These species may also have a other, relatively minor utilitarian values. For instance, *Zebrina pendular* is often used in introductory **botany** classes to demonstrate the size of plant vacuoles, and to show the presence of certain mineral structures of plants. In *Zebrina*, vacuoles contain long needle-like crystals of **calcium** oxalate, called *raphides*, which are easily identified using a **microscope**. These vacuoles also contain the anthocyanin pigments that give the plant a purple **color**. Also, the leaf epidermal cells of *Zebrina* are large and easily removed from the rest of the leaf. These various features make *Zebrina* a good plant for demonstration purposes.

See also Horticulture.

Resources

Books

The American Horticultural Society. *The American Horticultural Society Encyclopedia of Plants and Flowers.* New York: DK Publishing, 2002.

Heywood, Vernon H. ed. *Flowering Plants of the World.* New York: Oxford University Press, 1993.

Kindscher, K. *Edible Wild Plants of the Prairie.* Lawrence, KS: University Press of Kansas, 1986.

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Spin of subatomic particles

Spin, s, is the **rotation** of a particle on its axis, as the **earth** spins on its axis. The spin of a particle is also called intrinsic angular **momentum**. Angular momentum is momentum (**mass** times **velocity**) times the **perpendicular** lever arm (distance between point of rotation and application of **force**). An intrinsic property is one that depends on the essential nature of an object. The total angular momentum of a particle is the spin combined with the angular momentum from the moving particle.

Spin of the electron

The idea of spin has been around for a long time. In 1925 G. E. Uhlenbeck and S. Goudsmit proposed that the **electron** has a spin, and the spin of the electron has been proven experimentally. The spin of the electron combined with its **electric charge** gives the electron magnetic qualities because of the electromagnetic force.

Spin in quantum mechanics

The spin of microscopic particles is so small it is measured in special units called "h-bar," related to **Planck's constant**, h, which is defined as 4.1×10^{-21} MeV seconds. h-bar is defined to be h divided by two and by **pi** (3.14159...).

Quantum mechanics is a branch of **physics** focusing on **subatomic particles**, and dealing in probabilities. One of the rules of Quantum mechanics says spin can only have certain values. Another way of saying this is spin must be "quantized." Particles with spin values of one-half h-bar, three-halves h-bar, five halves h-bar, and so on are called fermions and described by a mathematical framework called Fermi-Dirac **statistics** in quantum mechanics. Particles with spin values of **zero** h-bar, one h-bar, two h-bar, and so on are called bosons, and are described by a mathematical framework called Bose-Einstein statistics. The quantization of spin means we have to add spins together carefully using special rules for addition of angular momentum in quantum mechanics.

In quantum mechanics, particles can also be represented mathematically using spinors. A spinor is like a vector, but instead of describing something's size and orientation in space, it describes the particle in a theoretical space called spin space.

Spin as a classification method

Every particle and every atom or **molecule** (combination of **atoms**) with a specific **energy** has its own unique spin. Thus spin is a way of classifying particles. Using spin, all particles that make up **matter** are fermions. For example, all **quarks** and leptons have spins of one-half h-bar. The particles which mediate, or convey, the fundamental forces are bosons with spins of one h-bar. Baryons are particles made of combinations of three quarks. They have spins of one-half h-bar or three-halves h-bar. Baryons include protons (spin one-half h-bar) and neutrons (spin one-half h-bar). Mesons are particles made of a quark and an antiquark. They have spins of zero h-bar or one h-bar.

KEY TERMS

Fundamental force—A basic force, which has its own elementary mediator particle(s). There are four fundamental forces: the strong force, the electromagnetic force, the weak force, and gravity.

Mega electron volt (MeV)—A unit of energy. One MeV is one million Electron Volts. An Electron Volt is the amount of energy an electron gains as it passes through one Volt of potential difference.

Quarks—Believed to be the most fundamental units of protons and neutrons.

Isospin

Spin should not be confused with a quantum mechanical idea called isospin, isotopic spin, or isobaric spin. Isospin is the theoretical quality assigned to quarks and their combinations, which enables physicists to study the strong force that acts independently of electric charge.

Resources

Periodicals

"Building Blocks of Matter." *Nature* 372 (November 1994): 20.

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Lesley Smith

An infant with spina bifida. *Biophoto Associates, National Audubon Society Collection/Photo Researchers, Inc. Reproduced by permission.*

Spina bifida

Spina bifida is a **congenital** neural tube defect caused by problems with the early development of the spinal cord.

The main defect of spina bifida is the failure of closure of the vertebral column (the bony column surrounding the spinal cord) during embryogenesis. Embryogenesis refers to the stages of a developing embryo after **fertilization** of the egg by the sperm. Without closure of the neural tube, which normally occurs by 28 days, the spinal cord fails to obtain the usual protection of the vertebrae, and is left open to either mechanical injury or invasion by **infection**.

Spina bifida is one of a number of neural tube defects. The neural tube is the name for the very primitive structure which is formed during fetal development, and which ultimately becomes the spinal cord and the **brain**. Other neural tube defects include anencephaly, in which the cerebral hemispheres (sites for all higher intellectual functioning) are absent.

Spina bifida occurs in 1 in 1000 births to North American whites, but in less than 1 in 3,000 births to blacks. In some areas of Great Britain, the occurrence is as high as 1 in 100 births. Women who have a child with spina bifida are at a slightly higher risk of having children with spina bifida in subsequent pregnancies. Women who have spina bifida or have had a previous pregnancy affected by any type of neural defect are also at a greater recurrence risk.

Clinical manifestations

The classic defect of spina bifida is an opening in the spine, obvious at **birth**, with a protruding a fluid-filled sac, including either the meninges (the membranes which cover the spinal cord) or some part of the actual spinal cord. Often, the spinal cord itself does not develop properly. In spina bifida occulta, a variation of spina bifida where the defect may be much more subtle, and may, in fact, be covered with skin, while in another variation called rachischisis, the entire length of the spine may be open.

The problems caused by spina bifida depend on a number of factors, including where along the spine the defect occurs, other associated defects, and the degree of disorganization of the spinal cord. Certainly, the most severe types of spina bifida (rachischisis) often result in death, either by virtue of greatly increased risk of infection (**meningitis**) due to the exposed meninges, or due to the extreme compromise in spinal cord function.

Complications associated with spina bifida

Different parts of the spinal cord are responsible for different functions, the location of the defect in spina bifida dictates the type of dysfunction experienced by the individual affected. Most patients with any form of spina bifida have some degree of weakness in the legs. This can be severe and may involve some degree of paralysis, depending on the condition of the spinal cord.

Spinal cord functioning is necessary for proper emptying of both the bladder and the bowels. These systems are greatly compromised in people with spina bifida. Difficulty in completely emptying the bladder can result in severe, repeated infections, ultimately causing kidney damage, which can be life-threatening.

There are many associated defects that accompany spina bifida. Arnold-Chiari malformations are changes in the architecture and arrangement of brain structures, and can contribute to the occurrence of **hydrocephalus** (commonly referred to as **water** on the brain) in people