International Day of Immunology
General Immunology

What is the Immune System?

Every day your body is being attacked by foreign organisms such as bacteria, viruses and parasites that can cause disease. These are called pathogens.

Humans have evolved a complex system of cells and chemicals which are released from cells to protect you from these invaders. This is called the immune system.

Components of your immune system travel around your body through the blood and lymph fluids patrolling for invading pathogens. Once a pathogen is recognized, the immune system swings into action to eliminate it. Parts of the pathogen may be broken down and recognized by the immune system as foreign material. These are called antigens.

Your immune system can also protect you from your own cells that are either over activated and can cause autoimmune conditions or that have become mutated and can cause cancer.

We can activate or suppress the immune system to protect ourselves from disease. Vaccines are used to boost the immune system against a certain pathogen. If the pathogen then attacks the body, the immune system is primed and ready to go. On the other hand, for organ transplants immunosuppressive drugs are used to quieten the immune system, so that the skin graft is not seen as foreign and is not attacked by the immune system and rejected.

Innate versus adaptive immune system

The immune system is composed of two different parts called the innate and the adaptive immune system. Both have different characteristics and complement each other.

Cells of the immune system

Immune cells are diverse. White blood cells including lymphocytes and neutrophils, as well as red blood cells, can be seen.

Actions of Immune cells

Our immune system recognises pathogens by:

- Pattern Recognition Receptors (PRRs). These form part of the innate immune system and give a quick response.

- Antigen presentation. Certain immune cells can present (put on their cell surface) antigens (molecules unique to the pathogen) to activate other immune cells. This is important for pathogen detection by the adaptive immune system.

- Antibodies. These are secreted by cloned B cells and can bind to pathogens.

Cells of the immune system communicate with each other through:

- Signalling molecules. Immune cells release molecules that activate other immune cells (e.g. cytokines) or attract other immune cells (e.g. chemokines).

Pathogens are killed in the following ways:

- Phagocytosis. Various immune cells (“phagocytes”) engulf the pathogen to destroy it and allow antigen presentation.

- Toxic molecules. Immune cells release toxic molecules to destroy pathogens, for example, by degranulation (the release of molecules from granules).

- Antibodies bound to pathogens can:
  (1) neutralise or damage
  (2) stimulate phagocytosis
  (3) activate complement

- Complement. A number of small proteins in the blood act following an activation cascade to help or “complement” the ability of antibodies or phagocytic cells to destroy pathogens. Complement proteins:
  (1) cover the pathogen to enhance phagocytosis (opsonisation),
  (2) attract phagocytes to the pathogen (chemotaxis), and
  (3) rupture the pathogen (lysis).
Vaccines

They have eradicated smallpox and are extremely effective at limiting the spread and impact of many once common diseases. Vaccines have dramatically reduced the prevalence of infectious diseases. Vaccines are one of the most effective and cost efficient medicines we have ever used.

Most of the time our immune system can keep up with these dangers, but sometimes it gets overwhelmed.

The armed forces of the body

White blood cells (T-cells and B-cells)
Phagocytes
Complement
Antibodies

A phagocytic cell engulfing bacteria
A winter Flu

Our B and T cells have good memories

They can remember a microbe for years so next time they see it, they can fight it off faster and more effectively. Rather than wait till we get sick, we can train the immune system to recognise a certain microbe by introducing it to a non-dangerous form of the microbe.

This is called vaccination

Vaccines

History of vaccination.
Edward Jenner, a British doctor, is known as the father of vaccination. He noticed that milkmaids rarely contracted smallpox and thought that cow pox infection (which is very mild in humans) may protect them from the vicious disease, smallpox. He vaccinated his patients with cow pox, which protected them from smallpox.

As a result of vaccination, smallpox has been eradicated. Who would have thought we owed cows for saving so much grief and eliminating a scourge of mankind?

Louis Pasteur coined the term vaccine in honor of Jenner’s work from the Latin name for cow. Pasteur did groundbreaking work on vaccines for all manner of infectious diseases.

What have vaccines done for you?

The good:
Vaccines are one of the most effective and cost efficient medicines we have ever used.

They have eradicated smallpox and are extremely effective at limiting the spread and impact of many once common diseases. Vaccines have dramatically reduced the prevalence of infectious microbes (Pathogens).

Bacteria, viruses, fungi and parasites

Infectious Microbes (Pathogens)

Influenza virus
Salmonella bacterium

Cancer Cells

They were once our normal cells, then they mutated and forgot to stop dividing.

They had outsmarted our immune system.

What have vaccines done for you?

The bad:
Early vaccines caused some side effects. Modern vaccines have very minimal side effects. It is personal preference to vaccinate your child but there is no doubt that mass vaccination has a much lower complication rate than the diseases they cure.

Australian cancer vaccine
Professor Ian Fraser while working in Melbourne and Brisbane developed Guardasil™. This is the first vaccine that has been licenced and marketed as a cancer vaccine.

It protects you from a number of strains of the Human Papilloma Virus which can cause cervical cancer. Other anti-cancer vaccines are being developed.

Why aren't there vaccines for every infection?

Some pathogens are very good at evading the immune system. Other pathogens frequently mask their outward appearance, making it difficult for the immune system to recognize them. It is very hard to develop a vaccine that offers protection from such pathogens.

Examples include many parasites including the malaria parasite, human immunodeficiency virus (HIV), and rhinoviruses and coronaviruses which cause the common cold. This is also why you need a new flu vaccine every year, as the influenza virus changes each year and can evade the immune response.

Examples of diseases caused by viruses

Influenza virus
Influenza virus
Available

Hepatitis A virus
Hepatitis A virus
Available

Poliovirus
Poliovirus
Available

Hepatitis B virus
Hepatitis B virus
Available

Hepatitis C virus
Hepatitis C virus
Not available

HIV
HIV
Not available

Examples of diseases caused by bacteria

Diphtheria
Diphtheria
Available

Tetanus
Tetanus
Available

Salmonella
Salmonella
Available

Legionnaires
Legionnaires
Not available

Athlete’s foot
Athlete’s foot
Not available

Examples of diseases caused by fungi/parasites

Athlete’s foot
Athlete’s foot
Not available

Yellow fever
Yellow fever
Not available

Malaria
Malaria
Not available

Trypanosoma brucei
Trypanosoma brucei
Not available
Autoimmunity
Examples of autoimmune disease include:
- Type 1 diabetes (pancreas)
- Rheumatoid arthritis (joints)
- Coeliac disease (intestine)
- Multiple sclerosis (brain and spinal cord)
- Systemic lupus erythematosus (multiple tissues)
- Sjogren’s syndrome (mucous membranes)

It is also important to know how we can turn an over-active immune system OFF!

Rheumatoid Arthritis
- Common autoimmune-mediated inflammatory disease
- Chronic synovial joint inflammation & eventual joint destruction
- Extra-articular features eg. vasculitis & cardiovascular disease

Comparison of normal and rheumatoid joint

Type 1 Diabetes
Endocrine disruption due to autoimmunity

Type 1 diabetes
- Juvenile-onset 1:200 pop.
- Adult-onset 1:200 pop. (10% of adult diabetes)
- Immune cells infiltrate the pancreas
  - Pancreas β-cell (beta-cell) destruction
  - Insulin deficiency
  - Hyperglycaemia

The rise and rise of diabetes

Treatment for diabetes
- Daily insulin injections (Insulin Pump/Pen)
- Pancreatic islet transplantation
- Nasal insulin delivery for diabetes prevention (in development)

Coeliac Disease
Gluten in
Wheat
Rye
Barley

Normal small bowel
Coeliac disease

Targets for drug development

Treatment Options
Currently the only treatment is a gluten-free diet
- this is expensive, difficult and
- fails in 50% of adults

Treatment in development
- Peptide immunotherapy
  (similar to allergy desensitisation)

Autoimmune Disease
Factors that can influence the prevalence of autoimmune diseases
- Infections eg. parasites
- Perinatal hygiene hypothesis
- Food, quantity & altered composition
- Exercise
- Climate-ambient temp
- UVW/vitamin D
- Sleep
- Drugs: antibiotics (infant)

Modifiers: culture, education, wealth, access to technology, family size, maternal age...

Infections:
- parasites
- perinatal hygiene hypothesis

Food:
- quantity
- altered composition
  (lipid, fructose etc)

Exercise:

Climate:
- ambient temp
- UVR/vitamin D

Sleep:

Drugs:
- antibiotics (infant)

Modifiers:
- culture, education, wealth, access to technology, family size, maternal age...

It is also important to know how we can turn an over-active immune system OFF!

Images and information provided by Prof Len Harrison, Dr Bob Anderson, Prof Ian Wicks and Dr Rachel Burt (WEHI)
Organ Rejection

Rejection occurs when the immune system of the recipient attacks the transplanted organ or tissue. This is a normal response of a healthy immune system which can detect foreign tissues and destroy them.

Graft versus Host Disease

After bone marrow transplantation, sometimes the transplanted marrow can attack the recipient in a process called “graft versus host disease” (GVHD).

Immunosuppression

Rejection can be reduced by tissue matching of donors and recipients, and by giving the recipient drugs that suppress their immune response.

Organ Transplantation in Australia

- Australia currently has one of the lowest organ donation rates in the developed world. Every organ donor can assist up to 10 recipients to enjoy renewed or improved life. People of all ages can be organ or tissue donors. There is effectively no age limit for corneal (eye tissue), bone tissue, kidney or liver donations.
- You can register online at The Australian Organ Donor Register to be an organ donor at http://www.medicareaustralia.gov.au/

Infection

CMV in the lung (black arrows)

CMV Disease

CMV is a virus commonly found in healthy people but can cause serious infections in people with impaired immunity. The infection can result in pneumonia, gastroenteritis, retinitis or encephalitis. Antiviral medications may stop the replication of the virus but will not destroy it.

History of Transplantation

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>1933</td>
<td>First human-human kidney transplant</td>
<td>Yu Yu Voronoy, Soviet Union</td>
</tr>
<tr>
<td>1954</td>
<td>First successful living donor kidney transplant</td>
<td>Dr. Joseph Murray and Dr. David Hume, Brigham Hospital, Boston</td>
</tr>
<tr>
<td>1962</td>
<td>First successful deceased donor kidney transplant</td>
<td>Dr. Joseph Murray and Dr. David Hume, Brigham Hospital, Boston</td>
</tr>
<tr>
<td>1963</td>
<td>First successful lung transplant</td>
<td>Dr. James Hardy, University of Mississippi Medical Center, Jackson, MS</td>
</tr>
<tr>
<td>1967</td>
<td>First successful liver transplant</td>
<td>Dr. Thomas Starzl, University of Colorado, Denver, CO</td>
</tr>
<tr>
<td>1967</td>
<td>First successful heart transplant</td>
<td>Dr. Christiaan Barnard, Groote Schuur Hospital, South Africa</td>
</tr>
<tr>
<td>1981</td>
<td>First successful heart/lung transplant</td>
<td>Dr. Norman Shumway, Stanford University Medical Center, Palo Alto, CA</td>
</tr>
<tr>
<td>1988</td>
<td>First successful small intestine transplant</td>
<td>Dr. Eberhard Deltz, Kiel, Germany</td>
</tr>
<tr>
<td>1989</td>
<td>First successful living donor liver transplant</td>
<td>Dr. Christoph Broelsch, University of Chicago Medical Centre, Chicago, USA</td>
</tr>
</tbody>
</table>

Organ Transplantation in Australia

- Australia’s transplant success rates are amongst the best in the world
- Pancreas transplants are the most successful at 94% survival at one year and 87% at five years
- Heart-lung operations have the lowest survival rate of 76% survival at one year and 60% at five years

Organ Rejection

Killer T Cells attacking “foreign” cells

History of Transplantation

People in end-stage organ failure require transplantation to survive. Over 30,000 Australians have received organ and tissue transplants since the 1960s. Transplanted organs include kidneys, heart, lungs, liver and pancreas. Tissues include corneas, skin, bone, heart valves and bone marrow.

Eyes / Corneas
Heart and Heart Valves
Lungs
Kidneys
Liver
Intestines
Skin
Femoral & Saphenous Veins
Bone
Tendons

CMV in the lung (black arrows)

CMV disease can affect many organs

Eyes / Corneas
Heart and Heart Valves
Lungs
Kidneys
Liver
Intestines
Femoral & Saphenous Veins
Bone
Tendons

www.lbl.gov
www.britannica.com
www.asm.org

People and tissues for donations

Eyes / Corneas
Heart and Heart Valves
Lungs
Kidneys
Liver
Intestines
Skin
Femoral & Saphenous Veins
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Tendons

www.blomede.com

CMV in the lung (black arrows)

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CMV disease can affect many organs
A detrimental immune response to common environmental agents that are otherwise harmless.

**What causes allergic disease?**

- Genetics
- Environment
- Immune system

**Detection of allergic antibody**

- Skin-prick testing
- Blood specific IgE testing

**Current treatment for allergic diseases**

**Non-specific**
- antihistamines
- β-2 agonists
- corticosteroids
- adrenaline

**Specific**
- allergen avoidance
- allergen immunotherapy

**Food allergy**

- egg
- milk
- peanut
- soya
- fish
- wheat

In 80% cases only 1 or 2 foods involved.

**Food allergy at different ages**

- In 5-6% of children, the overall incidence of food allergy is 1-2%.

**Mild symptoms**

- itching
- hand and groin
- hives
- flushing, rashes
- vomiting, diarrhea

**Moderate and severe symptoms**

- swelling
- lips, tongue
- throat
- wheeze (asthma)
- dizziness, loss of consciousness
- death (rarely)
Human Immunodeficiency Virus (HIV) & Acquired Immunodeficiency Syndrome (AIDS)

HIV
HIV is a retrovirus which is able to infect special cells of the human immune system known as CD4+ T-cells and macrophages. Retroviruses are unique as they are able to insert their genetic material into the human genome and manipulate the cell to allow the virus to hide from the body’s defences. Once infected, a cell will produce more HIV which can then infect other cells. This process gradually causes the destruction of the immune system and is referred to as Acquired Immunodeficiency Syndrome (AIDS). Following anti-HIV treatment, virus replication is stopped and in most cases, full health is restored.

Transmission
HIV can be transmitted during unprotected sex with an infected individual, sharing non-sterile injecting equipment, from a blood transfusion with contaminated blood, and from an infected mother to her child during pregnancy, childbirth or breastfeeding.

World Health Organisation Statistics
- In 2010 estimated that 34 million people are living with HIV around the world.
- There are approximately 2.7 million new infections every year.
- There are 1.8 million AIDS-related deaths every year, 69% of these deaths were in Africa.

World AIDS Day
Every year many countries host World AIDS Day events on December 1 with the intention of raising awareness of the disease, improve access to treatment, and fighting social stigma that is often experienced by people living with HIV. In solidarity with the cause people often wear a red ribbon.

Internet Resources
- Centers for Disease Control and Prevention http://www.cdc.gov/nchhstp/
- International AIDS Society http://www.iasociety.org/

Images and information provided by Gabriela Khoury and Prof Sharon Lewin (Monash University)
Vaccination was first formally demonstrated by Edward Jenner, who used exposure to cowpox to protect people against smallpox. Since then, vaccination has been used to eradicate diseases, including smallpox and polio, and to protect people against many other diseases, including deadly infections such as malaria and dengue fever.

Immunology research in Melbourne now

Melbourne is a leading centre for immunology research in Australia, and the world. Researchers in Melbourne are working on a diverse range of medical challenges, including fighting autoimmune disorders, fighting diseases such as malaria, and harnessing the power and intelligence of the immune system to fight cancer.

Research in Melbourne includes:

• Walter and Eliza Hall Institute of Medical Research
• University of Melbourne
• Burnet Institute
• Peter MacCallum Cancer Centre
• Monash University
• Ludwig Institute for Cancer Research
Monocyte/macrophage

**General features**

Monocytes and macrophages are main players of the innate immune system. They derive from blood stem cells in the bone marrow. Monocytes circulate in the blood and then migrate to the tissue where they differentiate into macrophages.

Once mature, macrophages play a very important role in the immune system. They "vacuum" up pathogens by a process called phagocytosis. Once inside the cell, the pathogens are broken up and parts of them are presented on the surface of the cell. This acts to signal other immune cells and alert them to an invading pathogen. Monocytes therefore act as messengers and interact with other cells such as lymphocytes.

Monocytes contain a large single nucleus which gives them their name meaning mononuclear phagocyte. Macrophages can also phagocytose damaged tissues and are important in wound repair.

**Modes of action:**

- Phagocytosis
- Present antigens to activate B and T lymphocytes
- Release of cytokines / chemical signals to induce inflammation
- Activate complement and antibody secretion

**Pathologies**

Over-activation of macrophages can lead to atherosclerosis (a heart disease) and autoimmune diseases such as arthritis.

Reduced function of these cells can lead to increased susceptibility to infection.

Macrophages also represent a reservoir of viral replication, for instance in the case of HIV infection.

Neutrophil

**General features**

Neutrophils are derived from blood stem cells in the bone marrow and then circulate in the blood. They are relatively short lived, lasting for only a few days. They belong to the innate immune system.

Neutrophils are one of the first immune cells to act against invading pathogens such as bacteria. They contain thousands of tiny granules - small sacks that contain chemicals which help kill pathogens. The neutrophil will engulf the bacteria in a process known as phagocytosis and once the pathogens is inside, it uses the chemicals in its granules to kill the cell.

The neutrophils' toxic activity often results in their own death. Dead neutrophils and their debris are the main constituents of pus at the site of infection.

A defining characteristic of neutrophils is their "multi lobed nucleus".

**Modes of action:**

- Phagocytosis
- Degranulation
- Cytokine secretion
- Neutrophil extracellular trap (NET), consisting of DNA and enzymes to form an extracellular web.

**Pathologies**

People with low levels of neutrophils are particularly susceptible to bacterial infection and may die if they are not treated. This can occur as a result of a genetic disorder, cancer, or as a side effect from drug treatment eg. chemotherapy.

Over-activation of neutrophils can result in autoimmune conditions such as arthritis.
**Eosinophil**

**General features**

Eosinophils are derived from blood stem cells in the bone marrow and then circulate in the blood. They belong to the innate immune system.

Eosinophils help defend the body against attacks by large invading pathogens. They contain thousands of tiny sacks called granules that contain toxic molecules. Once stimulated, eosinophils release these granules to kill pathogens, that are too big for cells of the immune system to engulf.

Eosinophils are especially important in defence against parasitic infections, eg: parasitic worms in the intestines.

Eosinophils turn a characteristic brick red after staining with the acidic dye eosin.

Once released, the content of granules act to kill parasites, but can also cause asthma.

Approximately 4% of white blood cells

**Modes of action:**

- Degranulation
- Cytokines secretion
- Phagocytosis

**Pathologies**

When eosinophils are wrongly stimulated, they release toxic molecules contained in their granules. This results in damage to the lining of airways causing asthma and/or damage other tissues in allergic reactions.

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**Basophil/mast cell**

**General features**

Basophils and Mast cells derive from the blood stem cells in the bone marrow.

Basophils are the rarest of the white blood cells. They contain huge numbers of granules that are used to store chemicals that cause inflammation. The main chemical within these granules is called histamine.

Mast cells are very similar to basophils but reside in tissues. They also contain huge numbers of granules. They are important in wound healing.

After activation, basophils and mast cells degranulate to release different molecules important to eliminate the pathogen. However, this reaction may also lead to allergic reactions.

Basophils are so named as they are “basic loving” ie they can be stained by basic dyes. Staining by Hematoxylin & Eosin will show those cells as blue. Basophils generally have a two lobed nucleus which is often obscured by granules after staining.

Approximately less than 1% of white blood cells

**Modes of action:**

- Release of toxic molecules
- Release of signalling molecules

**Pathologies**

One important pathology associated with basophils and mast cells is anaphylactic shock, which is a severe, whole body allergic reaction that can lead to death. This may be triggered by food (eg peanut), venom (eg bee sting), or medication.

After a first encounter with such a substance, your body may develop a special type of antibody called IgE against it. On a subsequent exposure, these IgE will recognise the substance immediately and will activate the mast cells inducing degranulation and release of large quantities of histamine.

An increased level of basophils can lead to cancer.
**B lymphocyte**

**General features**

B lymphocytes belong to the adaptive immune system. They develop in the bone marrow and subsequently reach the peripheral organs such as the spleen and the lymph node where they become activated.

Every B lymphocyte can recognize only one particular antigen. Upon encountering this antigen, the B lymphocyte will proliferate and differentiate into either plasma cells or memory B cells.

Plasma cells have an enlarged cytoplasmic compartment and secrete large amounts of antibodies. An antibody is a Y-shaped protein that can recognize and bind to a pathogen or an antigen. It can directly block the pathogen or trigger other defence mechanisms such as the complement system or phagocytosis by cells such as neutrophils, monocytes and macrophages.

Memory B cells are able to differentiate very quickly to become plasma cells if the same pathogen infects your body a second time.

**Modes of action:**

Antigen presentation

Cytokine production

Antibody secretion

**Pathologies**

During their activation process, B cells proliferate at a high rate and can accumulate a lot of mutations which may result in cancer called lymphoma.

When plasma cells become malignant, this is called multiple myeloma.

If B cells produce too many inappropriate antibodies, e.g., antibodies against a normal human antigen, this can result in autoimmunity. One example of this is lupus where antibodies can be generated against DNA and histones normally present in our own cells.

**T lymphocyte**

**General features**

T lymphocytes derive from blood stem cells in the bone marrow and migrate to the thymus where they mature. Like the B lymphocytes, they belong to the adaptive immune system.

There are two different classes of T cells - helper T cells and cytotoxic T cells. Every T cell of both classes expresses a specific T cell receptor (TCR). The TCR is a surface protein which enables the recognition of a specific antigen presented by antigen presenting cells. This interaction leads to the activation of T cell function. The activated helper T cells are important to activate B cells, and the activated cytotoxic T cells can directly kill cells infected with a virus.

Some T cells also differentiate into memory T cells to generate a more efficient response if your body encounter the same pathogen a second time.

By histology using H & E staining, B & T cells are indistinguishable.

**Modes of action:**

One T cell recognizes one type of antigen

Helper T cells activate B cells

Cytotoxic T cell recognize & lyse (kill) pathogens

**Pathologies**

When the activation and the proliferation of T cells is not perfectly regulated, a type of cancer known as T cell lymphoma may occur. T cell lymphoma accounts for up to 40% of lymphomas in childhood.

In HIV infection the virus destroys helper T cells. As a consequence, the immune system of the infected patient is very weak and the patient may die from infection by another pathogen (e.g., influenza virus), that they would normally easily fight.
Dendritic cell

General features

Dendritic cells (DC) derive from blood stem cells in the bone marrow. They belong to the innate immune system.

Dendritic cells are always patrolling the peripheral tissues in order to find pathogens. At the mature stage, they have a particular morphology with long projections called dendrites. This morphology is particularly helpful to scan the environment efficiently. They are able to phagocytose the pathogen and present antigen at the cell surface.

Once activated, DC migrate to the draining lymph node or the spleen, to present the antigen to B and T cells and activate them. They make a link between the innate and the adaptive immune systems.

Less than 1 % of white blood cells

Pathologies

Abnormal proliferation of certain types of dendritic cells can lead to a form of histiocytosis, a disease very close to cancer.

Complement system

General features

A number of small proteins in the blood act following an activation cascade to help or “complement” the ability of antibodies or phagocytic cells to destroy pathogens.

Over 25 proteins or fragments of small proteins form the complement system. These are originally produced mainly in the liver and circulate through the blood in an inactive state. Several triggers set off a cascade of events that act to amplify and activate the complement system. These can include binding of complement precursors to antibody-antigen complexes and direct binding to the pathogen itself. Complement activation leads to the formation of the Membrane Attack Complex (MAC) that forms on the pathogen surface.

Tight regulation of the complement system is necessary as the system has the ability to damage our own tissue.

The following are the basic functions of the complement system: (1) opsonization - complement and antibodies cover the pathogen to enhance phagocytosis, (2) chemotaxis - attracting phagocytes to the pathogen and (3) lysis - rupturing of the pathogen through the MAC.

Modes of action:

Complement proteins:

(1) cover the pathogen to enhance phagocytosis (opsonisation),

(2) attract phagocytes to the pathogen (chemotaxis), and

(3) rupture the pathogen (lysis).

Pathologies

Decreased complement levels may be seen with:
Recurrent bacterial infections
Autoimmune diseases
Various types of kidney disease

Complement protein levels are usually increased during acute or chronic inflammation.
Internet Resources

- Australasian Society for Immunology, Inc. Basic Immunology information page, with link to an immunology related quiz.

- British Society for Immunology. A concise and easy to follow description of the immune system, its importance and how it works.
  http://www.immunologyexplained.co.uk/

- European Federation of Immunological Societies (EFIS). An entertaining and interesting site designed to inform people about their immune system. Links to downloadable films and books, including “Your Amazing Immune System - How It Protects Your Body”.
  http://www.immunology-info.org/

- A downloadable game where you must navigate a nanobot through a 3D environment of blood vessels and connective tissue in an attempt to save an ailing patient by retraining her non-functional immune cells. Learn about the biological processes that enable white blood cells to detect and fight infections. Brought to you by the Federation of American Scientists.
  http://fas.org/immuneattack/

- Australian government “Immunise Australia Program” website. Includes vaccination program guide and links to publications and references on topics of vaccination.

- United States (CDC) vaccination information site.
  http://www.cdc.gov/vaccines/

- Walter & Eliza Hall Institute for Medical Research – TV. A number of cool biomedical animations, including immunology related.
  http://www.wehi.edu.au/education/wehi-tv

- Cells Alive. Look inside and understand the way cells work. Descriptions and animations of various immunological processes including making antibodies, phagocytosis, cytotoxic T cell killing etc. Also includes a quiz and links to other cell biology areas.
  http://www.cellsalive.com/toc_immun.htm

- Images of antibodies. Webpages on immunoglobulin structure and function prepared by Mike Clark, PhD, Cambridge University, Cambridge UK.
  http://www.path.cam.ac.uk/~mrc7/mikeimages.html

- The Biology Project (Arizona University) – Immunology. Basic tutorial on the immune system and antibody structure. HIV and AIDS. Further www resource links.
  http://www.biology.arizona.edu/immunology/immunology.html

- A collection of Allergy and Asthma resources on the Internet.
  http://www.immune.com/allergy/allabc.html

- Immunology university course materials. Includes flash animations to help students learn immunology.
  Requires ‘Shockwave’ plugin.

- A general Science education website by the Howard Hughes Medical Institute (USA). Includes “Cool Science for Curious Kids”.
  http://www.hhmi.org/coolscience/