crease turgidity, and movement of leaf, stem, or flower will occur. These osmotic engines are driven principally by ionic pumps across the cell membrane that usually transport K^+ or Ca^{2+} (or both), and in some cases, such as the leaf folding in the sensitive mimosa plant, an action potential is involved.

Examples of movement by differential growth on opposite sides of a plant organ include phototropism, gravitropism, the opening and closing of some flowers, and the coiling of stems and tendrils. In the case of the stilt palm (*Iriartea gigantea*) (*2*), the trunk is held aloft on supporting brace roots, and movement of the tree toward a light-gap can occur by differential growth of the brace roots on the lighted side and abandonment of such roots on the shaded side (see the figure).

The stilt palm "walks" toward a lighted area by differential growth of its stilt-roots.

Another group of movements involves localized cell degradation to produce a throwing action. Such movements include the explosive projection of pollen, spores, or seeds, which occur when tension is released in a cluster of cell walls that have degraded, resulting in a catapult-like action.

Movement can also occur by negative growth. Below-ground bulbs or stems can move down to a desirable depth by means of contractile roots. These roots have been found in more than 90% of the plants studied (*3*). They become thickened and develop extensive wrinkles as the root contracts. The irreversible contraction effect is achieved by a combination of thickening and shortening of individual cells along the root axis, combined with programmed cell death of layers of cells in the root cortex.

And finally, there is a large array of thigmo movements, movements stimulated by touch (mechanical perturbation) (*4*). The coiling of tendrils around an object involves two component movements (*5*): an initial movement (involving a contractile adenosine triphosphatase) resulting in hydraulic changes that lead to rapid coiling, followed by differential growth on opposing sides of the tendril, which allows the tendril to continue coiling around the support. There is evidence that such thigmo coiling movements involve the classic stimulus-response syndrome, including the opening of calcium channels and a probable sequence of phosphorylations.

Another example of thigmo movement is the motor pulvinus of the sensitive mimosa plant (*Mimosa pudica*) (*6*). When a leaf is touched, the signal is transmitted to the base of the leaf by a lever action. An action potential is generated. Special structures called tannin vacuoles in the motor cells at the base of the leaf, analogous to the sarcoplasmic reticulum in muscle sarcomeres, release Ca^{2+} into the cytoplasm. This causes actomyosin microfilaments to contract, opening putative potassium channels in the plasma membrane. The K^+ effluxes, drawing water after it by the osmotic engine mechanism. The turgor of these cells thus decreases, causing the leaf to bend downward as a result of the turgor differential between the upper and lower sides. Action potentials then travel up and down the stem, activating motor cells at the bases of other leaves.

In conclusion, the various movements performed by plants are special in that they are primarily based not on contractile proteins, but on physical and cellular alterations. The wide array of repositioning movements and adaptations for reproductive effectiveness has evolved principally as components of photosynthetic and reproductive strategies.

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In the "Movement" special issue, the News article "In nature, animals that stop and start with the race" by Elizabeth Pennisi (7 Apr., p. 83) misses one of the neatest examples. Once fish discovered the energetic advantages of "burst-and-coast" swimming (*1*), they also discovered the advantage of coasting above the surface of the water, to minimize drag and increase the distance covered by the coasting phase—hence, "flying fish." This was also discovered (independently) by flying squids, which inherently have a burst-and-coast mode of locomotion.

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I was writing up notes from Gary Taubes' News article, "Biologists and engineers create a new generation of robots that imitate life" (7 Apr., p. 80). Taking the notes was a bit troublesome because of the lack of a convenient term to categorize robots based on cockroaches, spiders, snakes, fish, and so on. The descriptive phrase "zoologically inspired robots" worked, but was a bit clumsy. The answer was then obvious—"zoobots."

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A Chicken in Every Pot, Thanks to Sulfonamide Drugs

In his Review article "Drug discovery: A historical perspective" (special issue on Drug Discovery, 17 Mar., p. 1960), Jürgen Drews focuses particular attention on the sulfonamide class of drugs and its impact on treating human disease. The historical importance of sulfaquinoxaline, first introduced by Merck under the direction of Max Tishler in 1948 (*1*), may not be widely appreciated, however.

Herbert Hoover's political sound bite in the 1928 presidential election, which equated "a chicken in every pot" with "two cars in every garage," may best reflect how luxurious a commodity chicken once was. Sulfaquinoxaline enabled a revolution in the practice of poultry production, by allowing birds to be raised economically in broiler houses at high density (*2*) through the control of infection by the parasite *Eimeria* and the subsequent economically devastating effects of the coccidiosis caused by it (*3*). In turn, these developments led to a dramatic fivefold decline in the price of poultry that has continued unabated to this day (see the figure).

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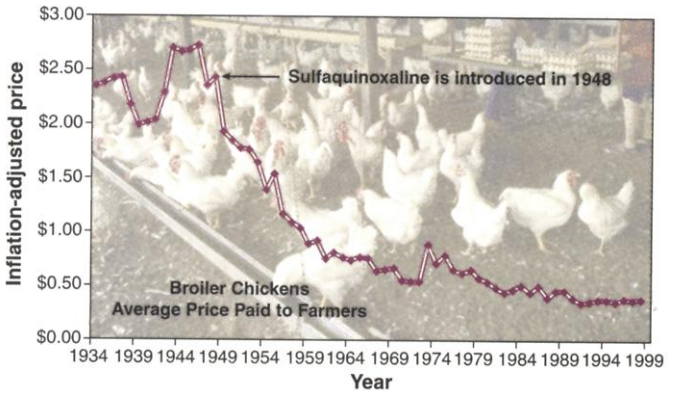
Today, the development of resistance has greatly reduced the role of the sul-



Average price received by farmers for broiler chickens (in dollars per live-weight pound) from 1934 to 1998. The data are adjusted for inflation and show prices in 1998 dollars (*4*, *5*). The arrow indicates sulfaquinoxaline's introduction in 1948 as a coccidiostat.

fonamides in the prevention of coccidiosis; control of *Eimeria* infection is now largely dependent on monensin and related ionophores. However, a sea change in agricultural practice was precipitated by the introduction of sulfaquinoxaline and its analogs. Therefore, one might wonder if the sulfonamide class has benefited humankind more by the provision of plentiful and inexpensive dietary protein than by the cure of specific illnesses directly.

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5. Thanks to D. Kennerson and K. Bruce of NASS for their assistance in obtaining the historical price data, and to H. Geer and R. Nolan for their advice on correcting these data for inflation.

Response

Navia raises an interesting point, quite apart from the medical uses of sulfonamide drugs. As to whether this class of drugs has perhaps been more beneficial in the provision of plentiful and affordable dietary protein than in the treatment of human diseases, I don't know the answer. As I pointed out in my Review article, however, sulfonamides were not only important as antibacterial drugs in their own right but also as the starting point for many structurally related but functionally diverse classes of drugs: diuretics, antidiabetic drugs, and antihypertensives. Sulfonamides continue to be valuable drugs in the treatment of microbial infections, although the emergence of resistance has reduced their usefulness. It may well be that the use of sulfonamides in the prevention of coccidiosis has accelerated the generation of resistance in medically relevant bacterial strains.

The history of sulfonamides is one of many examples that argue in favor of a strict separation of antibiotics for medical uses on the one hand, and for uses in animal nutrition or the mass treatment of livestock on the other. The latter uses often entail broad and uncontrolled exposure of the environment to antibiotics with consequences that are difficult to manage.

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CORRECTIONS AND CLARIFICATIONS

News of the Week: "In contrast to Dolly, cloning resets telomere clock in cattle" by Gretchen Vogel (28 Apr., p. 586). The credit for the upper right photo should have read, "Peter Lansdorp, Terry Fox Laboratory, Vancouver."

Reports: "Rapid progression to AIDS in HIV$^+$ individuals with a structural variant of the chemokine receptor CX_3CR1" by S. Faure *et al.* (24 Mar., p. 2274). The values for the variables RR (relative risk) and *P* (probability) listed in Fig. 1B were incorrect. They should have been RR = 2.44 and *P* = 0.016, as stated in the text. And in Fig. 2, the black circles are data for the haplotype I249 M280, not I249 T280.

Random Samples: "Guinea worm banished from India" (17 Mar., p. 1917). The organism that nurtures Guinea worm eggs, *Cyclops*, is a crustacean (subclass Copepoda), not an aquatic insect.

Reports: "A piston model for transmembrane signaling of the aspartate receptor" by K. M. Ottemann *et al.* (10 Sept. 1999, p. 1751). In the legend for Fig. 4, the descriptions of the thick solid line and dashed line were reversed. The second sentence should have read, "Spectra in the presence (dashed line) and absence (thick solid line) of aspartate when the aspartate receptor is mixed with equimolar amounts of CheA and CheW."

SOURCE: BACKGROUND IMAGE, USDA