What are the basic principles of vaccinology? What are the different kinds of vaccines?

Vaccines work by eliciting long-lasting immunity – so to understand vaccines, you must have a basic understanding of immunology.

The immune system is divided into two arms: the innate system and adaptive system. Vaccines make use of several parts of the adaptive immune response, which has **pathogen**-specific responses and long-lasting memory cells that can respond to infection years or decades after the initial exposure. Remember, a **pathogen** is a bacteria, virus, parasite, or other organism that causes disease. The innate system responds generally and non-specifically to pathogens, and does not have the memory component that is critical for vaccinology, although it does deal with the majority of infections you experience in your lifetime.

Both branches of the immune system are further divided into **humoral immunity** and **cell-mediated immunity**. You may remember from your biology studies that the immune system features both B cells and T cells, which have different features that help fight off pathogens. Humoral immunity is characterized by B cells (named for their origin in bone marrow) that make antibodies that recognize foreign materials (**antigens**). Cell-mediated immunity uses T cells, which can kill other cells directly (cytotoxic T lymphocytes), activate macrophages and natural killer cells, or stimulate other cells to produce cytokines (small molecules that are secreted by cells) that have anti-pathogen effects. Both humoral and cell-mediated immunity begin a few days after initial infection and, if properly stimulated, can produce long-lasting memory cells that are reactivated if the same or a similar pathogen later infects the body.

For a review of the immune system and its functions, read the following:

http://www.nobelprize.org/educational/medicine/immunity/immune-detail.html

The innate immune system responds first to a pathogen, with the adaptive response following five or six days after the initial exposure (the primary response). Each time the immune system encounters the same pathogen (secondary response), the innate response is the same, but the adaptive response is more rapid and more effective. This is what makes vaccines work: since you have already been “exposed”, you mount a stronger immune response that can fight off the pathogen. How then do you simulate the experience of pathogen exposure without actually making someone sick?

There are many ways to induce a protective immune response to a pathogen. They vary in their levels of relative safety and effectiveness, and the vaccines in use today make use of all the different types.

Live attenuated: *Attenuated* means to reduce the force of something: for vaccines it means making a pathogen weaker or less deadly so that it cannot cause harm to a person, but is still alive. In this approach, the pathogen is modified so that it cannot reproduce effectively or cause disease (often by removing key genes or otherwise mutating it so its fitness is

decreased). This usually produces the most robust immune response since it is closest to actually being infected with the live pathogen. However, there is the risk of the attenuated pathogen reverting (via random mutations) to an infectious and hazardous form. One of the forms of the polio vaccine uses a live attenuated virus.

Killed/inactivated: The pathogen is killed so it cannot reproduce, and is then formulated into a vaccine, which is often easier to transport and store since you don't need to worry about keeping it alive. The pathogen has no risk of reverting to its original form and becoming infectious, but the immune response is not as robust as a live attenuated vaccine.

Toxoid: Some pathogens cause disease by producing a toxin when they infect humans. Toxoid vaccines are made by manufacturing the toxin and isolating and inactivating it before formulating it into a vaccine. This produces an immune response to the toxin, not to the organism that makes it.

Subunit: Subunit vaccines are made by isolating some part of the pathogen (often an external element of the virus or bacteria), manufacturing it, and formulating it into a vaccine. This produces a more narrow response than to a live attenuated or killed vaccine (since the immune system recognizes only a part of the pathogen and not the whole thing) but that can be sufficient to neutralize the pathogen.

DNA vaccines and recombinant vector vaccines are being studied, but are not currently approved for use.

Read more about the types of vaccines here:

http://www.niaid.nih.gov/topics/vaccines/Pages/typesVaccines.aspx