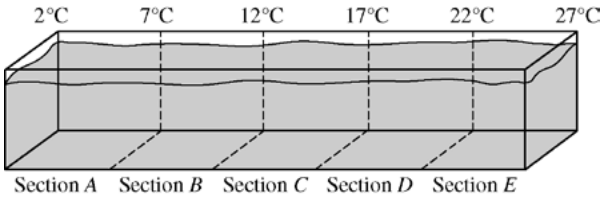
AP® BIOLOGY
2009 SCORING GUIDELINES

Question 1

An experiment on a species of small freshwater fish recorded their behavioral responses to different temperatures. Ten fish were each tested once, one at a time.

To begin the experiment, a fish was removed from a stock tank (maintained at 22°C) and placed in the temperature-gradient tank drawn below. After the fish had spent 30 minutes in the temperature-gradient tank, the section where the fish was located was recorded. Additional observations were recorded every 5 minutes, for a total of 7 observations per fish. A summary of the combined data for all 10 fish appears below.



Section	Fish/Section
A	9
B	11
C	34
D	12
E	4

(a) On the axes provided, **construct** the appropriate type of labeled graph showing the relationship between water temperature and fish distribution. **Summarize** the outcome of the experiment. **(4 points maximum)**

Graph **(1 point each; 3 points maximum for graph)**	**Summarize** **(1 point maximum for summary)**

• Correctly labeled and scaled axis
  o Temperature range may be indicated by section with legend
• Correct orientation: *x*-axis = temp; *y*-axis = # fish observed
• Correct bar graph/scatter plot
  o Discrete data points only if range is indicated
  o NO point for line graph
	• Fish were distributed by temperature, e.g., most fish were observed at moderate temperature range, or 12–17°C

AP® BIOLOGY
2009 SCORING GUIDELINES

Question 1 (continued)

(b) **Identify** TWO variables that were not specifically controlled in the experimental design, and **describe** how these variables might have affected the outcome of the experiment. **(4 points maximum)**

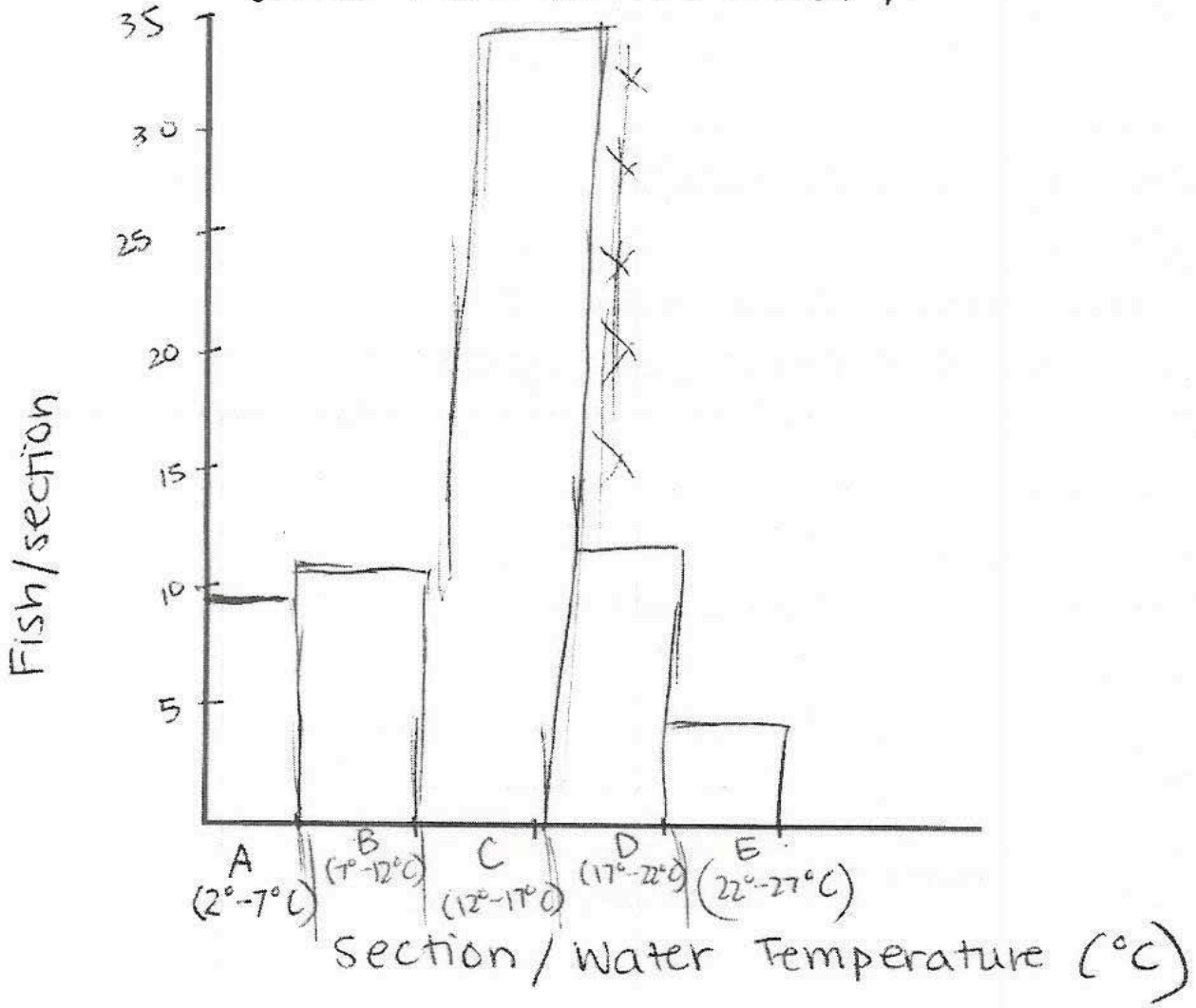
Variable* **(1 point each; 2 points maximum)**	**Describe** **(1 point each; 2 points maximum)**
Fish characteristics, e.g., age, size, sex, schooling, health	Age/mating behavior/sex, SA:V ratio, tendency to school may affect activity levels/distribution of fish
Tank characteristics, e.g., depth, shape, size, gravel, plants, sections/ends	Depth/shape/size/pressure/ends of tank may affect distribution of fish "control" tank at constant temperature
Water quality, e.g., pH, salt, chemicals, microbes	Attraction/avoidance influences fish response to temperature
Placement of fish, time in stock tank	Tendency of fish to remain where placed, effect of shock on fish
External stimuli, e.g., light, noise	Attraction/avoidance influences fish response to temperature
Oxygen concentration	Attraction/avoidance influences fish response to temperature
Time of day/biological rhythms or when observations recorded	Temperature preference or activity of fish differs with time of day, e.g., diurnal vs. nocturnal
Other acceptable variables**	Other acceptable descriptions

* 1 point for **each** variable, may include two from same category
** NOT type of fish, NOT temperature, since these were set by experimenters

(c) **Discuss** TWO ways that water temperature could affect the physiology of the fish in this experiment. (**4 points maximum)**

Effect (directional) **(1 point each; 2 points maximum)**	**Explanation of effect** **(1 point each; 2 points maximum)**
Metabolic rate/activity increase with temperature increase	Related to kinetic energy, enzyme activity (NOT denaturation)
Heart rate/circulation/blood flow increase with temperature increase	Related to kinetic energy, blood vessel constriction/dilation, etc.
Respiration rate, operculum movement, "breathing rate" increase with temperature increase	Related to diffusion rates, metabolic rates
Shock/stress prevent normal activity	Nervous system impairment alters fish movements
Gas exchange (O_2 or CO_2) altered at different temperatures	Dissolved oxygen increases at lower temperatures

Title: Graph showing relationship between water temperature/section and fish distribution.



a cont'd). ~~MOS~~ The greatest number of fish was found in Section C, 12°-17°C. The least number was found in the hottest section E. The overall distribution was like a bell curve, with a small amt. in A, greater amt. in B, greatest amt. in C, lesser amt in D, and least amt. in E.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

b) One variable that was not controlled was the pressure. If there were greater pressures in the extremes (A and E), that may have accounted ~~for~~ partially for the lesser distribution of fish in these areas. The fish would probably go to the area with the average amount/normal amount of pressure.

Another variable not ~~accounted for~~ controlled was the solute in the water. If more solute was present towards the ends of the tank, the fish (since they are freshwater fish) may not want to be there, so they would ~~not~~ go to the area with a normal amount of solute, perhaps section C.

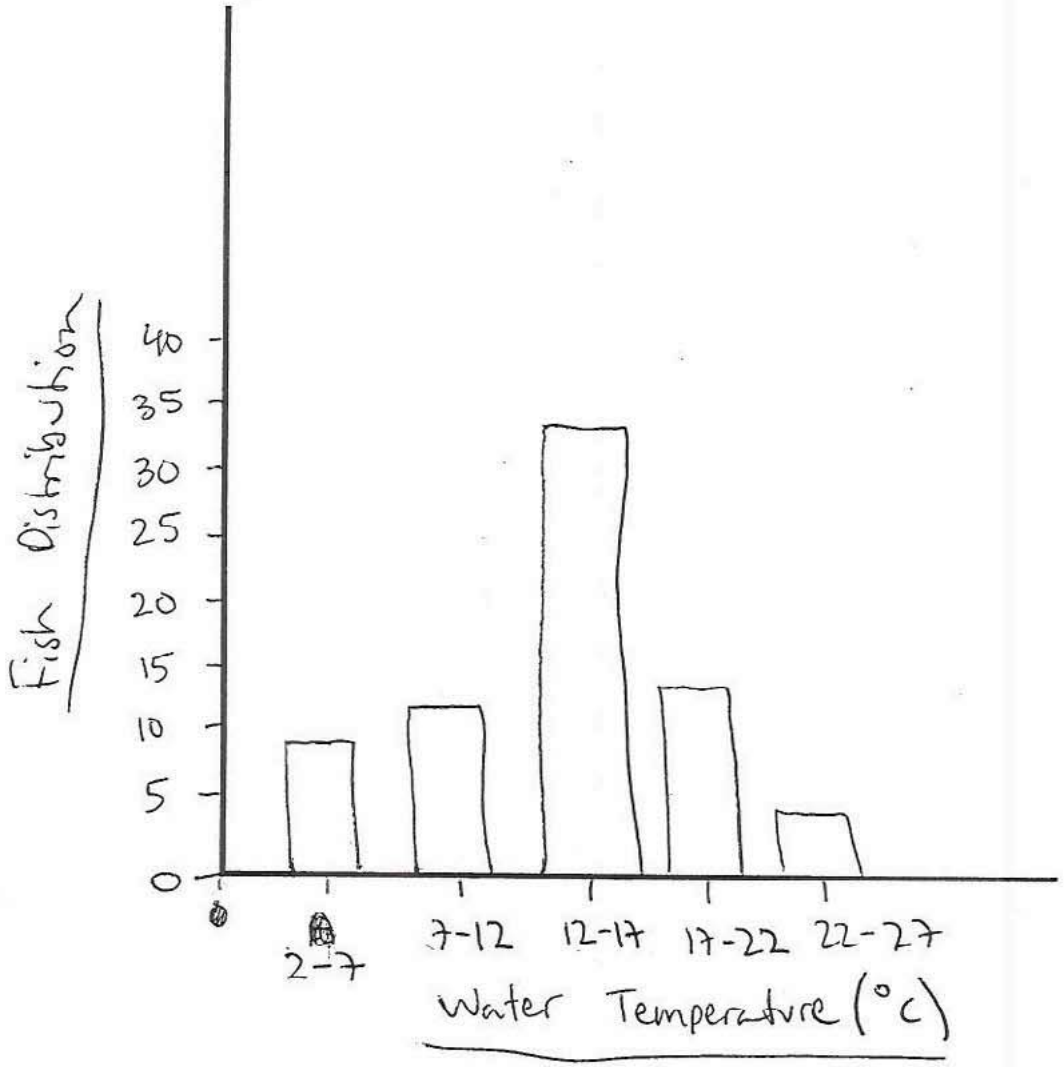
c) ~~First,~~ higher water temperature could make the fish need more energy in the greater temperature sections. This could lead to two things: the heart rate of the fish could increase, for increased blood flow of nutrients to the cells, and second, the fish would take in more O_2 through countercurrent exchange of its gills. Both of these would lead to increased cellular respiration, which means more ATP for the fish

1A3

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

to ~~maintain~~ have energy to swim through the heated waters. Increased heart rate would also provide for an increase in the overall body temperature of the fish.

Water Temperature v.s. Fish Distribution



a) The fish tended to locate in the temperature range of 12-17°C, a type of stable selection for the more moderate temperature. While most of the fish (34) were in the temperature of 12-17°C, much less fish located to temperatures above and below that: 20 fish went below 12°C, and 16 fish went above 17°C.

b) The content of the water was not controlled. The fish may have selected for one section over another because a certain nutrient drew them there, or a certain

1B2

toxin or chemical repelled them from another section. For example, pollution or higher salt concentration may have driven fish away from certain sections. Light was another factor that was not controlled. Certain fish may prefer darker conditions than others, which may have influenced the section they located to, rather than the intention of the experiment (temperature).

c) Colder water has a higher concentration of dissolved oxygen. Certain fish, such as trout, need cold water for its oxygen supply. Warm water cannot hold as much oxygen and therefore is an unsuitable habitat for certain fish. Fish habitats reflect their oxygen needs in the temperature of the water. Water temperature also impacts the maintenance of homeostasis in regard to the internal body temperature of the fish. It requires energy, or ATP, to heat an organism. If an organism lives in cold water it will use more ATP and therefore more energy in heating itself. This requires an increased rate of cellular respiration to produce ATP, which uses glucose as an organic molecule to convert to ATP (energy). Fish in cold temperature must, also, take in more food to supply the increased rate of cellular respiration. Warmer water creates less

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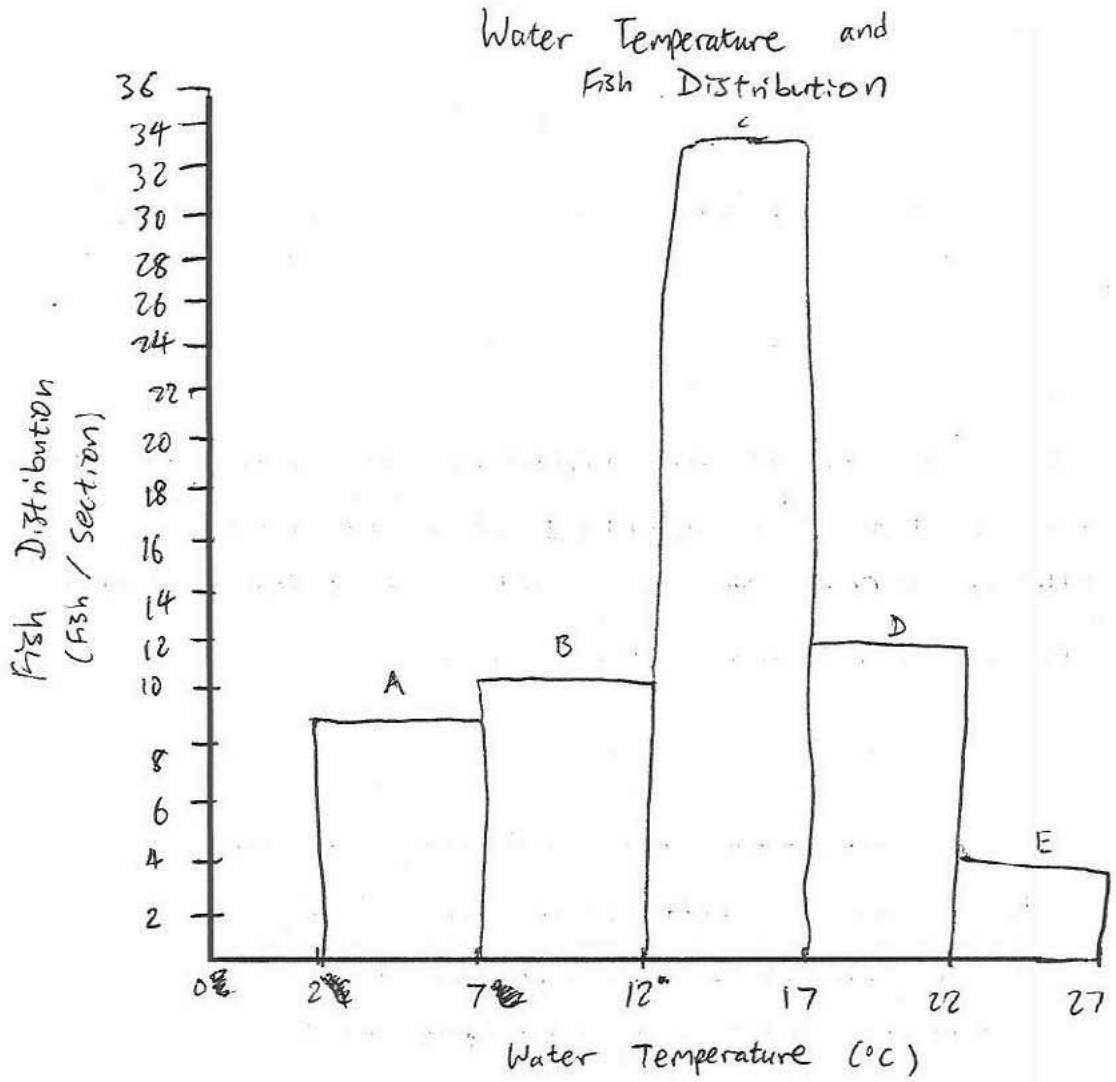
of a need for an organism to heat itself and will use less ATP heating itself. However, if the water is too warm it may denature enzymes and disrupt homeostasis.

1C,



The experiment shows that most fish prefer Section C which contains water between 12°C and 17°C. Out of 70 total observations for the fish in the experiment, 35 observations were made for fish in Section C of the tank. As the temperature increased or decreased from this interval, the number of fish decreased. This indicates an optimal point for the fish between 12°C and 17°C. Since each fish had been tested one at a time, it shows their individual preferences of water temperature, not influenced by any fellow fish.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

However, some variables may not have been specifically controlled in the experimental design. There was no mention of controlling variables such as light and fish species. The presence of varying light in different sections of the tank could influence the fish's taxis and preference. Certain fish may be more inclined to approach lighted areas or darker regions. The specie of fish also refferts an issue. Though all ten fish used in the experiment are "small freshwater fish," there can still be room for variations based on more specific types of fish. Different species of fish would have different preferences in terms of water temperature. Some fish prefer the surface of the water in the wild while others prefer deeper zones. Thus, uncontrol variables such as light and fish specie may tamper with an accurate outcome of the experiment, especially if there had been a high amount of a certain specie but a low quantity of another. If light had been brighter on Section C, perhaps that is why most fish had been observed there. The experiment heavily relies on the consistencies of these variables and the individuality of the fish.

These particular fish demonstrate a sense of physiology as they purposefully move toward a preferred water temperature. Though some movements may be the result of kinesis, unintentional movements, it is assumed that the data collected reflects positive taxis in movemer to a prefered region of the tank. These fish had been previously contained in a stock tank maintained at 22°C with no choice on how warm the water would be. Once placed in the temperature-gradient tank, they were free to find the region most suited to them. Being ectothermic animals, the fish position themselves in an

1C3

area of desired temperature to maintain a desired body temperature. Each fish moved to the section where they perceived to be most comfortable to their functioning. As most of the fish were observed in section C, it can be concluded that most small freshwater fish have a physiology that shows they prefer temperatures between 12°C and 17°C.

AP® BIOLOGY
2009 SCORING COMMENTARY

Question 1

Overview

The understanding of experimental design and the analysis of numerical data underlie the development of scientific knowledge, including our understanding of the physiology and behavior of animals. In the setting for this question, behavioral observations of a particular species of fish showed that the fish were most likely to be observed in the water at 12–17°C, with fewer fish found at temperatures higher or lower than this range. Students were asked to graph the relationship between water temperature and fish distribution and to summarize the data. They were then asked to identify and describe two specific variables that were not controlled in the original experiment and to discuss two ways that temperature could affect the physiology of the fish in the experiment.

Sample: 1A
Score: 10

In part (a) an ideal graph is constructed, properly labeled, oriented, and scaled, showing a temperature range for each section and a correct bar graph. The response summarizes that the "greatest number of fish was found in Section C, 12°C–17°C" and adds that "[t]he overall distribution was like a bell curve." The response earned the maximum of 4 points in part (a).

In part (b) the response identifies pressure as the variable, earning the point for tank characteristics, and describes the effect it has on fish distribution: "The fish would probably go to the area with the average amount/normal amount of pressure." The second variable identified is solute in the water, earning the point for water quality. A correct description of the effect, "[i]f more solute was present towards the ends of the tank, the fish . . . may not want to be there," earned 1 point.

For part (c) the response clearly provides an indication of the direction of temperature change. "Higher water temperature could make the fish need more energy. . . . [T]he heart rate of the fish could increase, . . . and . . . the fish would take in more O_2 through countercurrent exchange of its gills." The explanation states that both "lead to increased cellular respiration." Thus the response earned 1 point for each effect and 1 point for the explanation, receiving the maximum of 4 points in part (c).

Sample: 1B
Score: 8

In part (a) an ideal graph is constructed, properly labeled, oriented, and scaled, showing a temperature range for each section and a correct bar graph. The response summarizes the data, stating that "[t]he fish tended to locate in the temperature range of 12–17°C," earning the maximum of 4 points in part (a).

In part (b) the response identifies the variable "content of the water was not controlled." The response elaborates on water content, identifying nutrients, toxin, chemical, pollutant, and salt concentration, earning 1 point for identification of the water quality variable and a second point for describing the effect of the variable on fish distribution in the tank: "may have driven fish away from certain sections." A second variable, light, is identified, and the student states correctly that it "may have influenced the section they located to." The response earned the maximum of 4 points in part (b).

In part (c) the response correctly describes cold water as having a higher dissolved oxygen concentration but never relates oxygen content to fish physiology. The discussion of cellular respiration generating heat ("If an organism lives in cold water it will use more ATP and therefore more energy in heating itself") is an incorrect statement for ectotherms and did not earn points.

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2009 SCORING COMMENTARY

Question 1 (continued)

Sample: 1C
Score: 6

In part (a) an ideal graph is constructed and properly labeled, oriented, and scaled, showing a temperature range for each section and a correct bar graph. The response summarizes the data, "most fish prefer Section C, which contains water between 12°C and 17°C," earning the maximum of 4 points in part (a).

For part (b) the response earned 2 points: 1 point was earned for identifying light as a variable. The experiment was on a given species of small, freshwater fish, therefore "species of fish" was not acceptable as an uncontrolled variable. The response earned a description point for the statement, "The presence of varying light in different sections of the tank could influence the fish's taxis and preference."

In part (c) no points were earned because the response discusses fish intention rather than physiological effects.