In fiddler crabs, the timing is important for feeding. If the crab emerges too early from its burrow, the mud flats it feeds on will still be under water. If it emerges too late, there may not be enough time to feed before the next high tide. In other organisms, longer environmental cycles, such as seasonal changes (e.g. day length and temperature), are important cues for triggering migration and breeding.

37. NCEA Style Question: Biological Clocks in Plants (page 50)

1. (a) Long day flowering (short nights).
   (b) Phytochrome is found in two forms, inactive P*r* (phytochrome red) and active P*fr* (phytochrome far red). P*r* is converted to P*fr* when exposed to light. P*fr* is converted to P*r* during darkness. The relative levels of the P*r* and P*fr* give the plant a way to measure day length. Carnations are long day plants, so they require a sufficiently short length of night and long length of day to produce enough P*fr* to trigger flowering.
2. The opening of flowers during the day and closing during the night enhances the tulip's reproductive success because the flower is only open and available to be pollinated when its day-active pollinators (bees) are present. Closing the flowers at night prevents non-pollinating insects plundering the flower's resources. Night closure also stops the pollen become dew-wet, which reduces its ability to be spread by pollinators during the day and it reduces the chance that anthers and stigmas will be damaged.
3. Environmental cues for dormancy are those that signal a decline in growth conditions, e.g. shorter days and colder temperatures (especially soil temperatures). Cues for growth are those signalling improving growth conditions, such as warming temperatures and increasing day length. The plant often needs multiple cues to begin or arrest growth and, in many plants, growth will only resume once a sustained period of cold (signifying winter) has passed. This is called vernalisation and ensures the plant is not 'tricked' into resuming growth by a brief warm spell in autumn. These responses are adaptive because the plant can withdraw resources (e.g. by losing leaves), shut down, and save energy through the non-growing season and then maximise growth when conditions are favourable. Growth is timed to coincide with the best conditions for survival, growth, and reproduction.

38. KEY TERMS AND IDEAS: Orientation in Time (page 51)

1. biological clock (I), biological rhythm (K), circadian rhythm (J), endogenous (L), entrainment (A), exogenous (F), free-running period (G), long-day plant (E), photoperiodism (C), phytochrome (D), short-day plant (B), zeitgeber (H).
2. (a) Whelk: circatidal
   (b) Human: circadian
   (c) Mouse: circadian
3. (a) A = short day
   (b) B = Long day
   (c) C = Day neutral
4. (a) Longer
   (b) The activity pattern drifts to the right.

39. Species Interactions (page 52)

1. (a) Mutualism: Domesticated animals (e.g. dogs and cats in western culture, work horses) and plants not grown for consumption.
   (b) Exploitation: Using plants and animals for food source, skins/pelts for clothing, timber and other plant products for shelter and building materials.
   (c) Competition: Invertebrate pests and some fungi feeding on our crops (e.g. insects such as aphids, locusts, caterpillars; slugs, snails, mildew, rusts).
2. (a) The acacia produces a toxic alkaloid compound.
   (b) The toxin may be unpalatable to the giraffe and cause it to stop eating the acacia, moving to another tree and thus preventing over-browsing.
3. (a) Mutualism.
   (b) Both parties benefit by being protected from their predators.
4. (a) Mutualism.
   (b) Large herbivore benefits by having parasites removed, and are warned of approaching predators. Bird benefits by obtaining food for relatively low effort.
5. (a) Parasitism.
   (b) *Dactylanthus* benefits by obtaining all of its required nutrition from the host tree. The host tree is harmed by the withdrawal of sugars, minerals, and water.
   (c) Mutualism.
   (d) Short-tailed bat benefits by obtaining a source of food (nectar). The *Dactylanthus* benefits by having its flowers pollinated.
6. (a) The interaction between the scale insect and beech tree is commensal. The scale insect benefits by obtaining food (plant phloem sap) food and the beech tree is unharmed.
   (b) The interaction between the kaka and the wasp is competitive. Both species are harmed because each has less honeydew resource available to it.

40. Mutualism Involving Animals (page 54)

1. (a) A mutualism is a symbiotic relationship between two species in which both species benefit.
   (b) In an obligate (obligatory) mutualism, neither species can survive without the other. In facultative mutualism, both species benefit from the interaction but can survive without it.
2. (a) Obligate
   (b) The worms rely on the bacteria for their nutrition and the bacteria could not survive outside the internal environment of the worm. They require each other for survival.
3. (a) Resources, e.g. food
   (b) Services, e.g. protection
   (c) Habitat, i.e. a place to live
4. When one looks more closely at apparent service-service mutualisms, there is a resource component somewhere even if it is indirect. In the clownfish-anemone mutualism, the anemone does not directly obtain a resource from the clownfish but the anemone's symbiotic algae, which are held in the anemone's tissues, do, because they benefit from the nitrogen excreted by the clownfish. The anemone depends on its photosynthetic algal symbionts so if they gain a resource from the clownfish, the anemone benefits from that resource.

41. Mutualism Involving Plants (page 56)

1. (a) Plant benefits by gaining nitrogen (as amino acids) from the metabolic activities of the *Rhizobium*.
   (b) The bacterium receives a carbohydrate supply from the plant and a low-oxygen environment in which to fix nitrogen.
2. Legumes would have a clear advantage over non-N-fixing plants when growing in low nitrogen soils. They can fix their own nitrogen as a result of their mutualistic relationship with nitrogen-fixing bacteria so their growth is not hampered by lack of available soil nitrogen.
3. In the vascular plant-mycorrhizal fungus relationship, the fungus colonises the roots of the plant (inside or outside the cells depending on the species) and forms an association called the mycorrhiza. The fungal association greatly increases the surface area over which the plant roots can access water and minerals and also provides phosphate ions to the plant, which are difficult for the plant to access. The fungus gains a supply of carbohydrate provided by the plant (via photosynthesis elsewhere in the plant).
4. (a) Adding a mycorrhizal inoculum improves the nutrition for the young plant, enabling it to access water and mineral ions more readily.
   (b) Addition of phosphorus fertiliser might impair the development of the mycorrhizae. The plant would be receiving the phosphorus it needed artificially so the amount of root colonisation by the mycorrhizal fungi would be diminished. **Teacher's note:** Plant roots can control the

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