Window on the Womb

Ultrasound imaging allows physicians to observe fetal behavior

By JULIE ANN MILLER

A pregnant woman often wonders just what her baby-to-be is doing during its stay in the womb. Is it listening, is it sleeping, is it thinking as it floats in the amniotic fluid? Glimpses into the prenatal world via ultrasound imaging occasionally show seemingly coordinated behaviors, such as a fetus sucking its thumb or yawning. Researchers are now using the powerful ultrasound techniques to systematically study fetal movements to learn when in fetal life specific nervous system activities originate and how to distinguish when something has gone wrong.

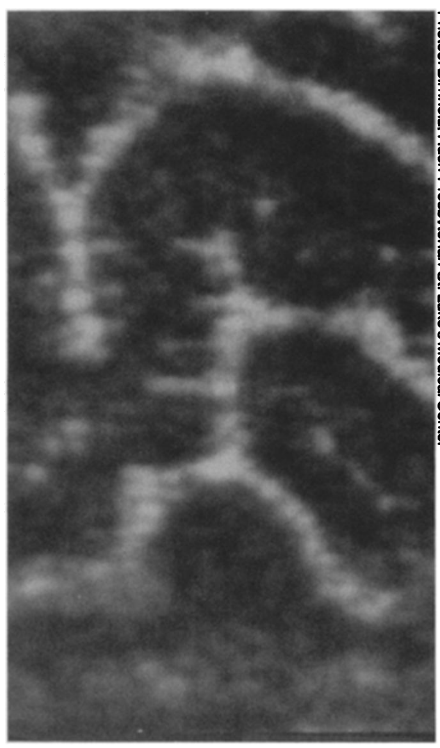
A variety of techniques are currently being applied to the prenatal development of the central nervous system (SN: 10/20/84, p. 247). Of these, ultrasound provides the most direct observations of the human fetus. Ultrasound imaging is in widespread obstetrical use, although some researchers are concerned that it might have subtle detrimental effects (SN: 2/18/84, p. 102). In the technique, acoustic pulses are sent into the pregnant woman's body from a probe applied to the abdominal skin. A computer, by analyzing the pulses that are reflected back to the skin, maps structures within the body. The most sensitive techniques have a resolution of less than 1 millimeter, and they can reveal structures as small as the pupil of an eye of a second-trimester fetus.

Pregnant women report that a fetus may start kicking in response to the sound of a doorbell, vacuum cleaner or drum. Jason C. Birnholz of Rush Medical College in Chicago examines fetal development with a more subtle "hearing test." He sounds a buzzer outside a pregnant woman's abdomen directly above the fetus's ear, which has been located with ultrasound. Then he observes the fetus respond to the buzz with a characteristic blink, a forceful clenching of the eyelids. This response begins abruptly at about 25 weeks of gestational age and is always present in normal fetuses more than 28 weeks old, Birnholz reports.

The blink response indicates that the parts of the nervous system involved in hearing and its influence on movement are in operation by the beginning of the third trimester. In addition, the blink response may be used to check on the development of an individual fetus. Birnholz reports that he found, among 680 fetuses more than 28 weeks old, eight with no blink response to the buzzer. In two of these cases, the newborns were deaf. Four others had major structural abnormalities affecting the nervous system. The remaining two were "severely compromised" fetuses; one died *in utero* and the other died shortly after an emergency delivery.

Among normal fetuses, the response to sound becomes more sophisticated with development. After 30 weeks of gestational age, the fetus is able to "tune out" a repeated loud sound. "This habituation involves a relatively high level of organization of the central nervous system," Birnholz and Elaine E. Farrell of Northwestern Medical School in Chicago say in the December 1984 AMERICAN SCIENTIST. They suggest that observations of this response may be used to monitor a fetus's condition: If a fetus never develops the mature habituation response, or if it regresses to the more immature response, physicians should suspect that the fetus is in danger and that it should be delivered early.

Continued on p. 77



Photos: Birnholz, Rush-Presbyterian-St. Luke's Medical Center

The complex pattern of ridges and grooves covering the surface of the brain can be examined in a fetus. In the ultrasound image of a normal full-term fetus (above), the grooves, or sulci, appear in white. With this technique, physicians can detect abnormalities in fetal brain structure; for example, the sulci appear thin and delicate in fetuses with Down's syndrome.

Profile (in oval at top) shows ultrasound image of some bones and tissue in the head of a 20-week fetus.

achieved by moving plasma waves through regions of varying density, particularly if the density can be made to vary periodically—which, Brooks says, "is hard to do physically." Predictions go as high as 100 GeV per meter.

A plasma is an active medium—it takes an important role in the action of acceleration. J.R. Fontana of the University of California at Santa Barbara proposes a passive medium, an electrically neutral gas. "All we want from it is an index of refraction," he says. When a light beam passes the boundary between substances with different indices of refraction, it bends. Given a material with the right index of refraction, two laser beams can be bent so that their waves interfere with each other. It makes a region where the forces are all in the direction of acceleration, and it should accelerate particles. This is known as inverse Cherenkov effect. The limits Fontana sees on the process are electrical breakdown of the gas and too many collisions between the particles to be accelerated and the gas.

Laser light striking an undulating surface, say a grating, at a low angle should also provide forces in the direction of acceleration. However, a disposable grating is necessary as the required light intensity will burn out the grating rather quickly—in 10 picoseconds, according to Robert B. Palmer of Brookhaven National Laboratory in Upton, N.Y. He figures that such an arrangement would need a narrow disposable grating and a laser with pulses that are short compared to 10 picoseconds. The solution is to use rows of droplets spaced a few micrometers apart. The droplets would be made by forcing liquid through a series of holes 1.5 micrometers across.

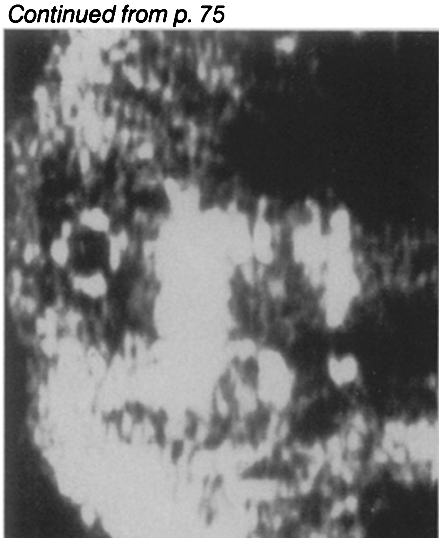
Technology for making such droplets exists. Sessler points out that it is used with ink in certain printing procedures. Ten picoseconds is short for a laser pulse, but Palmer points out that the Canadian National Research Council has a high-pressure carbon dioxide laser with pulses that can be compressed down to 2 picoseconds. He calculates that a 5-trillion electron-volt accelerator (5 TeV), which is five times the maximum energy of any existing accelerator, would require a length of 600 meters, 300 5-joule lasers and a repetition rate of 3 kilohertz.

Instead of an undulating surface, one can use an undulating magnetic field—in a device known as an inverse free-electron laser. The undulating magnetic field is provided by a so-called wiggler magnet. A free-electron laser is designed to take energy from high-energy electrons and use it to amplify a light beam. As the electrons pass through the undulating field they wiggle up and down. The wiggling induces them to radiate energy, and if there is a light wave passing through that resonates with the electrons, they will amplify that beam as they radiate. The *inverse* free-electron laser attempts to work the scheme the other way — extracting energy from the light and getting the electrons to absorb it.

"The free-electron laser works," says Sessler, "—or one thinks it works" (SN: 12/8/84, p. 359). An Italian physicist, Claudio Pellegrini, has worked out specifications for an inverse free-electron laser. With a 10,000-watt carbon dioxide laser and an undulator field of 1 tesla, an energy gain of 289 GeV should be possible. Sessler comments that this is 200 GeV in 2 kilometers or so. The SLC, when it is completed in a year or two, will be the most energetic conventional linear accelerator of electrons in the world. It will get 50 GeV in a little over 4 km.

Certain combinations also seem possible. M. A. Piestrup of Adelphi Technology in Woodside, Calif., and J. A. Edighoffer of TRW propose combining the inverse free-electron laser and the inverse Cherenkov effect into a gas-loaded inverse free-electron laser. The index of refraction provided by the gas, they figure, will change the synchrony between the laser light and the electron beam so as to reduce the undulator's magnetic field. This would reduce the amount of energy that the electrons lose to synchrotron radiation. As the electrons gain energy, they also lose it, and one of the necessities is to keep the gain higher than the loss. In published proposals for simple inverse free-electron lasers, Piestrup says they find the loss to synchrotron radiation very high. □

Continued from p. 75



A fetus begins opening its eye in the sequential images at right. Half of the face is "illuminated" by the imaging technique. A fully open eye of another fetus is shown in the image above. Such images reveal movements of the eyelids and eyes, both spontaneous and in response to stimuli.

While there isn't much for the fetus to see *in utero,* its eyes are already in motion, Birnholz finds. He has used ultrasound to observe patterns of eye movement during the second half of gestation. One pattern is movement of the pupil from a central position to the outer, lower corner of the eye, followed by a return to its central position. This movement is normally present by 16 weeks, Birnholz finds. But another pattern — a complex, nonrepetitive sequence of brisk, jerky movements — was observed only after 24 weeks. This pattern is a component of the rapid eye movements (REM) observed in newborn infants, Birnholz says.

Still later in gestation, he observes an inactivity of the fetal eyes, resembling deep sleep. This normally occurs after 36 weeks gestation. Earlier inactivity might be interpreted in some cases as accelerated development due to stress and in other cases as an analog of coma.

Like the blink response, eye movements can be used to assess fetal well-being and recognize abnormal development. An observation of rapid eye movements indicates that the fetal brain is working properly, Birnholz said at the recent meeting in Anaheim, Calif., of the Society for Neuroscience. He also has observed eye movement abnormalities in fetuses with abnormal brain structures (SN: 8/29/81, p. 142).

From ultrasound imaging, Birnholz and Farrell now expect "a quantum advance in knowledge" of normal fetal development. But Birnholz also warns scientists not to project capabilities onto the fetus from brief glimpses provided by ultrasound. For example, sequential views of a 34-week-old fetus show eyes scrunched closed and mouth wide open. It is tempting to speculate that these images illustrate crying *in utero,* Birnholz says. But, he cautions, no one knows for certain. □