The immune system is a complex array of organs, cells and chemicals that determine self from non-self, identify potential dangers to the body and eliminate them by mounting an immune response.

Most (but not all) infections result in lifelong immunity. Some infections are innocuous while others cause serious disease, permanent damage to the host and sometimes death. Rather than risk the serious illnesses it is possible to vaccinate against a number of potentially serious diseases.

Vaccination is offered from a young age against a number of diseases as an alternative to experiencing natural infection and the associated risks.

It is important to immunise infants as soon as possible to protect against disease particularly as the infant immune system is known to be effective and responsive. However, their immune system is naïve i.e. has not been exposed to any pathogens.

Therefore the infant needs to develop immunity to every pathogenic organism it encounters. By the time of birth the baby will have large numbers of circulating antibody passed across the placenta from the mother. This antibody will protect the baby against some infections initially, until the baby forms its own immune response to pathogens.

The following document is a summary of the immune system in humans and will give an insight into the way immunity is developed.

**Key messages**

- At birth the infant has a naïve immune system which needs exposure to foreign antigen in order to develop normally.
- Maternally acquired immunity does not protect against all types of infection and is temporary.
- The infant immune system has the capacity to cope with a vast array of antigens at any one time
- Immunisation of young infants is both safe and effective.
Background - Overview of the immune system

Our immune system protects us against viruses, bacteria and parasites which can cause infectious diseases. The immune system responds to antigens. An antigen is a substance that stimulates a specific immune response, especially the production of antibodies. Basically this involves shape recognition. Antigens are usually proteins or polysaccharides, but can be any type of molecule. Infectious agents such as viruses and bacteria have unique antigens that the immune system responds to. Vaccines contain these antigens (often purified parts of the original organism).

Figure 1. The immune response depends on shape recognition

Types of Immunity

The white blood cells of the immune system are produced in the bone marrow. The cells are carried in the blood to specialised organs such as lymph nodes, where they develop and communicate to launch immune responses against infections.

We have three types of immunity:

a) Non-specific immunity – is a first line of defence and generally keeps infections from entering the body. Examples of this are skin (physical barrier), mucus, tears, stomach acid.

b) Innate immunity – is the second line of defence. In this situation certain white cells engulf infectious agents. These cells are capable of recognising antigens which are non-self (ie coming from an infectious agent), however they cannot recognize particular pathogens. For example, these cells would not be able to distinguish an influenza virus from a hepatitis virus, but they would be able to distinguish that there was a viral infection occurring. Over 90% of infections are controlled by these cells. However when the infection becomes too great these cells will alert the specific arm of the immune system.

c) Specific or adaptive immunity – This is the third line of defence. In this situation white blood cells called lymphocytes identity each antigen individually by recognising different sequences of amino acids. This specific response initially takes longer to generate (4-7 days) than the non-specific arm but results in a memory to the specific antigen. The memory response becomes quickly activated. This means that when an individual is re-infected with the pathogen, this memory response will remove the infectious agent before it can cause disease (ie in 2-3 days). This is the response that vaccination exploits.
**Effector Functions of White Blood Cells:**

Innate Immunity: Some white blood cells, like macrophages and neutrophils, eat bacteria and damaged cells. They can also kill bacteria through the release of inflammatory molecules, such as cytokines, nitric oxide and reactive oxygen intermediates.

Specific Immunity: there are two main groups of lymphocytes involved, B lymphocytes and T lymphocytes:

- B lymphocytes (B cells) produce antibodies (immunoglobulin or Ig, of which there are several different classes), which can neutralise viruses, bacteria or toxic proteins in the blood and other body fluids.
- T cells develop into killer cells, which can recognise host cells that have become invaded by a micro organism. T cells can bind to these infected cells and kill them. This prevents the spread of the micro organism within the body.

Both T and B cells have receptors on their surface that recognise particular pathogens. Therefore in an infection only a few T or B cells will become activated. In any one person there will be at least $10^{16}$ (that's 10,000 trillion) different antigens that can be recognised by the receptors on the surface of lymphocytes.

Each arm of the immune response involves many different cells. These cells need to communicate with each other to co-ordinate the immune attack. In addition cells from different arms of the immune response also need to communicate with each other. The way all the white blood cells communicate is by using small molecules called cytokines. Cytokines are also often referred to as immune hormones. These messengers can act to promote or inhibit production of certain types of cells, induce cell proliferation and recruit cells to areas of injury or infection.

**Immune Memory**

While development of the immune system begins very early in fetal life exposure to antigen doesn't occur until after birth. It is to this exposure to pathogenic antigen that the infant needs to develop a memory response. The exposure to microbial antigen can occur in two ways a) from infection, or b) from vaccination, and exposure serves to educate the immune system about those infections and form immune memory. This means that when the infant is infected with the pathogen(s) again, it will have a faster immune response and quickly neutralise them before they cause disease, or at least ameliorate the severity of the infection. The “memory” resides in the form of specific T-cells and B-cells.

**What is different about the infant immune system?**

The infants' immune system is intact but immature at birth. Some vaccines such as BCG and Hepatitis B work well when they are administered at birth whereas others do not generate as strong a response.

The main problem with babies’ immunity is that it is very naïve. At the time of birth babies have not been exposed to any pathogens. This means that babies have to generate a full immune response to every pathogen they encounter. Each immune response takes about 10 days to generate. This is where maternal antibody can be important when present. It will help to protect an infant if they are exposed to a pathogen in those first 10 days. Unlike other animals (such as ruminants) which rely mainly on passive transfer of maternal antibodies in breast milk, humans receive most of their maternal antibodies through placental transfer of IgG. However, there will still be some antibodies transferred in breast milk, but the levels are much lower. In addition human babies don't have a porous stomach (like calves do) in order to absorb the antibody. Therefore most of the antibody in breast milk will work in protecting pathogens crossing the oral cavity.
<table>
<thead>
<tr>
<th>Function</th>
<th>Difference during infancy</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Specific immunity</td>
<td>Phagocytes cannot migrate towards infectious sites, although their bactericidal (killing) activity is normal.</td>
<td>Slow response to infection</td>
</tr>
<tr>
<td>Cytokine production</td>
<td>Poor production of cytokines, in particular Th1 cytokines such as interferon gamma by T-cells</td>
<td>Impaired responses of other cell populations that rely on their functions such as natural killer cells.</td>
</tr>
<tr>
<td>Natural killer T cell cytotoxicity (killing)</td>
<td>Is incomplete. These abnormalities are probably caused by immaturity in cytokine production of T cells and monocytes</td>
<td>Inefficient killing of viruses</td>
</tr>
<tr>
<td>Complement system</td>
<td>Develops progressively during the first year of life</td>
<td>Inefficient phagocytosis</td>
</tr>
<tr>
<td>Specific immunity (T-cells and B-cells)</td>
<td>Develops early in prenatal life</td>
<td>Relative naivety of T and B cells mean primary immune response is relatively inefficient accounting for the particular susceptibility of newborns, especially premature babies, to bacterial and viral infections. Repeated antigenic stimulation leads to the complete maturation of specific immunity during the first few years of life.</td>
</tr>
<tr>
<td></td>
<td>T and B cells first appear in key organs from an early point in fetal development:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Bone marrow (8-10 weeks)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Thymus (8 weeks)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Spleen (8 weeks)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lymph nodes (11 weeks)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Appendix (11 weeks)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Tonsils (14 weeks)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Specific immune responses appear to be possible after as little as 12 weeks of fetal development. However, T and B cells are 'naive', encountering antigens for the first time.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IgG sub group not produced until the second year of life</td>
<td></td>
</tr>
<tr>
<td>Immunoglobulin (Ig or antibody) production</td>
<td>Impaired production of some isotypes. Low serum IgM, IgA and IgE. IgG mostly of maternal origin.</td>
<td>Inability to respond to polysaccharide encapsulated bacteria such as meningococcal and pneumococcal until about 2 years of age. Inability to respond to polysaccharide vaccines</td>
</tr>
<tr>
<td>Maternal antibody protection from placenta</td>
<td>IgG against some infectious organisms crosses the placenta. Wanes during first year of life.</td>
<td>Gives protection against some infections that mother exposed to or immunised against including measles and meningococcal disease. Can interfere with vaccines such as MMR. Little or no protection against other diseases such as whooping cough.</td>
</tr>
<tr>
<td>Maternal protection from breast milk</td>
<td>Mostly IgA</td>
<td>Provides additional protection against gut microbes, less effective against respiratory infections</td>
</tr>
</tbody>
</table>
The immune system in the developing fetus during pregnancy

Maternal
The immune system is designed to recognise 'self' versus 'non self'. This means our own immune system can recognise our own cells as being safe and anything else as being a threat. Obviously this has implications in pregnancy, where a developing fetus will be expressing antigens from the father. Therefore during pregnancy modifications occur in the maternal immune system at many levels. These changes are necessary to ensure a successful pregnancy. In the absence of such changes the mother’s immune system would recognise the fetus as foreign (like a pathogen) and reject it. Potentially dangerous T-cell responses are down regulated (reduced) and some aspects of the non-specific immune system are activated. As previously mentioned, at this time specific IgG antibody passes from the mother through the placenta to the developing fetus providing it with temporary protection against some of the infections that the mother has been exposed to or vaccinated against. This gives opportunities to provide newborns with transient protection against some diseases.

Infant
The infant’s immune system is relatively complete at birth. It is clear that the IgG antibodies received from the mother are important for the protection of the infant during the first few months of life while the infant is starting to develop its own repertoire. Passive transient protection by IgA against many common illnesses is also provided to the infant in breast milk. Mothers milk provides IgA against a wide range of microbes that the mother has had in her gut. Breast milk has also been shown to assist in the development of the infant’s own immune system. There is some, although weak, evidence to show that breastfed infants respond better to some vaccines. The major impetus however for the expansion of lymphocytes (B and T cells) is the exposure to microbes which colonise the gut during birth.

Premature and low birth weight infants are at increased risk of experiencing complications of vaccine preventable diseases and although the immunogenicity of some vaccines may be decreased in the smallest preterm infants, the antibody concentrations achieved are usually protective.

Figure 3. The protective effect of maternal antibodies in serum and milk.

Figure 3. Panel A – if maternal antibodies are present they afford protection to the infant. They can also attenuate (weaken) infections should they occur allowing the infant to develop their own immunity. Panel B – There is no protection offered to the infant in the absence of maternal antibody.


The relative immaturity of the infant immune system leaves them unable to respond well to certain infectious agents, as well as some types of vaccine.

For the reasons discussed above, young infants are at particular risk of some diseases. Each disease comes with its own set of peculiarities listed below.
### Disease | Risk to young infants
---|---
**Pertussis (whooping cough)** | Young infants are at highest risk from complications from this disease and morbidity and mortality are inversely associated with age – the younger the more dangerous. 90% of deaths occur in infants <4 weeks of age. 75% of cases in first year of life are hospitalized. Most deaths occur in infants under 1 year of age. Breastfeeding offers no protection from pertussis regardless of the mothers’ immune status.

**Measles** | Young infants are at lower risk from contracting measles as they receive protective antibody from their mother. This maternal protection wanes from about 6-9 months. Vaccination is not offered until 15 months of age as giving it early creates the possibility that the maternally derived antibody inactivates the vaccine. Vaccination occurs later to ensure the infant develops its own lifelong immunity. In situations of high risk from measles babies can be immunised against measles at a younger age however the vaccine may be less effective.

**Mumps** | Same as above

**Rubella** | Rubella is not usually a serious disease of childhood however if contracted during pregnancy can have disastrous consequences for the fetus. Immunisation against rubella occurs at 15 months with measles and mumps vaccination.

**Meningococcal disease** | Babies are vulnerable to meningococcal disease due to their inability to produce high levels of IgG2. The most vulnerable period is when any maternal protection conferred has waned (6 – 12 months). Group B vaccine can be given from 6 weeks of age and 4 doses are required. Group C vaccines can also be given from 6 weeks. (Not funded in NZ)

**Pneumococcal disease** | Babies are more vulnerable to pneumococcal disease due to their inability to produce high levels of IgG2. Vaccination is recommended and available from 6 weeks of age. (Not fully funded in NZ)

**Tetanus** | Any unimmunised person is at risk from tetanus including infants as the bacterium is present in soil.

**Hepatitis B** | Consequences of hepatitis B are inversely associated with age and if acquired early in life is very likely to result in chronic infection and associated morbidity and mortality. Infants of carrier mothers should be immunised starting from birth.

**Haemophilus influenzae type B (Hib)** | As with meningococcal and pneumococcal, infants are at particular risk from this disease due to their inability to produce IgG2

**Diphtheria, Polio** | No longer endemic in New Zealand however until global eradication occurs it is important to continue to immunise.

### General principals of action of vaccines

Most vaccines are injected directly into muscle tissue, some are subcutaneous. Briefly the following occurs*:

1. Vaccine antigen disassociates from adjuvant (e.g. aluminium hydroxide).
2. Cells of the non-specific immune system (i.e. macrophages and dendritic cells) recognise the antigen as foreign and engulf it. These cells then chop the antigen into smaller fragments and display these on their cell surfaces.
3. The dendritic cells move through the lymphatic system to a local lymph node where specific T cells and B cells which recognise the fragments of antigen generate a specific immune response.
4. Other components in the vaccine such as the adjuvant and preservative, if present, are absorbed into the blood where they circulate and are excreted in the stools and urine.

*Live viral vaccines multiply several times in the relevant tissues as per natural infection, however these viruses are attenuated so they cannot multiply as much as a the normal infectious virus.

Different vaccines stimulate the immune system in different ways. Some provide a broader response than others. Vaccines influence the context of the immune response by the nature of the antigens, the amount of antigens, route of administration as well as adjuvants present.
The Hygiene Hypothesis

The hygiene hypothesis states that an excessively hygienic environment in early childhood may predispose some people towards asthma, allergies, and other autoimmune diseases. The mechanism behind this is the predominance of a type of T-helper cells called Th2 which drive the production of a class of antibody –IgE which is associated in allergy. The dominance of Th2 results in the inhibition of a Th1 response which is more effective at clearing most types of intracellular (ie viral) infection. At birth all infants have an immune response which is often shifted towards a Th2 response. During early life this usually shifts to Th1 and evidence suggests one of the key drivers for this shift is exposure to microbes.

Some people are concerned that immunisation may deprive infants of infections that strengthen their immune system. There is evidence to support the importance of the exposure to microbes in the development of the immune system, however studies that have looked at the effect of vaccination on immune dysfunction do not support a causal association. Immunisation exposes infants to crippled (attenuated) microbes or fragments of microbes. The specific immune responses to these can be either Th1, Th2 or both, depending on the vaccine. They are however specific to the vaccine microbe and do not "skew" the immune system. In contrast, highly pathogenic infections such as pertussis can overwhelm the infant immune system causing severe disease before contributing to a “strengthened” immune system.

Frequently asked questions

Is it safe to immunise infants as young as six weeks of age?
Absolutely. Infants are at no more risk from adverse events than older children. The problems associated with immunisation of young infants are those of lower responses to some vaccines (see below) resulting in reduced protection conferred by the vaccine. NB. Some vaccines are effective in neonates, such as Hepatitis B vaccine.

Do vaccines work in young infants?
Vaccines on the childhood schedule have been proven both safe and effective in 6 week old infants. It is important to ensure the vaccines are given on time to ensure protection as soon as possible and that all doses are received as strong protection does not occur after only one dose. Some vaccines (such as the MeNZB™ vaccine) require babies receive more doses than older children to get the same level of protection, as they do not respond as vigorously.

Does it matter if we delay vaccination until the infant is older?
It is important that infants receive protection while they are at their most vulnerable and for many diseases this is in the first year of life. An infant cannot be considered fully protected until it has received all the recommended doses of vaccine (usually at 6 weeks, 3 months and 5 months of age) so it is important to start on time. Infants who are late with their immunisations are 4-6 times more likely to be admitted to hospital with whooping cough than those who have been immunised on time.
Do very young infants have more adverse events than older infants after being vaccinated?
No.

Do multiple vaccines overload the immune system?
Absolutely not. Current studies do not support the hypothesis that multiple vaccines overwhelm, weaken, or "use up" the immune system. On the contrary, young infants have an enormous capacity to respond to multiple vaccines, as well as to the many other challenges present in the environment. By providing protection against a number of bacterial and viral pathogens, vaccines prevent the "weakening" of the immune system and consequent secondary bacterial infections often resulting from natural infection.

How many antigens could the immune system respond to at once?
An infant has more T and B cells per cc of blood than an adult. There are actually $>10^{15}$ different antigens that an infant could potentially recognise and respond to.

How many antigens is the infant exposed to naturally?
- At birth colonisation with genital tract flora occurs (about 18 species)
- At birth colonisation with faecal flora occurs (about 400 species)
- Breast milk contains around 8 species of microbe.
- Each species have around $3-6\times10^3$ different proteins
- Therefore infants are exposed to $>10^6$ different proteins naturally.

How many antigens are infants exposed to in vaccines?

<table>
<thead>
<tr>
<th>Year</th>
<th>Antigens</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>~200 (Smallpox vaccine)</td>
</tr>
<tr>
<td>1960</td>
<td>~3217 (included smallpox vaccine and whole cell pertussis)</td>
</tr>
<tr>
<td>1980</td>
<td>~3041 (Included whole cell pertussis vaccine)</td>
</tr>
<tr>
<td>2000</td>
<td>~50</td>
</tr>
</tbody>
</table>

- Infants receiving NZ scheduled vaccines receive around 50 different antigens at one time.

Do vaccines produce a different immune response than infections by bypassing the natural route of entry?
Most infections enter through the respiratory route however vaccines are injected directly into the body, bypassing natural defences.

Immunity to vaccination is not always of the same quality as that acquired from natural infection; however this is specific for each antigen. Vaccines do not "skew" the entire immune system. Vaccines do use the same pathways and actions of the immune system as natural infection does, even if they do not always engage as broad a response as the natural infection.

**Glossary**

**Active immunity**
The production of antibodies against a specific disease by the immune system. Active immunity can be acquired in two ways, either by contracting the disease or through vaccination. Active immunity can wane but is usually permanent, meaning an individual is protected from the disease for the duration of their lives.

**Adverse event following immunisation (AEFI)**
An unwanted reaction following administration of a vaccine, which may or may not be caused by the vaccine; adverse events may be at the site of injection, or may be a general illness or a general allergic reaction.

**Adjuvant**
A preparation (e.g. aluminium salts), which may be added to a vaccine to improve the immune response to the vaccine.

**Amino Acids**
Amino acids are the basic structural building units of proteins. They form short polymer chains called peptides or polypeptides, which in turn form structures called proteins. Fragments of only a few amino acids in length are required for immune recognition.

**Antibody**
An antibody is a protein used by the immune system to identify and neutralize foreign objects like bacteria and viruses. Each antibody recognises a specific antigen unique to its target. Production of antibodies is referred to as the humoral immune system. There are several classes of antibody. Also referred to as Immunoglobulin (Ig).

**Antigen**
An antigen is a substance that stimulates an immune response, especially the production of antibodies. Antigens are usually proteins or polysaccharides (sugars), but can be any type of molecule, including small molecules (haptens) coupled to a carrier-protein.
Attenuation
The process of modifying a virus or bacteria so as to reduce its virulence while retaining its ability to induce a strong immune response (immunogenicity).

Bacteria
A major group of living organisms that are smaller than a blood cell but bigger than a virus; examples of bacterial infections are diphtheria, tetanus, pertussis, and tuberculosis. Most are microscopic and unicellular, with a relatively simple cell structure lacking a cell nucleus and organelles such as mitochondria and chloroplasts.

BCG
Bacillus of Calmette Guérin, a vaccine that protects against tuberculosis.

Cellular mediated immunity
Immune response that involves effector T lymphocytes and not the production of humoral antibody.

Conjugate
(Paired together) Some vaccines (e.g., pneumococcal conjugate vaccine) are made from the chemical linking (conjugation) of the bacterial polysaccharide cell coat with a protein carrier such as tetanus toxoid, in order to improve the immune response to the vaccine.

Contraindication
Any condition, especially any condition of disease, which renders some particular line of treatment improper or undesirable.

Cytokines
Cytokines are small protein molecules that regulate communication among immune system cells and between immune cells and those of other tissue types. Cytokines are actively secreted by immune cells as well as other cell types in response to external stimuli.

Efficacy
The ability of a vaccine to protect against disease under trial conditions i.e. the number of immunised people getting disease divided by the number immunised.

Effectiveness
The ability of a vaccine to prevent disease in a population. A vaccine may be only 85% efficacious however with high coverage may reach 100% effectiveness by eradicating disease from the population.

Epitope
An epitope is the part of a foreign organism or its proteins that is recognised by the immune system and targeted by antibodies, cytotoxic T cells or both. Most epitopes can be thought of as three-dimensional surface features of an antigen molecule although some are linear epitopes which are determined by the amino acid sequence (the primary structure) rather than by the tertiary structure (the 3-dimensional shape) of a protein.

Excipient
Any more or less inert substance added to a prescription in order to confer a suitable consistency, as a vehicle, or an active ingredient. Excipients can also be used to aid the process by which a product is manufactured. In general, the active substances i.e. antigen may not be easily administered and absorbed by the human body; they need to be put in some appropriate form. The active substance is then dissolved or mixed with an excipient.

Humoral immunity
A form of immunity whereby B lymphocytes and plasma cells produce antibodies to antigens and stimulate T lymphocytes to attack them (cellular immunity).

Immunisation
The process of inducing immunity to an infectious agent by administering a vaccine.

Immunity
The ability of the body to fight off certain infections; immunity can result from natural (‘wild’) infections or from vaccination.

Immunogenicity
The ability of a vaccine to induce protective levels of humoral or cellular immunity.

Immunoglobulin
A specific protein substance that is produced by plasma cells to aid in fighting infection. Injection of immunoglobulins provides temporary immunity against certain infections. Examples include IgG, IgM, IgA, IgD and IgE.

IgG2
The immunoglobulin subclass of IgG2 is particularly important for the removal of some bacteria such as pneumococcus and meningococcus. This subclass of immunoglobulin is not functional until over the age of about 2 years.

Lysozyme
Lysozyme is an enzyme, commonly referred to as the “body’s own antibiotic” since it kills bacteria. It is abundantly present in a number of secretions, such as tears, cytoplasmic granules of the polymorphonuclear neutrophils (PMN) and released through the mucosal secretions (such as tears and saliva).

Meningitits
Acute onset of major illness with fever and often neck stiffness/positive meningeal signs. Symptoms may be subtle or similar to those of encephalitis. CSF pleocytosis is usual.

Passive immunity
Immunity acquired passively either from the placenta or breastmilk or from the administration of immunoglobulin. Passive immunity is only transient.

Peptides
Family of molecules formed from the linking, in a defined order, of various amino acids.

Phagocytes
A phagocyte is a cell that ingests (and destroys) foreign matter, such as microorganisms or debris via cellular digestion, a process known as phagocytosis, in which these cells ingest and kill offending cells by cellular digestion. These phagocytes are extremely useful as an initial immune system response to tissue damage.
Polysaccharide
A group of complex carbohydrates (sugars). These can be found on the outside coating of some bacteria. Polysaccharides are not immunogenic in the very young.

Protein
Complex, organic compound consisting of amino acids joined by peptide bonds. Proteins are essential to the structure and function of all living cells and viruses, many are enzymes or subunits of enzymes, catalyzing chemical reactions. Other proteins play structural or mechanical roles. Proteins are one of the classes of biomacromolecules, alongside polysaccharides, lipids, and nucleic acids that make up the primary constituents of living things. The coding sequences of genes determine the amino-acid sequences of almost all naturally occurring proteins. It is very common for proteins to work together to achieve a particular function, and often physically associate with one another to form a complex. Proteins serve important roles in both the immune system and also as antigens.

Specific immunity
The combination of humoral immunity and cell-mediated immunity specific to a particular disease. Specific immunity is acquired actively either by infection, vaccination or passively by maternal antibodies or administration of immunoglobulin. Only actively acquired immunity is long-lived.

Toxin
Poisonous substance produced by living cells or organisms. Toxins are nearly always proteins capable of causing disease on contact or absorption with body tissues by interacting with biological macromolecules such as enzymes or cellular receptors. Toxins vary greatly in their severity, ranging from usually minor and acute (as in a bee sting) to almost immediately deadly (as in botulinum toxin). Toxin producing bacteria include Diphtheria and Tetanus

Toxoid
A toxoid is a bacterial toxin whose toxicity has been weakened or suppressed while other properties such as immunogenicity, are maintained. Toxoids are used in vaccines as they induce an immune response to the original toxin or increase the response to another antigen. For example, the tetanus toxoid is derived from the tetanospasmin produced by Clostridium tetani which causes tetanus.

Wild type
Wild type is one of the major genotypes of a species that occur in nature by evolution, in contrast to induced mutations or artificial cross-breeding. The naturally occurring variety.

Virus
A virus is a submicroscopic parasite that infects cells in biological organisms. Viruses reproduce only by invading and controlling other cells as they lack the cellular machinery for self-reproduction. Examples include measles, hepatitis and polio viruses.

Virulence
Virulence is a term used to refer to either the relative pathogenicity or the relative ability to do damage to the host of an infectious agent.

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