general goal of developing tolerance and resistance in crop plants.

The impending completion of several other bacterial and fungal plant-pathogen sequences, and the initiation of genome sequencing of *Rhizobium meliloti* (the nitrogen-fixing symbiont of legumes), adds further to the exciting possibilities in agricultural genomics. Moreover, the near-completion of the sequence of the favoured model plant *Arabidopsis* and the start of rice genome sequencing, along with farm-animal genome projects that draw strongly on mouse and human genome sequencing, are establishing a solid foundation for research. This is research with eminently practical ends: tackling current or imminent problems in food production, human nutrition and environmental degradation. For example, disease-resistant crops, and plants better adapted to grow in extreme conditions, are nearly ready for large-scale use.

Finally, to return to South America, this first implementation of large-scale sequencing in Brazil is only a harbinger of things to come. The same consortium is now sequencing another plant pathogen, *Xanthomonas citri*. This is the cause of citrus canker, a worldwide disease that can severely damage citrus crops unless strict quarantine zones are enforced. The citrus industry in Florida is currently under threat from *X. citri* spread by a tornado in 1996 (ref. 5). The successful sequencing of *X. fastidiosa* also shows that genome projects are a highly effective tool for science policy. Such projects provide a strong direction to and framework for biological investigations; they direct disparate areas of biology towards common themes; and they result in the distribution of the latest technologies to many laboratories, allowing scientific talent to flourish more widely. ■

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Developmental biology

Bringing two hearts together

Wolfgang Driever

Vertebrate development is a complicated business. Many structures, such as limbs, form as left–right pairs. Of other organs — such as those of the digestive system, which form by budding off the central gut tube — there is only one. And a few organs, most notably the heart, have a much more complicated genesis. The heart's origins can be traced back to the early embryo, specifically to two patches of tissue (primordia) located on either side of the vertical axis that marks the embyro's centre. During development, the heart primordia move towards this so-called dorsal midline and merge, forming the heart (Fig. 1, overleaf). How the primordia find each other has been one of life's mysteries. On page 192 of this issue[1], Kupperman and colleagues shed first light on this process, by characterizing a gene — called *miles apart* — that is essential for guiding the migration of the primordia.

The hearts of higher vertebrates have left and right chambers, but this does not mean that the heart is initially organized bilaterally. After the heart primordia merge, a single tube forms (Fig. 1c), which then undergoes a complex looping process to generate the chambers[2]. Because of this, the dual origin of the heart was not always clear. The first evidence came from observations of developmental defects that cause two heart tubes to form, a condition called cardia bifida. Found in a variety of organisms, from fish to humans, this disorder generally leads to death of the embryo because proper blood circulation cannot be established.

Zebrafish (*Danio rerio*) have proved a particularly useful genetic model for studying cardia bifida: their embryos are transparent, so the two heart tubes can be easily observed long before the embryos die of circulatory defects[3]. Systematic mutation of zebrafish genes and screening of the mutant animals has resulted in the identification of eight genes that, when mutated, cause cardia bifida[3]. One of these genes is *miles apart*.

In zebrafish with mutations in *miles apart*[3], mesodermal tissue (from which muscle, blood and various other tissues form) forms the heart primordia in the normal way, but the primordia do not converge at the midline. Heart differentiation does not depend on this convergence — two beating heart tubes form, one on the left and one on the right of the embryo. Kupperman *et al.*[1] now show that *miles apart* encodes a receptor that binds lysosphingolipids. Members of one family of lysosphingolipid receptors transmit signals into the cells on which they are found via guanine-nucleotide-binding proteins, and the Miles apart protein belongs to this family.

Kupperman *et al.* also show that the sphingolipid sphingosine-1-phosphate is probably the ligand that binds to the Miles apart protein to guide migration of the heart primordia. This lipid can be generated by cells from scratch or from sphingomyelin, a lipid that is stored in cell membranes[4]. Interestingly, the authors find that the Miles apart protein does not need to be expressed on the migrating heart precursor cells themselves:

Atmospheric physics

Polar lights in the Caribbean

RAYMOND GEHMAN/CORBIS

Auroras are spectacular displays of multicoloured light (right), rarely seen at low latitudes. But users of the world's largest radio telescope in Arecibo, Puerto Rico, can now create their own light shows. As L. M. Kagan *et al.* describe in *Physical Review Letters* (**85**, 218–221; 2000), shining powerful radio waves into the night sky produces a green fluorescent glow. This provides us with the first ever pictures of clouds of metal ions in the lower ionosphere — a phenomenon that strongly disrupts radio and satellite communications.

The ionosphere is an ion-rich region of the Earth's atmosphere that reflects radio waves over long distances. The density of ions increases with altitude in response to the ionizing effects of the Sun's radiation. A faint airglow — caused by emission of green and red light from ionized oxygen and nitrogen — can be seen at higher altitudes by sensitive detectors. But the lower ionosphere, such as the E layer, doesn't glow.

Metal ions in the E layer, torn from passing meteorites, can build up into patches of stronger ionization that interfere with satellite signals. Intense radio waves from Arecibo were used to excite these metal ions, which in turn heat up free electrons. These energetic electrons collide with oxygen ions making them glow, as in a natural aurora. Who needs northern lights when you can have aurora equatoralis? **Sarah Tomlin**

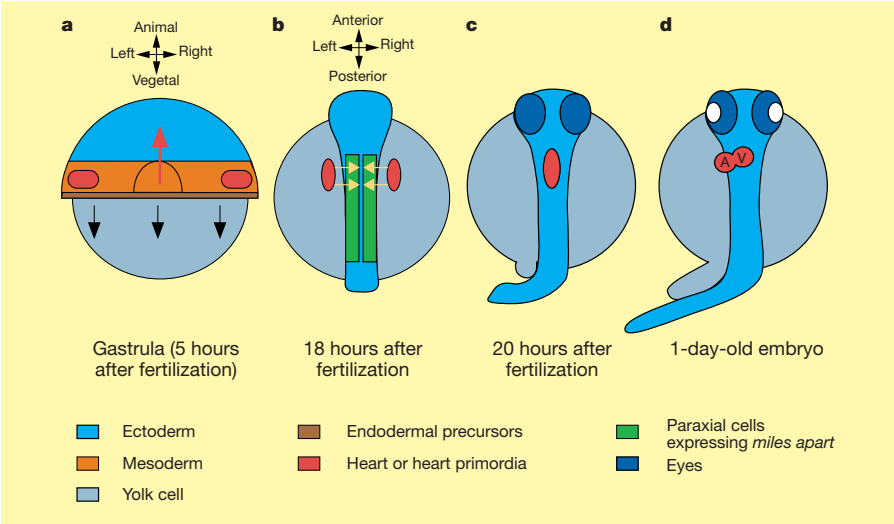

Figure 1 **Making two hearts beat as one. We are looking down onto the dorsal side of the zebrafish embryo at various developmental stages.** a, **The onset of gastrulation, an early stage in development, 5 hours after fertilization of the egg. The forming dorsal axis will extend (red arrow) towards the 'animal pole' (see directional indicator), while other cells of the embryo will cover the yolk cell (black arrows). The heart precursor cells (heart primordia) form bilaterally.** b, **As shown by Kupperman *et al.*[1], stripes of cells (green) next to the midline that express *miles apart* messenger RNA are likely to be required for proper migration (yellow arrows) of the heart primordia and joining of the two bilateral groups of heart precursor cells.** c, **By 20 hours after fertilization, a single medial heart tube has formed.** d, **The heart starts to beat and circulation begins at 24 hours after fertilization; by 36 hours, looping movements have positioned the heart's atrium (A) to the left of the more centrally located ventricle (V).**

such cells with mutations in *miles apart* migrate normally when transplanted into normal (non-mutant) embryos. Rather, *miles apart* messenger RNA is found in so-called paraxial cells, located either side of the midline (Fig. 1b). So the sphingosine-1-phosphate signal may tell these cells to direct cardiac precursor cells to the midline.

This is the first time that sphingosine-1-phosphate has been shown to have a role in cell migration during embryogenesis. It was already known to have a variety of effects on cell growth and survival, and to participate in cellular functions that depend on cytoskeletal filaments, including enhancing adhesion, initiating contraction and inducing protein secretion[5]. So several different mechanisms can be envisaged by which sphingosine-1-phosphate encourages the migration of cardiac precursor cells. For example, it could cause changes in the cell surfaces on which cardiac precursors migrate, or alter cell–cell adhesion properties. Or perhaps it encourages the release of extracellular matrix components or of a diffusible signal, which could act as attractants for cardiac precursor cells.

The Miles apart protein seems to be essential for the control of only a few cell-migration events during embryonic development. This is perhaps not surprising. Cell migration in the vertebrate embryo more closely resembles the tangled network of highways around Los Angeles than the tranquil lanes of a rural area. Whole sheets of cells can move, for example during gastrulation, an early stage in development. And individual cells — such as neural-crest cells, limb-muscle precursors and many others — migrate. If we look just at the zebrafish trunk region either side of the midline, we can see heavy traffic in all directions. Heart precursors migrate towards the midline; neural-crest cells migrate away from the dorsal neural tube; germline cells move towards the posterior gonadal ridge[5]; and muscle precursors migrate from next to the midline towards the sides of the embryo to form slow muscle cells[6].

Many distinct ligands are required to direct this flow of cellular traffic. Until now, only peptides and proteins — diffusing through the embryo or bound to cell surfaces — had been suggested to control cell migration in vertebrate embryos (see, for example, ref. 7). Lipid metabolites had been found to be involved only in the control of germ-cell migration in *Drosophila*[8,9]. Sphingosine-1-phosphate is the first lipid metabolite known to be involved in controlling cell movement in a vertebrate embryo. The added complexity that this result is sure to bring to research on heart development only goes to prove that affairs of the heart have never been simple. ■

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Daedalus

Jet-age cleaning

Cleaning dirty surfaces is a tedious, labour-intensive task. Dirt often adheres to a surface so strongly that detergents cannot simply float it away. It has to be dislodged by mechanical scrubbing. One neat way out is the ultrasonic cleaning bath, whose detergent solution is agitated by a source of high-frequency sound. Daedalus is now extending the idea.

DREADCO engineers are fitting a standard high-pressure water-hose with a powerful piezoelectric ultrasonic generator. It launches a beam of ultrasound along the emerging water jet. Ultrasound is transmitted very efficiently by water; it can travel many tens of metres with little loss. Furthermore, the strong refractive mismatch between air and water will prevent the sound escaping from the jet and spreading wastefully out into the air. Nearly all the ultrasonic energy will hit the target, and will dislodge the dirt with great vigour. The water will then wash it away. Even if the jet breaks up into droplets during its journey, its scouring action will not be lost, for water droplets resonate strongly at ultrasonic frequencies (which is why bats don't like fog). The rapidly vibrating droplets will still deliver their ultrasonic energy to the target surface.

The DREADCO 'Ultrajet' cleaning hose will abolish many tedious jobs, notably external window-cleaning and the renovation of grimy public buildings and monuments. Scaffolding and suspended cradles, buckets and brushes and chamois leather, will no longer be needed; a simple high-velocity water-jet aimed from the ground will do the job. A thin jet of modest flow rate should be quite adequate, especially if a suitable detergent is dissolved in the water. Urban grime, peeling paint, pigeon-droppings and maybe even graffiti will be speedily and efficiently stripped from our urban eyesores. On a smaller scale, bus and train cleaning and the humble car-wash itself will be splendidly speeded and transformed.

Domestic applications are also possible. Sadly, the Ultrajet will not replace the vacuum-cleaner or the duster for internal household maintenance. But it could powerfully upgrade the action of the washing machine and the bathroom shower. An ultrasonically assisted shower would clean and exfoliate the user with a bracing ultrasonic massage. And DREADCO's Ultrajet toothbrush will vigorously dislodge dental grime and plaque, and give an unprecedented tingling-fresh sensation into the bargain. David Jones