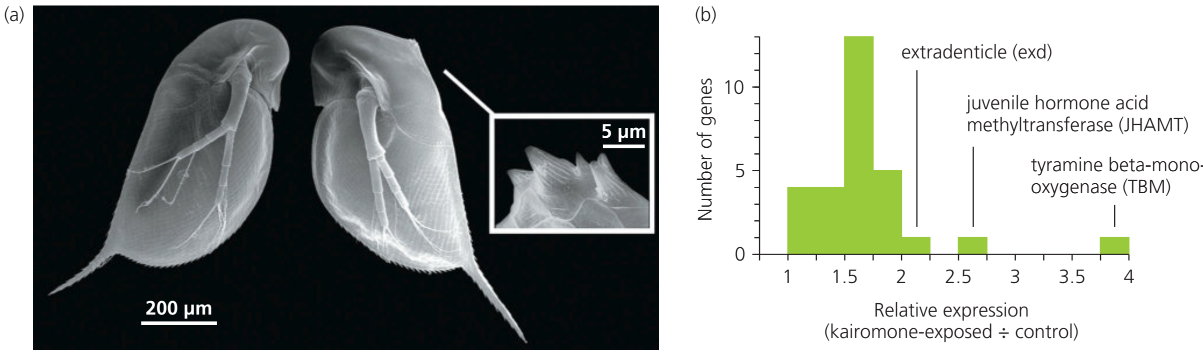

Figure 5.8 Inducible defenses in *Daphnia* (a) Juveniles that smell phantom midge larvae grow neck teeth and other defenses. Photo by Christian Laforsch. (b) This involves boosting production of many proteins. From data in Miyakawa et al. (2010).

The graph in Figure 5.8b shows the expression of 29 candidate genes in kairomone-exposed *D. pulex* relative to their expression in unexposed individuals. In every case, the exposed water fleas made more messenger RNA and thus presumably more protein. The proteins with the largest increase in expression upon exposure to kairomone were extradenticle (exd), juvenile hormone acid methyltransferase (JHAMT), and tyramine beta-monooxygenase (TBM). Exd acts during development to influence the identity of appendages in arthropods. JHAMT is an enzyme required for the synthesis of juvenile hormone, a major regulator of arthropod development. TBM is an enzyme that catalyzes the synthesis of neurotransmitters, chemicals used by nerve cells to send messages to each other.

Many details remain to be discovered, but Miyakawa's results show that the mechanism by which *D. pulex* changes its phenotype when it smells phantom midges involves changes in the production of a variety of proteins.

Environmental Variation and Evolution

Many other organisms alter the identity or quantity of the proteins they make in response to changes in the environment, thereby altering their phenotype. Human athletes living at low altitude, but training at simulated high altitude, produce more vascular endothelial growth factor (VEGF) than athletes living and training at low altitude (Hoppeler and Vogt 2001). The extra VEGF stimulates the growth of capillaries in the muscles. Environmental variation is ubiquitous.

The non-genetic influences on protein expression, and thus phenotype, even include chance. The *Escherichia coli* bacteria in Figure 5.9 are genetically identical. Michael Elowitz and colleagues (2002) inserted into the DNA of their common ancestor two copies of the gene for green fluorescent protein (GFP). The two copies encode distinct variants of GFP that emit different colors of light when they fluoresce. They are controlled by identical promoters—the switches that turn genes on or off. A bacterium making equal amounts of both versions of GFP would be yellow, a cell making more of one version would be green, and a cell making more of the other version would be orange. The explanation for the diversity of colors in the photo is random variation in the interactions between the promoters and the regulatory proteins that activate and deactivate them.

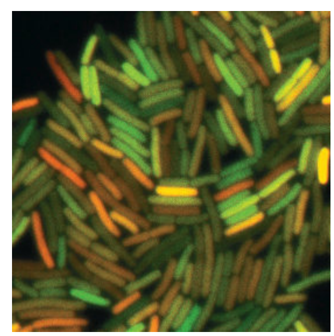

Figure 5.9 Random variation in protein production in genetically identical bacteria These cells are different colors because they are making different amounts of two fluorescent proteins. From Elowitz et al. (2002).

Despite its ubiquity, environmental variation supplies no raw material for evolution. This is because environmentally induced changes in phenotype are not transmitted to future generations. Whether a water flea born by clonal reproduction has neckteeth is determined not by the genes she inherits, but by the