

Passage I

Green anoles and brown anoles (2 species of reptiles) behave differently when the species are together in a habitat than when the species are in separate habitats. Table 1 lists the anole species present in each of 3 habitats (Habitats X, Y, and Z).

Habitat	Anole species present:
X	green only
Y	green and brown
Z	brown only

Figure 1 shows, for each anole species, the average perching height in a habitat.

Figure 1

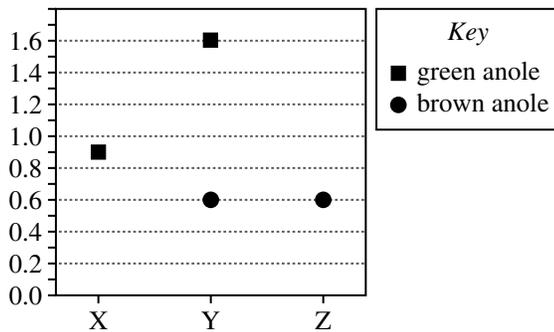


Table 2 lists the number of times each of Behaviors 1–4 was displayed by the anoles in a habitat. Green anoles display Behaviors 1–3 only; brown anoles display Behavior 4 only.

Behavior	Number of times behavior was displayed in Habitat:		
	X	Y	Z
1	4	5	N.A.
2	3	6	N.A.
3	24	13	N.A.
4	N.A.	5	17

Note: N.A. indicates the behavior was not displayed in the habitat.

Table 3 lists, for the anole species in a habitat, the average display time for Behavior 5.

Anole species	Habitat	Average display time for Behavior 5 (s)
Green	X	23.1
Green	Y	23.7
Brown	Y	49.6
Brown	Z	33.1

Figure 1 and Tables 2 and 3 adapted from Jessica R. Edwards and Simon P. Lailvaux, "Display Behavior and Habitat Use in Single and Mixed Populations of *Anolis carolinensis* and *Anolis sagrei* Lizards." ©2012 by Blackwell Verlag GmbH.

Passage II

The coastline of Antarctica consists of many ice shelves (floating 100–1,000 m thick sheets of ice that extend from a landmass). Many of these ice shelves are melting, causing them to calve (break off) large pieces known as icebergs. Four students each explain iceberg calving.

Student 1

Antarctic ice shelves melt due to the warming of the air above the surface of the ice during the summer. When the air temperature increases, the surface ice melts and water pools. The meltwater moves downward into the ice shelf, causing fractures to form. The accumulation of many fractures in the ice over many summers gradually leads to icebergs calving from an ice shelf.

Student 2

Student 1 is correct that an increase in air temperature during the summer leads to surface ice melting and water pooling, causing fractures to form in the ice. However, the action of the meltwater alone is insufficient to produce fractures deep enough to cause calving. When the air temperature lowers at the beginning of winter, falling snow accumulates in the fractures, increasing the pressure on the ice, eventually causing calving. After a large snowfall, calving can occur within a few days.

Student 3

Antarctic ice shelves melt only from below. During the summer, ocean currents circulate water that is just above freezing into and out of the basal cavity (the area underneath an ice shelf), causing the ice within the cavity to melt. For every 0.1°C that the ocean water is above freezing, the water melts a thickness of 10 m of ice from the bottom per year. When the ice shelf thickness has been reduced by at least 50 m, calving occurs.

Student 4

The warmer water circulated by ocean currents melts the ice shelf as described by Student 3. However, calving cannot occur from this process alone. Snow accumulates on the surface of the ice each winter, but each following summer, warm air leads to the melting and compaction of the snow. The compaction lowers the surface of the ice shelf, pushing the ice down into the basal cavity, where it is melted by the ocean water. After several winter-summer cycles, the ice shelf becomes top-heavy due to the snow and the melting from below, and calving occurs.

Passage III

Amphiprion percula, a species of clownfish, are kept in many home aquariums. Two experiments were conducted to determine how diet and stocking density (number of fish per liter of seawater, fish/L) affect the specific growth rate (SGR; percent increase in length per day, percent/day) in *A. percula*.

Experiment 1

Each of 12 identical 15 L tanks received 10 L of seawater having a salinity of 33 parts per thousand (ppt), a temperature of 27°C, and a pH of 8.2. Salinity, temperature, and pH were kept constant over the course of the experiment. *A. percula* of similar lengths were selected, and their lengths were measured, in cm, with a ruler. Then they were equally distributed among the tanks at a stocking density of 1 fish/L. The tanks were then divided equally into 4 groups.

For 4 months, each group was fed a different diet (Diets Q–T). Each group was fed the same mass of food 3 times daily. At the end of 4 months, the length of each fish was measured, in cm, with a ruler, and the SGR of each fish was calculated. The average SGR was then determined for each group (see Table 1).

Diet	Average SGR (percent/day)
Q	0.30
R	0.40
S	0.50
T	0.35

Experiment 2

The procedures for Experiment 1 were repeated except that each group was kept at a different stocking density, 0.5 fish/L, 1 fish/L, 2 fish/L, or 3 fish/L, and all fish were fed Diet T. At the end of 4 months, the average SGR was determined for each group (see Table 2).

Stocking density (fish/L)	Average SGR (percent/day)
0.5	0.50
1	0.35
2	0.25
3	0.20

Tables adapted from João Chambel et al., "Effect of Stocking Density and Different Diets on Growth of Percula Clownfish, *Amphiprion percula* (Lacepede, 1802)." ©2015 by Springer.

Passage IV

Scientists hypothesized that heating tomatoes affects the concentration of nutrients such as vitamin C and lycopene (a red pigment) in the tomatoes. They conducted 2 experiments to test their hypothesis.

Experiment 1

Two kilograms of a particular variety of raw tomatoes were sliced and then blended in a food processor until a homogeneous (uniform) tomato mixture was produced. The mixture was divided into 4 equal samples (Samples 1–4). Each sample was placed in a separate plastic bag, and the bags were sealed. The bag containing Sample 1 was immediately frozen at -40°C . The bags containing Samples 2–4 were each incubated in a water bath at 88°C for a different period of time (see Table 1) and then frozen at -40°C .

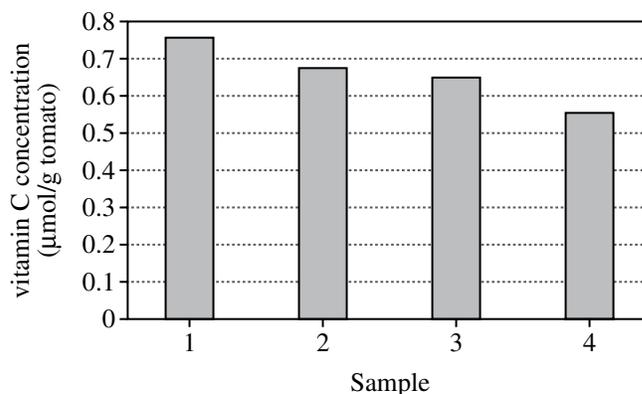
Sample	Incubation time at 88°C (min)
1	0
2	2
3	15
4	30

Then, 2 days later, Steps 1–3 were performed for each sample.

1. The sample was thawed, and then 100 g of the sample was placed in a beaker containing 200 mL of Solvent A.
2. The contents of the beaker were mixed for 5 min at 25°C and then filtered using a paper filter. The filtered liquid was collected.
3. The filtered liquid was analyzed to determine the vitamin C concentration in micromoles per gram of tomato ($\mu\text{mol/g}$ tomato).

The results for each sample are shown in Figure 1.

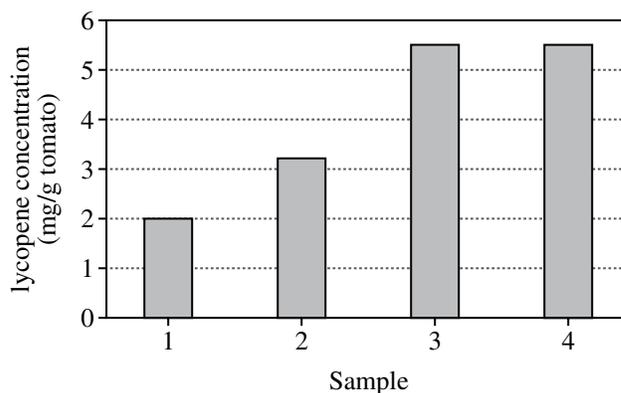
Figure 1



Experiment 2

Experiment 1 was repeated except that in Step 3 the filtered liquid was analyzed to determine the lycopene concentration in milligrams per gram of tomato (mg/g tomato). The results for each sample are shown in Figure 2.

Figure 2



Figures 1 and 2 adapted from Veronica Dewanto et al., "Thermal Processing Enhances the Nutritional Value of Tomatoes by Increasing Total Antioxidant Activity." ©2002 by American Chemical Society.

Passage V

A molten alloy (a mixture of 2 or more metallic elements) can be poured into a cylindrical mold and cooled to form an ingot. Crystals form inside the ingot as it cools. The average crystal length, L , in micrometers (μm), determines how brittle the ingot will be. A method for reducing L using rotating magnetic fields was applied to Alloy Q as it cooled in the molds. Table 1 shows the elemental composition of Alloy Q. Figure 1 shows the effect of the relative magnetic stirring force, F , on L for ingots formed from molten Alloy Q that had an initial temperature of either 280°C or 550°C .

Element	Symbol	Percent by mass in Alloy Q
Aluminum	Al	88.7
Silicon	Si	10.8
Manganese	Mn	0.28
Magnesium	Mg	0.22

Figure 1

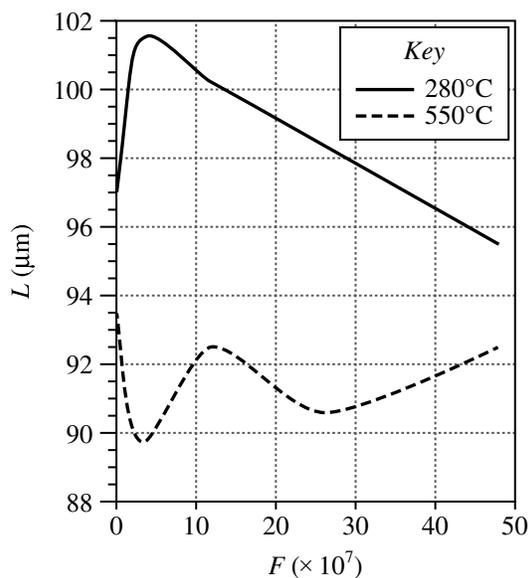


Figure 1 is adapted from S. Denisov, et al., "The Effect of Traveling and Rotating Magnetic Fields on the Structure of Aluminum Alloy During Its Crystallization in a Cylindrical Crucible." ©2014 by Institute of Physics, University of Latvia.

Passage VI

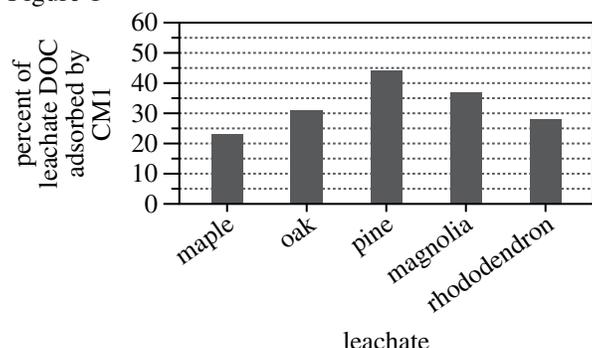
In a lake, water leaches (dissolves out) soluble organic compounds from decaying tree leaves, producing dissolved organic carbon (DOC). DOC is subsequently removed from the water if it is adsorbed by (becomes adhered to the surface of) clay mineral particles that are suspended in the water. Three studies done at a lake examined DOC adsorption by 3 clay minerals—CM1, CM2, and CM3—found in the lake’s sediment.

Green leaves were collected from 5 types of trees around the lake (maple, oak, pine, magnolia, and rhododendron). A 5 L volume of lake water was filtered to remove all solid particles. The following procedures were performed for each type of leaf: A 100 g sample of the leaves was mixed with a 1 L volume of the filtered lake water. The mixture was then placed in the dark for 10 weeks at 4°C while leaching occurred. At 10 weeks, the mixture was filtered to remove all solid particles. The resulting liquid (the leachate) was analyzed for DOC.

Study 1

The following procedures were performed for each leachate: A 100 mL volume of the leachate was mixed with 10 g of CM1. The mixture was stirred continuously for 2 hr, then filtered to remove all solid particles. The resulting liquid (the filtrate) was analyzed for DOC. The percent of the leachate DOC that had been adsorbed by CM1 was calculated (see Figure 1).

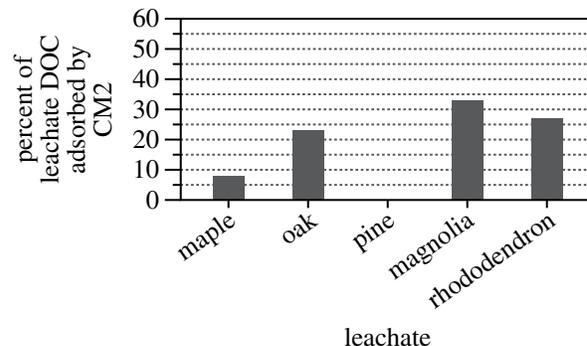
Figure 1



Study 2

Study 1 was repeated, substituting CM2 for CM1 (see Figure 2).

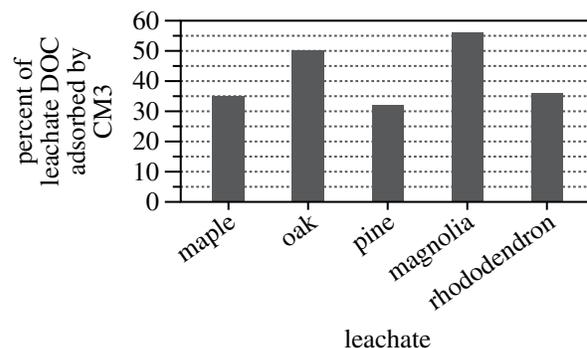
Figure 2



Study 3

Study 1 was repeated, substituting CM3 for CM1 (see Figure 3).

Figure 3



Figures and table adapted from Todd Tietjen, Anssi Vähätalo, and Robert Wetzel, “Effects of Clay Mineral Turbidity on Dissolved Organic Carbon and Bacterial Production.” ©2005 by the Swiss Federal Institute for Environmental Science and Technology.

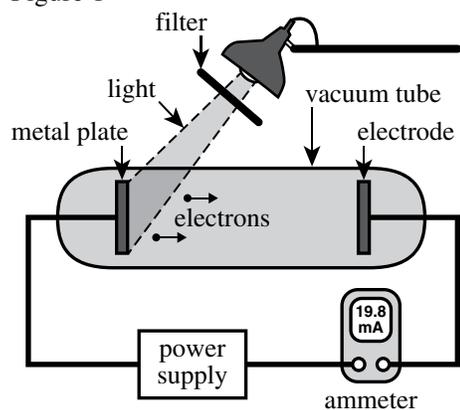
Passage VII

When light shines on a metal plate, electrons can be ejected from the plate. An electron will be ejected if the energy, E , of a photon (particle of light) striking the plate is greater than the minimum energy, M , required for the electron to be removed from the plate. The maximum kinetic energy of the ejected electron, K , is the difference between E and M as shown in the equation:

$$K = E - M$$

Students conducted 2 experiments to examine how differences in the light striking a metal plate affect K . The setup included a light source, a removable filter, a circuit with an ammeter to measure current, a power supply that could be adjusted to measure K , and a vacuum tube containing a metal plate and an electrode (see Figure 1).

Figure 1



Experiment 1

A filter was placed between the metal plate and the light source, and the K of the ejected electrons was measured. This procedure was repeated with each of 4 additional filters. Each filter transmitted light of only one frequency. Table 1 lists the following:

- color of light transmitted by the filter
- frequency of light in hertz, Hz
- E in electron volts, eV
- K in electron volts

Color	Frequency ($\times 10^{14}$ Hz)	E (eV)	K (eV)
Red	4.4	1.81	N.A.*
Yellow	5.2	2.14	N.A.*
Green	5.6	2.31	0.11
Blue	6.3	2.60	0.40
Violet	7.5	3.10	0.90

*N.A.—Not available; no electrons were ejected.

Experiment 2

With the same setup as in Experiment 1 except without a filter, the current, in milliamperes (mA), and K were measured as the intensity of the light was varied. Table 2 shows the current and K for 4 different relative light intensities, each given as a percent of maximum intensity.

Relative intensity	Current (mA)	K (eV)
100%	40.0	0.90
50%	19.8	0.90
25%	9.8	0.90
12.5%	4.8	0.90