been anywhere near as large as the increase in scientific potential. I cannot describe here in any great detail the succession of inventions and technological advances which have made this evolution possible. Let me just name a few.

The early accelerators, and the present day machines operating at low energy, are electrostatic. The maximum energy attainable by such methods is thus limited by the technology of producing and maintaining extremely high voltages (some millions of volts). This limitation was removed by the invention of the cyclotron by E. O. Lawrence. Here the accelerating voltage is supplied by a high frequency power source, and the same gap is traversed over and over again by confining the particles in a spiral orbit through the use of a large electromagnet. The geometry is arranged so that synchronism is achieved between the time that the particles transit the gap and the crest of the alternating voltage. A similar idea was also proposed to accelerate particles in a straight line, first by Ising in Sweden in 1926, but it was not applied to very high energy acceleration until after World War II.

The cyclotron had its limits in that synchronism between the particle transit and the alternating voltage could not be maintained once particle speeds approached a fraction of that of light. In that case relativity limits the particle speed, while the radii of the particle orbits in a magnet continue to increase with increasing particle energy. In addition to achieving particle synchronism with the accelerating voltage, it is also necessary to focus the particle orbits so that in the long trajectory from start to target, only a minimum of particles is lost. The struggle to achieve both synchronism with an alternating field and particle focusing at the same time was attacked by several ingenious ideas; the simple cyclotron does not permit this at particle energies beyond about 20 MeV. One idea, that of L. H. Thomas, was proposed in 1938, but was then understood by only few physicists. Thomas proposed an azimuthal variation in the field of the circular magnet of Lawrence in order to achieve focusing and synchronism simultaneously. The Thomas idea was not applied extensively until after the war, and then only to machines of moderate energy.

The second idea, which led to much higher energies, was independently conceived in 1945 by Vexler in the Soviet Union and McMillan in the United States. Vexler and McMillan showed that if particles were not accelerated at the crest of an alternating field, but rather during either the rising or falling part of that field, then dynamic conditions could be achieved where the phase of acceleration of the particles would automatically be maintained. Those particles which are not accelerated by the ideal amount will arrive either early or late. Depending on the geometrical configuration and the energy, stable acceleration is achieved by an appropriate choice of transit time across the accelerating gap during either rising or falling voltages. Particle focusing can then be attained in a manner less tightly related to the conditions of acceleration. This 'phase stability' principle led to a variety of machines, including the synchrocyclotrons, electron synchrotrons and proton synchrotrons of the post-World War II era.

The next essential technological advance was the invention of the 'strong focusing' principle in 1950 by Nicholas Cristofilos in Greece, and then independently in 1952 by Courant, Snyder and Livingston in the United States. This principle made it possible to focus particle beams with magnets of much smaller aperture, and therefore led to a major reduction in the cost of particle accelerators. The combination of this principle with the phase stability principle is the basis of all large circular accelerators of today.

As these techniques approach their limits, attention has begun to shift from beams striking stationary targets, which made possible the type of experiments such as the scattering measurements I described earlier, to colliding beam devices, or colliders as