By 1960 they were standard equipment at particle accelerators around the globe.

Bubble chambers had several distinct advantages over other particle detectors of the day. Not only did they serve as a large-volume target, but they also enabled experimenters to reconstruct the fine details of collisions in a rapid, straightforward manner. Picture after picture could be snapped and then carried back to home universities, where teams of "scanners" set to work searching the negatives for characteristic patterns.

After Glaser's invention, nobody contributed more to bubble-chamber technology than Luis Alvarez and his group of Berkeley physicists. They built a series of ever-larger chambers at the Bevatron, culminating in a device 72 inches long containing 500 liters of liquid hydrogen. Completed in 1958, this was by far the largest bubble chamber of its day. Surrounded by an enormous electromagnet, it was housed in a separate building adjacent to the Bevatron. For spearheading the development of this immense chamber, and for its contributions to the discovery of new particles, Alvarez won the 1968 Nobel prize in physics.

Bubble chambers were particularly effective in discovering new particles with extremely short lifetimes, such as the resonances mentioned in Chapter 2, which were far too short-lived to leave visible tracks in *any* detector. They travel hardly a trillionth of an inch before decaying into two or three other particles. All one can see in a bubble chamber picture is a spray of tracks emanating from the point where the resonance originated. But by measuring the length, curvature, and starting points of the paths of these telltale offspring, physicists could reconstruct the parent and deduce its intrinsic properties.

A group of spin-1 resonances, predicted during the late 1950's, were discovered during the early 1960's using bubble chambers. The first of these was the K* at a mass of 890 MeV, thought to be a high-energy cousin of the kaon, which was discovered with the 72-inch device in 1960. Many other resonances with a variety of properties soon turned up in bubble chambers at Berkeley and Brookhaven.

To restore order in the particle kingdom, physicists again resorted to taxonomy. Striking regularities could be found among properties of mesons and baryons. The masses of the baryons, for example, seem to increase in rough proportion to

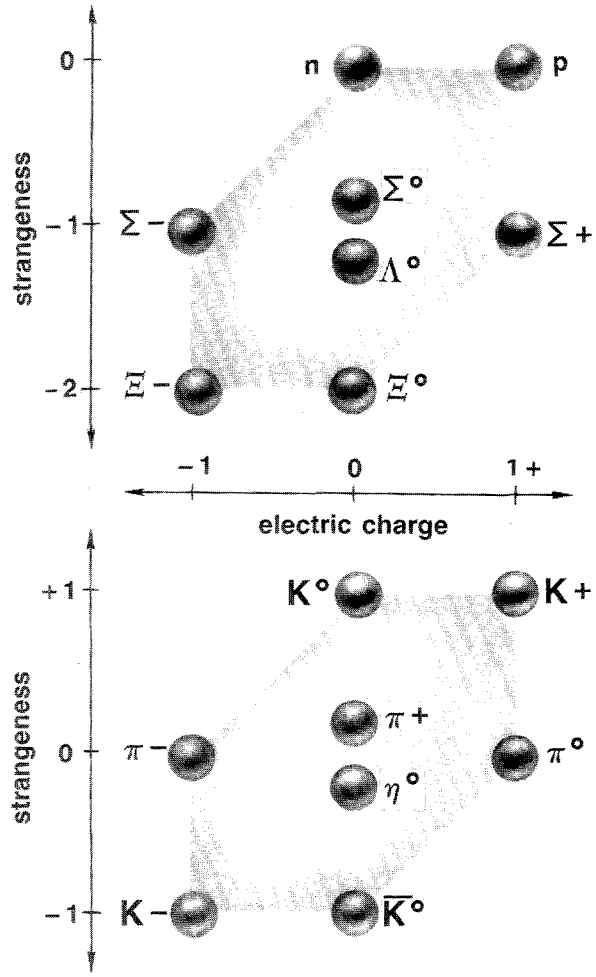

Figure 8. Octets of spin-½ baryons (top) and spin-0 mesons.

their spin. A similar behavior was observed among the mesons. These regularities enabled physicists to group the baryons and mesons along, when plotted on a graph, what were called *Regge trajectories* of related particles.

Another approach, pioneered in 1961 by Murray Gell-Mann, was to group together those mesons and baryons with identical spins. For example, the proton, neutron, lambda, three sigmas, and two xis are known collectively as the "spin-1/2 baryons." If one plots them on a graph according to their charge and strangeness, a hexagonal pattern of eight members called an *octet* results. A similar pattern emerged among the known spin-0 mesons—the three pions and four kaons—except that at the time there were a total of only seven members.

Based on the discrepancy between these two patterns, Gell-Mann predicted the existence of an