IJSO Theory mock test

Biology Mock Test no. 1

This is an IJSO Biology mock test, designed to mimic the style, breadth, depth, and difficulty of IJSO biology questions. Its aim is to provide students with an array of problems to help them prepare for the IJSO and IJSO-like biology competitions.

The questions in this paper were made by the following past IJSO participants (in alphabetical order):

- Mila Porjazoska (North Macedonia)
- Parthipan Kasiban (Sri Lanka) – Biology Mock no. 1 coordinator
- Tamara Bračko (Croatia)

Total points: 30

No.	Problem	Problem Author	Marks
1	Adaptations In Organisms Living In Freezing Conditions	Parthipan Kasiban	10 points
2	Homeostasis	Parthipan Kasiban; Tamara Bračko	15 points
3	Global warming and biodiversity in the Arctic	Mila Porjazoska	5 points

In solving the questions, you might need to use the following constants:

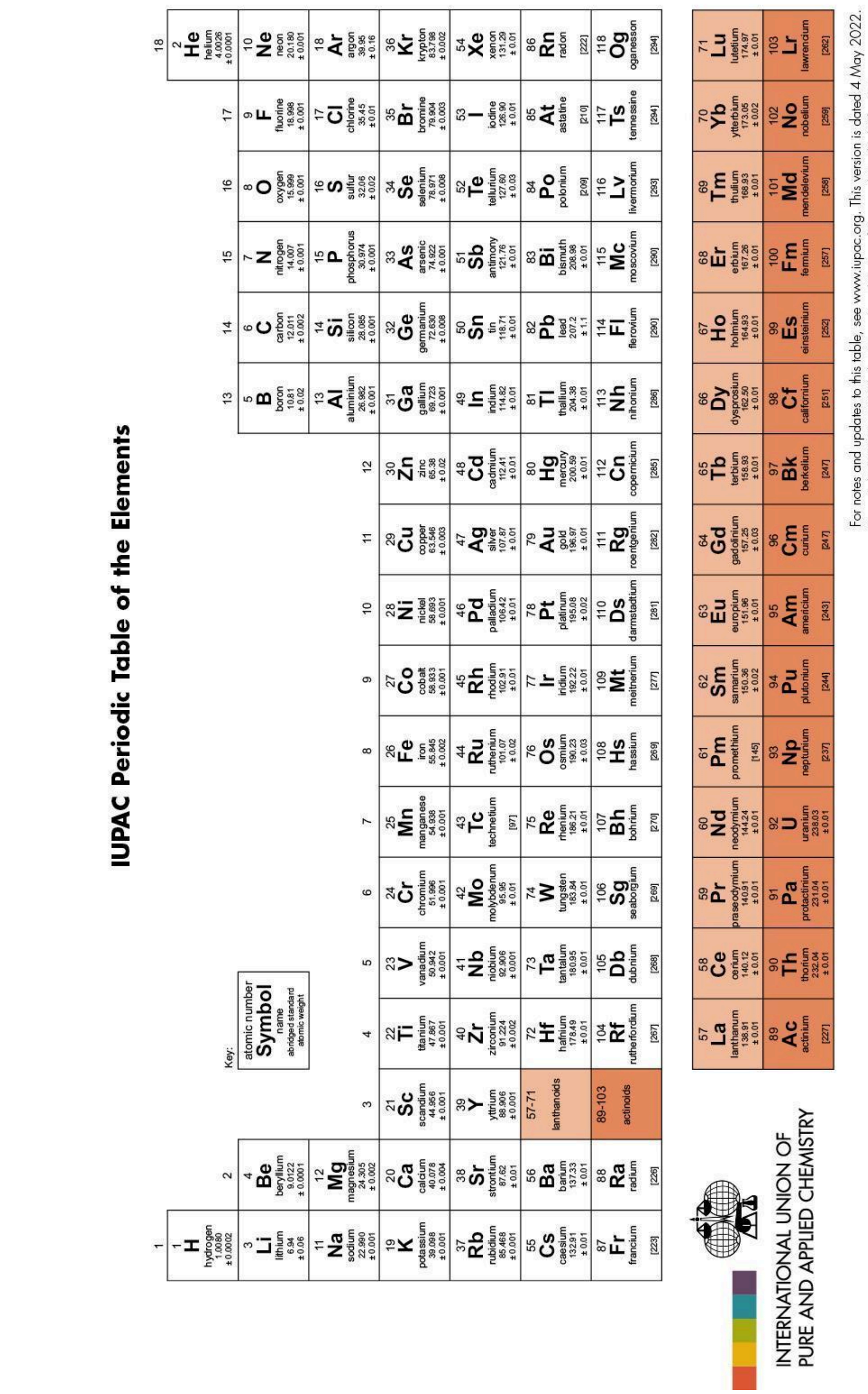
Constant	Notation	Value
Acceleration due to gravity	g	$9.8\ ms^{-2}$
Gravitational constant	G	$6.67 \cdot 10^{-11}\ m^3/\ kg \cdot s^2$
Planck's constant	h	$6.62 \cdot 10^{-34}\ J \cdot s$
Elementary charge	e	$1.6 \cdot 10^{-19}$ C
Speed of light in vacuum	c	$3 \cdot 10^8\ ms^{-1}$
Density of water	ρ	$1000\ kg\ m^{-3}$
Stefan-Boltzmann constant	σ	$5.67 \cdot 10^{-8}\ \frac{W}{m^2 K^4}$
Universal gas constant	R	$8.314\ J\ mol^{-1}\ K^{-1}$ $0.0821\ atm\ L\ mol^{-1}\ K^{-1}$
Avogadro's number	N_A	$6.022 \cdot 10^{23}\ mol^{-1}$
Faraday's constant	F	$96\ 500\ C/mol$
Pi	π	3.14
Electrical permittivity of free space	ε_0	$8.85 \cdot 10^{-12}\ F \cdot m^{-1}$
Magnetic permeability of free space	μ_0	$4\pi \cdot 10^{-7}\ H/m$
Mass of Earth		$5.97 \cdot 10^{24}$ kg
Mass of Moon		$7.35 \cdot 10^{22}$ kg
Mass of Sun		$1.99 \cdot 10^{30}$ kg
Radius of Earth		$6.4 \cdot 10^6$ km
Radius of Moon		$1.7 \cdot 10^6$ km
Radius of Sun		$6.96 \cdot 10^8$ km
Specific heat capacity of water	c_w	$4200\ J/kg \cdot °C$
Average molar mass of air	M	$28.9\ g/mol$

If any other value is provided in the problem, use the value provided, not the one in the table. You can also use the following conversion formulas:

$T\ (K) = t\ (°C) + 273$	$t\ (°F) = \frac{9}{5} t\ (°C) + 32$
$1bar = 1atm = 101\ 000Pa = 760mmHg$	$1u = 1Da = 1.66 \cdot 10^{-27} kg$
$1L = 10^{-3}\ m^3$	1 day $= 24h$

If needed, you can use the periodic table given below:

(Use atomic masses rounded to two decimal places.)



Problem 1 – Adaptations In Organisms Living In Freezing Conditions (10.00 points)

Part A. The Molecular Biological Adaptations to the Cold (2.50 points)

Many organisms not only tolerate but thrive in near freezing temperatures. Life faces many challenges when living in such conditions and adaptations in the organism's molecular systems play a crucial role in the survivability of that organism.

A1. Many psychrophilic bacteria possess enzymes that maintain catalytic efficiency at low temperatures. A common molecular strategy to achieve this involves a higher proportion of:

A. Hydrophobic amino acids in the active site.

B. Rigid protein structures with fewer loop regions.

C. Charged residues and increased surface hydrophilicity, promoting greater conformational flexibility.

D. Cysteine residues forming disulfide bridges for enhanced stability.

(1.00 points)

A2. Fill in the blanks:

To prevent the formation of lethal ice crystals inside their cells, some freeze-avoiding organisms synthesize and accumulate osmolytes such as glycerol or glucose. These compounds act as __________ (electrolytes/ anti freeze/, cryo protectant) by lowering the intracellular freezing point and protecting cellular structures from dehydration. The cell membranes of organisms adapted to cold temperatures typically exhibit an increased proportion of __________ (saturated, unsaturated, trans) fatty acids. This structural modification is crucial for maintaining membrane __________ (permeability, fluidity, stability)at low temperatures, preventing it from becoming rigid and dysfunctional.

(0.50 points)

A3. Beyond simple freezing point depression, specialized antifreeze proteins (AFPs) in polar fish primarily function by:

A. Encapsulating water molecules to prevent their aggregation.

B. Inhibiting the growth of nascent ice crystals by adsorbing onto specific ice lattice planes.

C. Actively pumping water out of cells to prevent ice formation.

D. Increasing the viscosity of the cytoplasm to slow down ice propagation.

(1.00 points)

Part B: Physiological Architectures for Enduring Cold (2.00 points)

This section focuses on the organismal-level physiological mechanisms that allow animals to regulate body temperature, survive freezing, or manage energy in frigid environments.

B1. Endothermic polar animals like arctic foxes and penguins utilize a countercurrent heat exchange system in their extremities (e.g., paws, flippers). This mechanism functions by:

A. Generating metabolic heat directly in the extremities to keep them warm.

B. Transferring heat from outgoing arterial blood to cooler returning venous blood, minimizing heat loss to the environment.

C. Increasing the surface area for heat dissipation from the core to the periphery.

D. Rapidly circulating cold blood from the extremities back to the core to cool the animal.

(0.25 points)

B2. Check all that apply: Non-shivering thermogenesis (NST) in mammals, particularly relevant in cold adaptation, involves which of the following processes in brown adipose tissue (BAT)?

A. [ ] Direct hydrolysis of ATP for heat release.

B. [ ] Uncoupling of the electron transport chain from ATP synthase.

C. [ ] Proton leakage across the inner mitochondrial membrane via thermogenin (UCP1).

D. [ ] Increased shivering of muscle fibers at a cellular level.

E. [ ] Enhanced fatty acid oxidation to fuel proton pumping.

(1.25 points)

B3. Some freeze-tolerant organisms, such as the wood frog (*Rana sylvatica*), can survive having up to 65% of their total body water frozen. This is largely achieved by:

A. Actively preventing all ice formation in any part of the body.

B. Promoting the formation of large, uniform ice crystals in extracellular spaces, while protecting cells.

C. Rapidly thawing and refreezing their tissues multiple times per day.

D. Converting all their body water into a glassy, amorphous state (vitrification).

(0.25 points)

B4. The exceptionally low heart rate and metabolic rate observed in some diving marine mammals (e.g., seals, whales) when under ice is an example of:

A. Obligate diapause.

B. Regional heterothermy.

C. Dive reflex with bradycardia.

D. Hibernation.

(0.25 points)

Part C: Ecological Dynamics of Polar Life (2.50 points)

This section explores the unique structure, energy flow, and interdependencies within polar marine ecosystems, heavily influenced by ice and seasonal changes.

C1. The formation of sea ice is crucial for the early spring bloom of ice algae (sympagic algae). These algae form the base of the "cryopelagic" food web. Check all that apply regarding the ecological advantages of growing within or on the underside of sea ice for these primary producers:

A. [ ] Protection from intense UV radiation.

B. [ ] Access to nutrient-rich brine channels.

C. [ ] Reduced grazing pressure from open-water zooplankton in early spring.

D. [ ] Enhanced light penetration compared to open water in winter.

E. [ ] A stable substrate for attachment in a turbulent environment.

(0.75 points)

C2. The biomagnification of persistent organic pollutants (POPs) is a significant concern in polar food webs. Which of the following statements best explains why apex predators like polar bears accumulate very high concentrations of these toxins?

A. Polar bears directly consume contaminated water, leading to high intake.

B. POPs are rapidly metabolized and excreted by lower trophic levels, concentrating in top predators.

C. POPs are lipophilic and accumulate in fatty tissues, becoming more concentrated at successively higher trophic levels.

D. Polar bears have unique metabolic pathways that actively synthesize POPs.

(1.25 points)

C3. During the polar winter, many marine birds and mammals migrate away from the extreme cold. However, species like Emperor Penguins endure the Antarctic winter. Their survival in breeding colonies during winter relies heavily on:

A. Switching to a diet of terrestrial plants to conserve energy.

B. Entering a state of true hibernation to minimize metabolic needs.

C. Huddling behaviors and a thick layer of blubber to reduce heat loss.

D. Increasing their metabolic rate to generate massive amounts of internal heat.

(0.50 points)

Part D: Global Change and the Cryosphere (3.00 Points)

This section explores the impacts of ongoing climate change on polar ecosystems and the potential biological feedback loops.

D1.

Fill in the blanks:

The thawing of vast permafrost regions in the Arctic is a significant concern for the global carbon cycle. As permafrost thaws, the immediate biological process that contributes to the release of greenhouse gases (CO_2 and CH_4) is the __________ (accumulation/ decomposition/ photosynthesis)of long-frozen organic matter by __________ (abiotic/ microbial/ geological) activity.

(0.5 points)

D2. Check all that apply: The accelerated melting of Arctic sea ice has several direct and indirect ecological consequences. Which of the following are likely to occur?

A. [ ] Increased primary productivity in newly opened ocean areas due to increased light penetration.

B. [ ] Reduced access to hunting platforms for ice-dependent predators like polar bears and some seal species.

C. [ ] Increased rates of coastal erosion in permafrost regions.

D. [ ] Enhanced albedo effect, leading to a cooling feedback loop.

E. [ ] Increased incidence of parasitic diseases in marine mammals due to warmer waters.

(0.75 points)

D3. Ocean acidification, driven by increased atmospheric CO_2 absorption, poses a particular threat to calcifying organisms in cold polar waters. This is because:

A. Cold water holds less dissolved CO_2, leading to higher surface ocean pH.

B. The solubility of CO_2 is higher in cold water, leading to a greater reduction in carbonate ion concentration.

C. Polar organisms have evolved with a narrow pH tolerance, making them more sensitive.

D. Acidification directly increases the metabolic rate of calcifying organisms, leading to shell dissolution.

(1.25 points)

D4. Fill in the blank:

The concept of "Arctic amplification" refers to the phenomenon where the Arctic warms faster than the rest of the planet. A key biological feedback mechanism contributing to this is the __________ effect, where the loss of highly reflective ice and snow cover leads to increased absorption of solar radiation by darker ocean and land surfaces.

(0.50 points)

Question 02: Homeostasis (15.00 points)

The remarkable ability of living organisms to maintain a stable internal environment despite external fluctuations is fundamental to their survival and proper functioning. This dynamic equilibrium, known as homeostasis, involves a complex interplay of physiological processes regulated by intricate feedback mechanisms. From maintaining a constant body temperature and blood glucose levels to regulating pH and water balance, virtually every biological system relies on homeostatic control. Disruptions to these finely tuned systems can lead to disease and even death, underscoring the critical importance of understanding how organisms detect changes, respond, and restore balance.

Part A: Glucose Homeostasis - Fundamental Mechanisms (2.50 Points)

A1. After a carbohydrate-rich meal, blood glucose levels rise. Which of the following accurately describes the immediate physiological response orchestrated by the pancreas to restore glucose homeostasis?

A. Alpha cells release glucagon, stimulating the liver to break down glycogen into glucose.

B. Beta cells release insulin, promoting glucose uptake by muscle and adipose cells and glycogen synthesis in the liver.

C. Delta cells release somatostatin, directly inhibiting the absorption of glucose from the intestine.

D. Both alpha and beta cells increase their secretion rates, leading to a simultaneous increase in both glucose synthesis and uptake.

(0.75 points)

A2. Fill in the blanks:

When insulin binds to its receptors on target cells (e.g., muscle and adipose tissue), it triggers the translocation of __________ (SGLT1 / GLUT4 / Na+/K+ pump) transporters to the cell membrane, thereby increasing cellular uptake of glucose from the bloodstream. Simultaneously, in the liver, insulin promotes the conversion of excess glucose into __________ (fatty acids / amino acids / glycogen) for storage.

(1.00 points)

A3. Check all that apply:

The maintenance of blood glucose homeostasis involves the coordinated action of several organs and tissues. Which of the following play DIRECT roles in regulating blood glucose levels by responding to or producing key hormones?

A. [ ] Pancreas (Islets of Langerhans)
B. [ ] Liver
C. [ ] Adipose tissue
D. [ ] Kidneys
E. [ ] Brain (Hypothalamus)

(0.75 points)

Part B: Glucose Homeostasis - Clinical Insights (2.50 points)

B1. A patient undergoes an Oral Glucose Tolerance Test (OGTT). After consuming a glucose solution, their blood glucose levels are monitored over several hours. In a healthy individual, which of the following glucose level patterns would be observed?

A. A sharp, prolonged rise in blood glucose, remaining elevated for more than 4 hours.

B. A rapid rise in blood glucose, followed by a return to baseline within 2-3 hours.

C. A minimal change in blood glucose levels, indicating no absorption of the glucose solution.

D. A continuous decline in blood glucose levels from the start of the test.

(1.00 points)

B2. Check all that apply: Prolonged and uncontrolled hyperglycemia (high blood glucose) in diabetes can lead to severe long-term complications affecting various organ systems. Which of the following are recognized consequences of chronic hyperglycemia?

A. [ ] Damage to the small blood vessels (microvascular complications) leading to retinopathy and nephropathy.

B. [ ] Increased risk of cardiovascular diseases due to damage to large blood vessels (macrovascular complications).

C. [ ] Enhanced immune response, making individuals less susceptible to infections.

D. [ ] Nerve damage (neuropathy), affecting sensation and organ function.

E. [ ] Reduced risk of cataracts and glaucoma due to altered osmotic balance in the eye.

(1.00 points)

B3. Fill in the blanks:

Type 1 diabetes mellitus is an autoimmune condition characterized by the destruction of pancreatic __________ (alpha / beta) cells, leading to an absolute deficiency of insulin production. In contrast, Type 2 diabetes mellitus is primarily characterized by insulin __________ (resistance / sensitivity), where target cells do not respond effectively to insulin, often compounded by a relative deficiency in insulin secretion over time.

(0.50 points)

Part C: Thermoregulation- Maintaining Core Body Temperature (3.25 points)

C1. When an individual is exposed to a cold environment, the body initiates several responses to conserve heat. Which of the following accurately describes a primary physiological response mediated by the hypothalamus to prevent excessive heat loss?

A. Vasodilation of cutaneous (skin) blood vessels, increasing blood flow to the surface to release heat.

B. Increased sweating through eccrine glands to facilitate evaporative cooling.

C. Piloerection (goosebumps) and shivering, leading to involuntary muscle contractions to generate heat.

D. Inhibition of brown adipose tissue activity to reduce non-shivering thermogenesis.

(1.00 points)

C2. Check all that apply: Beyond involuntary physiological responses, humans and many other endotherms employ conscious behavioral adaptations to regulate their body temperature. Which of the following are examples of such behavioral thermoregulation?

A) [ ] Seeking shade or shelter from extreme weather.

B) [ ] Changing clothing to adjust insulation.

C) [ ] Huddling together in groups during cold conditions.

D) [ ] Increasing metabolic rate by hormonal signals.

E) [ ] Altering blood flow to extremities.

(0.50 points)

C3. Fill in the blanks:

Heat is primarily transferred from the body to the environment through four main physical mechanisms: (conduction / convection / radiation). Heat transfer through direct contact is called __________ (conduction / convection / evaporation). Heat transfer by the movement of fluid (air or water) is called ________________.

(0.25 points)

C4. Approximately how much energy (in kJ) does the body use solely to convert 1 liter of cold water (5°C) to body temperature (37°C), without taking into account other metabolic processes? (Specific heat capacity of water = 4.18 J/g°C)

A. 134 kJ

B. 25.1 kJ

C. 167.2 kJ

D. 8.36 kJ

(1.50 points)

Part D: Interplay of Homeostatic systems (4.00 points)

D1. During prolonged strenuous exercise, both glucose homeostasis and thermoregulation are significantly challenged. Which of the following best describes a key physiological adjustment that allows the body to meet the increased energy demand and manage heat production simultaneously?

A. Increased insulin secretion to rapidly remove glucose from the blood, coupled with intense peripheral vasoconstriction to conserve heat.

B. Increased glucagon secretion and catecholamine release to mobilize glucose and fatty acids, along with increased sweating and peripheral vasodilation to dissipate heat.

C. Suppression of both glucose metabolism and heat-generating processes to prevent overexertion.

D. A complete shutdown of non-essential bodily functions to prioritize muscle energy supply.

(1.00 points)

D2. Check all that apply: Homeostatic control systems typically operate via negative feedback loops to maintain stability. Which of the following are essential components of a generic negative feedback loop?

A. [ ] A sensor (receptor) that detects changes in the internal environment.

B. [ ]A control center that processes information and determines the appropriate response.

C. [ ] An effector that carries out the response to correct the deviation.

D. [ ] A positive feedback mechanism that amplifies the initial stimulus.

E. [ ] A set point, representing the desired physiological value.

(0.75 points)

D3. Fill in the blanks:

Water plays a critical role in thermoregulation due to its high __________ (specific heat capacity / latent heat of vaporization / density), allowing the body to absorb and release significant amounts of heat with minimal temperature change. This property is particularly evident in the process of sweating, where the __________ (specific heat capacity / latent heat of vaporization / density) of water facilitates efficient cooling as sweat evaporates from the skin.

(0.25 points)

D4. During intense physical activity in hot conditions, the body can lose up to 2–3 liters of sweat per hour. If an athlete drinks water without replacing electrolytes, what is the most likely physiological outcome?

A. Hypoglycemia due to loss of sugar in sweat

B. Hypernatremia due to excessive water intake

C. Hyponatremia due to dilution of sodium in the blood

D. Alkaline acidosis due to loss of hydrogen ions

(1.00 points)

D5. Which mechanism precisely describes why the body inhibits the secretion of the hormone vasopressin (ADH) in a state of hyperhydration?

A. Increased plasma osmolality activates baroreceptors in the kidneys

B. Low plasma osmolality is detected in the hypothalamus, which inhibits ADH

C. Reduced filtration in the glomeruli stops ADH secretion

D. ADH is regulated solely by mechanical distension of the bladder

(1.00 points)

Part E: Effects of Physiological Modulators (2.75 points) - 0.4 PER correct sub-answer.

For each physiological process listed below, indicate whether the modulating factor described would typically have an Increasing (I), Decreasing (D), or Unrelated (U) effect on the rate or magnitude of the process.

Biological Process	Modulating Factor	Effect (I/D/U)
E1. Rate of nerve impulse conduction	Severe demyelination of the axon	
E2. Oxygen unloading from hemoglobin at peripheral tissues	Increased tissue CO_2 concentration (e.g., during exercise)	
E3. Glomerular Filtration Rate (GFR)	Severe constriction of the afferent arteriole	
E4. Net fluid movement out of capillaries at the arterial end	Significant increase in plasma protein concentration	
E5. Activity of the Na+/K+ pump	Absence of ATP	
E6. Secretion of Antidiuretic Hormone (ADH)	Significant decrease in blood osmolarity	
E7. Calcium reabsorption in the renal tubules	Increased parathyroid hormone (PTH) levels	

Question 03: Global Warming and Biodiversity in the Arctic

(5.00 points)

With the rise of global average temperature, the lives of many species have been endangered. There are a few ways an organism's life can change. To list a few, it may not be able to survive the rise of temperature, or it may not have enough food to survive. The range of fluctuation of a single ecological factor, within which the life of a certain organism is possible, is called ecological valence. Changes in temperature, as one of the main ecological factors contributing to the dispersion of a species, can lead to drastic changes in population size. Usually, when such changes occur, the population size decreases or individuals migrate toward habitats with more suitable conditions. A stenothermal species is a species where slight changes in temperature can alter the population size. Such a species is the Arctic fairy shrimp (Branchinecta paludosa), which plays a major role in many food chains in the arctic ecosystems.

Part A:

A1. Select the best answer with regards to the passage:

A. If the temperature changes, the population of snails and insect larvae will decrease because of the absence of arctic fairy shrimp

B. If the temperature changes slowly, like it is now, no noticeable changes will occur because the arctic fairy shrimp adapt quickly to their environment

C. The population of phytoplankton and algae will not noticeably change in a large period of time because the ecological niche previously occupied by the arctic fairy shrimp will be filled out by other species

D. There will be a sudden decrease in detritus when the shrimp enter their pessimal zone

(1.00 points)

A2: Determine if the statements are true or false **(4.00 points) –** 0.80 points PER correct answer

Statement:	True/false (mark T for true and F for false)
1. If organism A has a narrower ecological valence for a given factor than organism B, organism B is less likely to survive in an environment with a different intensity of the given factor.	
2. The ecological valence of an organism is more likely to change if there have been mixings between the gene pools of populations occupying different ecosystems and ecological niches.	
3. An isolated population is more likely to migrate when the abiotic factors are changing than a population with high gene flow.	
4. Climate change and global warming aren't one of the main reasons for species extinction.	
5. In the pelagic arctic biome there is bottom-up control because of the large populations of phytoplankton and algae.	