Briefing:

Cell Lineages Traced in Zebrafish Embryos

It was a major achievement when, a couple of years ago, all the divisions, migrations, and deaths of the 1000 or so body cells in the developing roundworm, *Caenorhabditis elegans*, were finally charted. The information provided a unique insight into the genetic and environmental influences that shape the assembly of the developing organism. By contrast, cell lineage maps of comparable completeness may never be achieved for vertebrates, partly because of their greater size and complexity, but investigators have nonetheless made a start, as reported on page 365 of this issue of *Science*.

Charles Kimmel and Rachel Warga, of the University of Oregon in Eugene, followed the progress of cells in zebrafish embryos during gastrulation, the stage of development when the three germ layers that give rise to the various tissues of the body are produced. This marks the first time that cell lineages have been traced in living vertebrate embryos at a time in their development that may be critical for determining cell fates.

For the zebrafish studies Kimmel and Warga used a method originally devised by David Weisblat and his colleagues at the University of California at Berkeley. They injected individual embryonic cells with a nontoxic, fluorescent dye that is partitioned during subsequent divisions to the daughter cells, the behavior of which can then be observed directly.

Kimmel and Warga found that before gastrulation, up to the time that the zebrafish embryo contains about 2000 cells, the cells are apparently not committed to a particular fate but have the potential of developing into any of several tissue types. After gastrulation the progeny of individual cells usually end up in just a single tissue type. This is consistent with traditional embryological studies.

Zebrafish development differs from that of *C. elegans* in a number of ways. For instance, the fates of cells in the roundworm appear to be largely determined by their lineages. From the very earliest divisions, one cell can be distinguished from another in terms of what each will ultimately become. But for the zebrafish, the position at which a cell finds itself during gastrulation may be a more important determinant of fate than lineage. In this regard, zebrafish development may more closely resemble that of the fruit fly.

In the earliest stages of the fruit fly embryo, the nuclei undergo several rounds of division without becoming encased in membranes to form individual cells. Then the nuclei form a single layer around the embryo and acquire cellular membranes. Before this happens, each nucleus still retains its full potential to develop into any type of cell. Afterwards, they become committed to forming specific segments of the fruit fly body. Nevertheless, the comparison cannot be taken too far. Kimmel and his colleagues have not detected the strict compartmentation of cells that is seen in the segmented fruit fly embryo.

The ability to monitor individual cells in the developing zebrafish embryo should make it possible to study the factors that influence cell commitment in this vertebrate. As has been done with *C. elegans*, for example, cells or groups of cells can be destroyed to see how that affects subsequent developmental events. ■ JEAN L. MARX

Bell Labs Transistor Sets a Speed Record

How fast can a transistor be? Three researchers (Shin-Shem Pei, Nitin Shah, and Charles Tu) from AT&T Bell Laboratories have the most recent answer: 5.8 picoseconds, substantially below the previous record of 8.5 picoseconds that was set last summer at Honeywell, Inc. For a key step in the fabrication of the device, the investigators collaborated with Richard Tiberio of Cornell University's National Research and Resource Facility for Submicron Structures.

Although the speed was measured in a simple circuit called a ring oscillator, the transistors are not simply laboratory curiosities. "At Bell Labs the main emphasis is on integrated circuits," says Shah. Last November at the Gallium Arsenide Integrated Circuits Conference, the leader of the group, Pei, reported the fabrication of a medium-scale digital logic integrated circuit called a 4×4 bit parallel multiplier, which contained over 300 of an earlier and somewhat slower version of the "selectively-doped heterostructure transistor " that now holds the speed mark.* Work is now under way on chips of similar complexity with the faster device.

In itself, the selectively-doped heterostructure transistor is not a new idea. The basic idea was invented at Bell Labs in 1978, while the earliest transistors of this type were made in Japan under the name high electron mobility transistor and in France, where it was called the two-dimensional electron gas field-effect transistor. The Bell Labs team has just done a particularly good job of designing a specific device structure and in executing its fabrication.

The first requirement for a fast transistor is that the electrons cross the active region of the device as quickly as possible. But lattice vibrations and ionized impurities scatter electrons and thereby reduce their average velocity, as measured by a parameter called the electron mobility. Lattice vibrations can be reduced by operating at low temperature, but the impurities (donors) are the source of the electrons, so simply purifying the semiconductor is no solution to reducing the transit time.

What does work is to use two semiconductors (the heterostructure), one of which is relatively pure (undoped) and one of which is loaded with donor impurities (*n*-type), the selective doping. The most common choice of materials is gallium arsenide for the undoped and the related ternary compound aluminum gallium arsenide for the *n*-type semiconductor. The electrons prefer to be in the gallium arsenide because their energy is lower there, resulting in the transfer of electrons from the aluminum gallium arsenide to a thin, for all practical purposes two-dimensional layer in the gallium arsenide just across the interface between the two materials. Because there are no ionized impurities here, the electron mobility is increased substantially.

Plainly, the quality of the interface is of utmost importance; it must be atomically flat and free of defects. The Bell Labs group used the technique of molecular beam epitaxy to build its transistor. The device structure comprises a semi-insulating gallium arsenide substrate on which are grown in succession, an undoped gallium arsenide layer, a 20- to 40-angstrom thick undoped aluminum gallium arsenide spacer layer, a *n*-type aluminum gallium arsenide layer, and an *n*-type gallium arsenide "capping" layer. The spacer minimizes any interactions between the silicon donors in the material above and the electrons below.

To further enhance the speed, the active region (gate length) of the transistor should be as short as possible. In fact, transistors with gate lengths ranging from 1 to 0.35 micrometer were fabricated to test the effect on device speed. Electron beam lithography equipment at Cornell's submicron facility was used for this purpose. As expected, the fastest transistor had the shortest gate length. The switching time of 5.8 picoseconds was measured at 77 K. At 300 K, where scattering from lattice vibrations is greater, the speed decreased to 10.2 picoseconds. ■ ARTHUR L. ROBINSON

*Institute of Electrical and Electronics Engineers, GaAs IC Conference, Monterey, California, 12–14 November 1985.