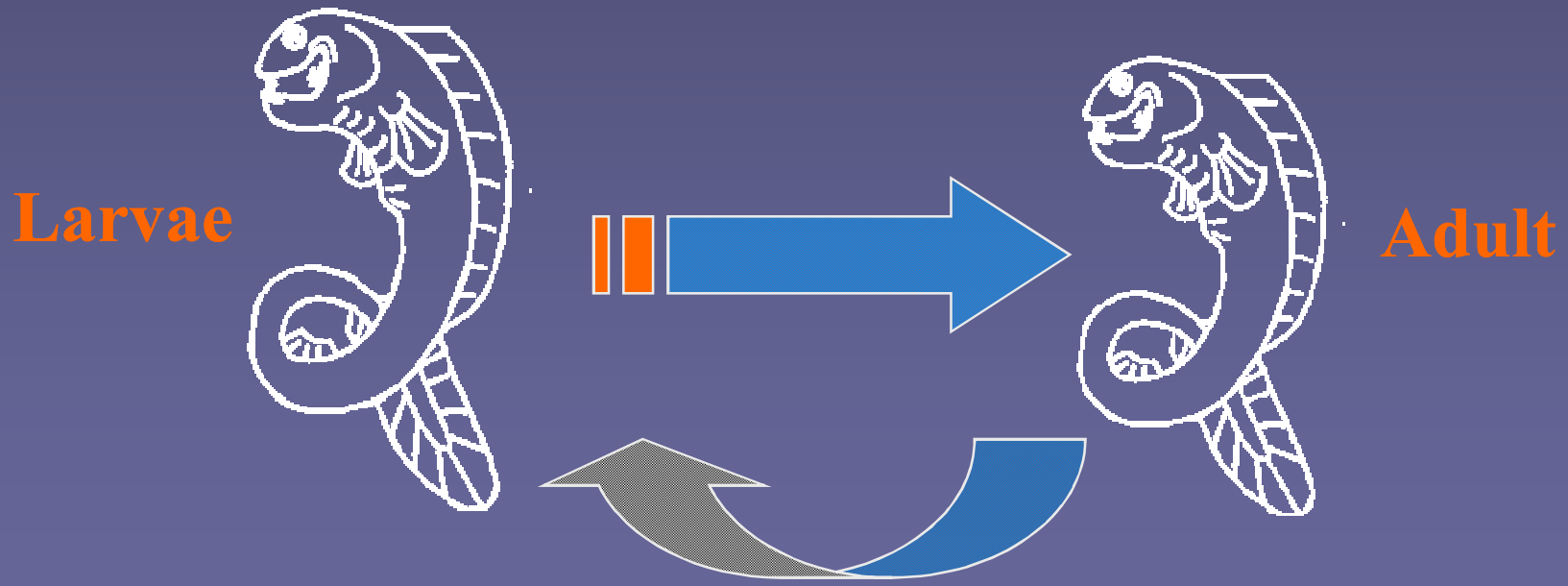
Eels (catadromic teleosts)



Life Cycle of Eels & their Physiological Adaptations

Sea Water

Fresh Water



In SeaWater

- Fish is osmotically more dilute than the medium
- Constant loss of water thru gills and urine
- Compensate by drinking seawater

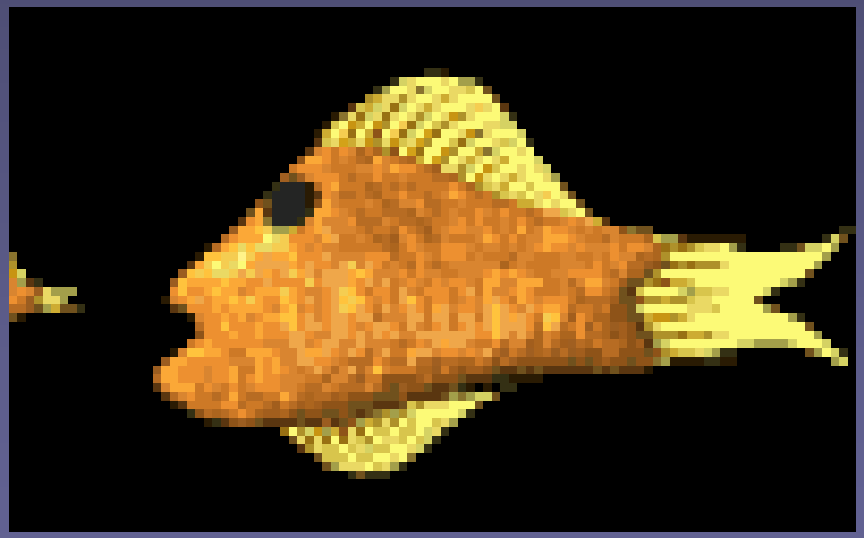
In SeaWater (continued…)

- Ingested salts (Na^+, Cl^-) are absorbed in the intestine & eliminated via the gills by active transport
- Mg^{2+} and SO_4^{2-} are excreted by the kidney

In FreshWater

- Fish is osmotically more concentrated than the medium
- Suffers steady osmotic influx of water thru the gills
- Excess water excreted as urine

In FreshWater (continued…)



- Large urine volume loss causes substantial loss of solutes
- Slightly permeable to ions, solutes are also lost thru the gills
- Solutes taken in with food & main uptake by active transport in gills

To maintain steady state during Diadromy in Eels

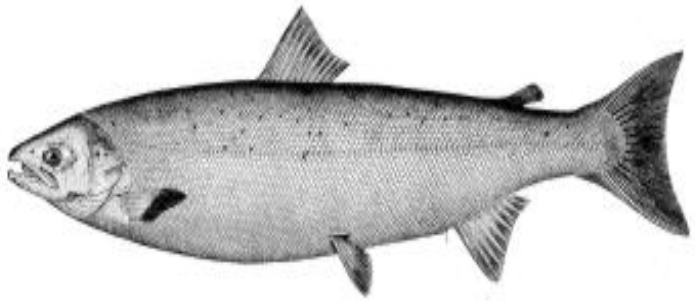
1. Osmotic flow of water changes direction

2. Active ion transport in gills also changes direction:

@ to achieve steady state and

@ compensate for solute gain/loss

Sal



- Physical, biochemical and metabolic changes
- Main organs involved in osmoregulation
- Hormonal changes

Types of Salmon

Pacific Salmon

Chinook (king) salmon ***(Oncorhynchus tshawytscha)***

Coho (silver) salmon ***(Oncorhynchus keta)***

Chum (dog) salmon ***(Oncorhynchus kisutch)***

Pink (humpback) salmon ***(Oncorhynchus gorbuscha)***

Sockeye (red) salmon ***(Oncorrhynchus nerka)***

Types of Salmon

Asia Pacific Salmon

- Masu salmon (*Oncorhynchus masou*) (yamame)
- Amago salmon (*Oncorhynchus rhodurus*) (biwamasu)

Atlantic Salmon

- Atlantic s*r*)
- Steelhead trout (anadromous form of rainbow trout) (*Oncorhynchus mykiss*)

Physical Changes

1. Silvery appearance of smolt
2. Emergence and growth of teeth in coho salmon
3. Growth and changes in shape of integumentary folds
4. Growth of scales
5. Body shape differences

Biochemical & Metabolic changes

1. Increase of oxygen consumption
2. Changes in haemoglobin form
3. Increase in blood ATP concentration
4. Decrease in total lipid content
5. Decrease in liver glycogen
6. Increase in body water content
7. Decline in general protein content
8. Changes in amino acids production

Main Organs in Osmoregulation

- Skin
- Intestine
- Kidney-urinary system
- Gills

Hormonal Regulation

- Prolactin
- T3 & T4
- Cortisol
- Growth Hormone
- Angiotensin

Conclusion

Problems FW ⇀ SW	Countermeasures
higher [osm] in SW - water efflux - primary : gills - urine	- drinking large amount of SW ingested monovalents - absorbed in intestine removed via gills by active- transport - divalent by kidney ↑ ↑ - cortisol : CC no. ↑ - GH: const bld plasma Na ↓ ↓ - PRL: urine vol.

Problems SW → FW	Countermeasures
lower [osm] in FW– –steady water influx –primary : gills –excess excreted as urine –large amount dilute urine –loss of solute	– ions intake by active absorption in gills and food ↑ ↑ – cortisol : CC no. ↑ ↑ – PRL: urine vol.