Presumed Knowledge for Theme III

Students entering Year A should have a clear understanding of each of the following biological terms, cellular processes, and biochemical principles. You are STRONGLY encouraged to review and refresh your knowledge of these concepts prior to the beginning of Theme III coursework. This is not a comprehensive list, but it will be to your advantage to consult peers, instructors, and/or external sources as soon as possible if you find gaps in your knowledge of any of these topics...

Physiology (Semester 1)

Energy, metabolism, and homeostasis

Prior to the commencement of Year A, students should be able to:

- Understand the types of "fuel" available for cellular activity, including carbohydrates and fats, and the differences in storage, activation, and breakdown of each type.
- Identify the major types of cellular respiration, including:
    - Anaerobic (alactic and glycolytic types)
    - Aerobic (oxidative phosphorylation, including NADH and $FADH_2$ substrates)
- Identify the major components of the electron transfer chain, including the roles of electron donors and acceptors at each step of the process, and understand the chemiosmotic coupling hypothesis.
- Understand how ATP hydrolysis (ATP → ADP + Pi) drives energy dependent processes across different types of cells.
- Compare and contrast digestion and mobilization of carbohydrates and lipids, and the differences in energy yield between the different types of macromolecules.
- Understand the different circumstances and time course for use of various macromolecular food sources, and the factors which regulate them.

Membrane transport & electrical properties of cells

Prior to the commencement of Year A, students should be able to:

- Understand how the structure of the cell membrane creates a semi-permeable barrier, and how this barrier helps to regulate the internal environment of the cell.
- Identify the following structures and their component substances: phospholipid bilayer, transmembrane protein, hemi-channel protein, glycoprotein, cytoskeletal filament.
- Understand how solutes affect passive movement of water in and out of cells.
- Understand the osmotic effects of IV fluids on blood cells.
- Define osmosis, osmolarity, osmolality, tonicity, diffusion, and filtration, and how they affect separation of the intracellular and extracellular compartments.

- Understand the composition of intracellular and extracellular fluids in terms of ionic concentration, protein concentration, and the how cells act to maintain concentration gradients for individual ionic species (Na^+, K^+, Cl^-, CA^{++}, etc.).
- Understand the concept of a resting membrane potential.
- Understand the effects of electrochemical and concentration gradients on movement of ions across the membrane during rest and during periods of excitation or inhibition.
- Understand the concepts of equilibrium potential, depolarization, and hyperpolarization, and Recognize how the location of a recording electrode affects the appearance of electrical signals obtained from the cell (i.e. why does depolarization of the cell membrane result in a relatively negative waveform on an extracellular recording?).

Intracellular & intercellular communication

Prior to the commencement of Year A, students should be able to:

- Identify the major cellular organelles and their roles in protein synthesis, transport, storage, release, and degradation (e.g. nucleus, golgi apparatus, ribosomes, endoplasmic reticulum, vesicles, lysosomes, etc.)
- Understand exocytosis and endocytosis.
- Understand why excitatory/inhibitory changes in membrane potential are local (i.e. they do not travel far down the length of the membrane).
- Understand the difference between an action potential and a graded potential.
- Identify the ion channels and currents involved in each phase of the action potential, including threshold, rising phase, falling phase, and refractory periods.
- Understand the difference between electrical and chemical neurotransmission, and define an electrical syncytium.
- Identify the major types of neurotransmitters and neuropeptides, and how they are synthesized and stored in the cell.
- Define presynaptic, postsynaptic, active zone, ion channel and metabotropic receptors, and excitatory and inhibitory postsynaptic potentials.
- Identify the differences between a neuron-neuron synapse and a neuromuscular junction synapse.
- Recognize that a postsynaptic neuron may receive input from several thousand (or more) presynaptic neurons.

Microbiology

Prior to the commencement of Year A, students should be able to:

- ❖ understand the normal flora of the body and its roles
- ❖ explore and understand the sources, routes of transmission and mechanisms used by bacteria to invade the human host
- ❖ describe and discuss the natural barriers of the human body to infection and its innate defence mechanisms
- ❖ understand the possible relationships between the human host and microorganisms
- ❖ describe the three domain structure of the living world
- ❖ compare the structure and functions of prokaryotic and eukaryotic cells
- ❖ identify the differences between bacteria and viruses
- ❖ understand the different methods that bacteria and viruses use to replicate
- ❖ understand the necessity for the detection of pathogens
- ❖ understand the concepts of appropriate specimen collection
- ❖ understand the methods used for isolation, culture and identification of microorganisms and examine alternate methods for detection of microorganisms
- ❖ understand how the host response may be used to determine infection and/or immunity
- ❖ understand some of the basic microbiological techniques used to isolate and identify bacteria from clinical specimens
- ❖ understand the types of bacteria that are present as normal skin flora
- ❖ understand the importance of handwashing and disinfection for removal of microorganisms
- ❖ understand the methods available to diagnose infectious diseases, with particular reference to microscopy, culture, serological and molecular techniques
- ❖ identify medically important infectious diseases and some of the associated risk and epidemiological factors
- ❖ understand methods that can be implemented to prevent infection
- ❖ define and understand the principles of sterilisation and disinfection
- ❖ gain knowledge in different procedures and agents that are used to sterilise and disinfect
- ❖ understand how antimicrobial agents work: antimicrobial targets
- ❖ understand mechanisms of resistance to antimicrobial agents
- ❖ gain knowledge in the diversity of fungi
- ❖ recognise how fungi are different from other organisms
- ❖ appreciate how fungal pathogens are classified
- ❖ acquire an understanding of the major diseases caused by fungal pathogens

- describe the general principles of diagnosis, prevention and control of fungal diseases
- understand the general classification of parasites
- gain knowledge of the diversity of parasites
- acquire an understanding of the routes of transmission of parasitic infections
- recognise that parasites can have simple or complex life cycles
- describe the different types of diseases caused by parasites
- describe the general principles of diagnosis, prevention and control of parasitic diseases
- acquire an understanding of what a virus is
- describe what determines the outcome of viral infection
- understand viral transmission and invasion and the different types of viral infections
- understand how viral infections can be controlled
- understand the factors involved in determining a microorganism as medically important
- understand the causes and control of some nosocomial infections
- understand the causes and control of some important community acquired infections
- identify the public health responsibilities required for a range of infectious diseases
- consider the transmission and infective processes of the following viruses: measles and influenza
- understand what features of viruses allow for their possible eradication or control
- understand the situation for each of the viruses listed and what difficulties have been encountered in efforts in their control
- define the meaning of antimicrobial resistance
- understand the bacterial targets of antibiotics
- gain knowledge in the mechanisms of antibiotic resistance
- understand how antibiotic resistance is transferred
- recognise the significance of infectious disease as a global health issue
- understand the mechanisms by which bacteria invade the human body and overcome host defences
- develop an appreciation for how bacteria can adhere to host cells and invade them
- understand the important role that bacterial toxins play in many infectious diseases
- be aware of the differences between bacterial endotoxins and exotoxins
- understand the mode of action of the major classes of bacterial exotoxins
- understand how bacteria cause the cell and tissue damage that leads to the clinical signs of disease
- understand how bacteria invade non-phagocytic cells
- understand how bacteria avoid host cell defences

- ❖ know how bacteria can grow and survive in phagocytic cells
- ❖ understand the general replication cycle of DNA (viral pathogenesis 1) and RNA viruses (viral pathogenesis 2)
- ❖ understand the possible effects of human DNA virus (viral pathogenesis 1) and human RNA viruses (viral pathogenesis 2) on host cells
- ❖ understand mechanisms of viral tumour induction
- ❖ explain in simple terms the life cycle of a retrovirus (HIV)
- ❖ understand the general replication cycle of DNA (viral pathogenesis 1) and RNA viruses (viral pathogenesis 2)
- ❖ understand the possible effects of human DNA virus (viral pathogenesis 1) and human RNA viruses (viral pathogenesis 2) on host cells
- ❖ understand mechanisms of viral tumour induction
- ❖ explain in simple terms the life cycle of a retrovirus (HIV)

Biochemistry

Prior to the commencement of Year A, students should be able to:

- define and describe the structure of protein at the primary, secondary, tertiary and quaternary levels
- describe the essential structural characteristics of amino acids and the nature of peptide bonds
- explain the role of hydrogen bonding in protein structure
- explain the role of hydrophilic/hydrophobic interactions in protein structure
- appreciate the structural significance of point mutations in the amino acid sequences of some proteins (eg haemoglobin)
- explain factors which govern the direction of cellular reactions
- discuss the different types of chemical reactions and the role of cofactors involved in catalysis
- describe the kinetics of enzyme-catalysed reactions and the different modes of enzyme inhibition
- identify the main groups of molecules associated with the life process and the structure of these in relation to their function in living cells
- explain the physical and chemical properties and structures of biological macromolecules in relation to their biological roles
- identify how stored macromolecules are mobilised and catabolised during physical activity (a long distance race) to provide energy for cellular function
- discuss why the body relies more upon carbohydrates as an energy source at the beginning of exercise and on lipids at later stages of exercise
- compare and contrast the amount of energy released from the breakdown of carbohydrates and lipids
- discuss the role of the glycolytic pathway
- discuss the oxygen dependent fates of pyruvate
- discuss the role of the pathway of β-oxidation
- discuss the central role of acetyl-CoA and the citric acid cycle in metabolism
- discuss the concepts of electron transfer and biological oxidation
- describe the features of the electron transfer chain
- identify the coupling between electron transfer and the synthesis of ATP
- compare and contrast the digestion and mobilisation of carbohydrates and lipids
- compare the energy yield of metabolism of carbohydrates (aerobic and anaerobic) and lipids
- discuss the metabolism of alcohol and its impact on varying metabolic pathways

- describe the major biochemical pathways involved in carbohydrate metabolism in the liver
- explain when these pathways are used by the liver
- identify how these pathways are regulated
- compare and contrast the digestion and mobilisation of carbohydrates
- summarise the fate of amino acids (amino groups and carbon skeleton) which enter the liver
- describe the role of the liver in amino acid metabolism
- explain the role of the liver in detoxification of ammonia
- discuss the pathway of ketone synthesis
- discuss inborn errors of amino acid metabolism
- summarise the fate of amino acids (amino groups and carbon skeleton) which enter the liver
- describe the role of the liver in amino acid metabolism
- explain the role of the liver in detoxification of ammonia
- discuss the pathway of ketone synthesis
- discuss inborn errors of amino acid metabolism
- After participating successfully in this session and related activities, students should be able to describe the pathways of lipid synthesis discuss the role and structure of lipoproteins.
- explain how excessive consumption of alcohol disrupts metabolic pathways leading to hypoglycaemia and fatty liver
- discuss the detrimental effects of reactive oxygen species and breakdown products of alcohol on metabolism
- explain the effect of alcohol consumption on the absorption of vitamins
- describe and compare the fuels which are used and stored by the liver, adipose tissue, skeletal and heart muscle, brain and red blood cells
- describe how different tissues use the metabolic pathways in different ways
- discuss when the body uses these pathways and factors that regulate them

Cell Biology

Prior to the commencement of Year A, students should be able to:

- outline the internal organisation of the cell and its relationship to function.
- review cell activities, including import, synthesis, storage, export, collection and disposal of wastes.
- discuss the different stages of the cell cycle of a somatic cell
- compare and contrast the stages of mitosis
- describe the process of meiosis and how it generates haploid cells.
- appreciate the importance of independent assortment and recombination in the generation of genetic diversity.
- discuss the different requirements of ova and sperm and the development of the gametes.
- describe the life cycle of a cell from proliferation, through maturation to eventual programmed cell death
- understand the basic biology of muscle and nervous tissue
- recognise the origin of muscle and nerve cells and interactions between them
- use an organ system to understand how cells and tissues maintain normal function
- discuss the concept of stem cells
- discuss the various development potentials of stem cells
- discuss proven vs Theoretical uses of stem cells in medicine
- discuss the structure of biological membranes
- explain how molecules are transported across biological membranes
- understand how the different types signal transduction work
- describe, in general terms, the key components of signal transduction pathways
- have an appreciation of the outcomes of signal transduction

Genetics

Prior to the commencement of Year A, students should be able to:

- ❖ explain the structure and function of DNA
- ❖ describe the key principles associated with gene and chromosome organisation
- ❖ explain the concept of information flow within cells
- ❖ explain the role of RNA in expressing genetic information
- ❖ describe the synthesis of RNA in cells, with an emphasis on mRNA
- ❖ outline key modes by which the control of gene expression is regulated
- ❖ explain the steps in the synthesis of protein using mRNA as a template
- ❖ describe the role of ribosomes and tRNA in translation
- ❖ describe possible post-translational modifications of proteins
- ❖ explain the basic principles of chromosome replication
- ❖ explain the steps in the replication of DNA
- ❖ explain how the base sequence of DNA can be determined
- ❖ understand the importance of complementary base pairing in the information flow in cells
- ❖ have an understanding of the genetic code
- ❖ know the nomenclature used for chromosome analysis of individuals
- ❖ understand the different classes of chromosomal abnormality: numerical and structural
- ❖ appreciate how the different abnormalities are generated and understand the impact they have on human health
- ❖ identify the different causes of mutations
- ❖ recognise the different types of mutations found in genes
- ❖ understand how different types of mutations can cause different structural and functional effects
- ❖ understand the effect of different mutations resulting in haemoglobinopathies
- ❖ understand the concept of epistasis and how different genes interact with each other
- ❖ know what is meant by the term ‘multifactorial’ trait or disease
- ❖ understand the influence of the environment
- ❖ understand the difference between continuous and discontinuous traits and how this relates to medical conditions
- ❖ recognise the value of twin and family studies in understanding multifactorial traits
- ❖ understand the difference between dominant and recessive traits
- ❖ know the inheritance patterns of autosomal dominant, autosomal recessive and X-linked traits and disorders
- ❖ appreciate the factors that may affect inheritance patterns

- describe the basic capabilities that underpin genetic engineering (eg to synthesise DNA chemically)
- understand the polymerase chain reaction (PCR) and how it has impacted on biomedical science
- understand the outcomes of gene targeting and why we might produce transgenic animals
- understand how DNA technology can be used to produce proteins to relieve disease
- appreciate the basic biochemistry and cell biology applied to the manufacture of protein products using recombinant DNA technology
- understand the basic technologies for mutation detection in DNA and their use for diagnostic applications
- appreciate the potential applications of DNA microarray technology
- Differential gene expression, detailing how proteins control gene expression at the level of transcription and including the involvement of microRNAs in gene expression.
- How nucleosomes are modified and how this influences local chromatin structure and in turn gene expression.
- DNA methylation and effects on gene expression.
- understand the basic concept of differential gene expression
- outline the basic properties of totipotent cells and stem cells
- understand the concept of therapeutic cloning
- understand the basic concepts and strategy in gene therapy
- to explain aspects of how recombinant DNA technology has provided materials for use in clinical treatment of diseases
- discuss the issues regarding use of such materials
- why people go for genetic counselling
- principles of genetic counselling
- importance of family history
- how to draw and interpret a pedigree
- ethical considerations regarding genetic health information
- be aware of the Hardy-Weinberg law and use it to determine allele and carrier frequencies
- understand the principles of positive and negative selection

Histology and Developmental Biology

Prior to the commencement of Year A, students should be able to:

- understand the different forms and use of light and electron microscopy
- practise the use of a light microscope
- identify various eukaryotic and prokaryotic cells
- stain buccal cells from your oral cavity and view with student microscopes and fluorescence microscopy
- differentiate between the structure of animal (buccal) and bacterial cells
- identify cellular morphology using micrographs
- understand that all organs composed of primary tissue types
- identify the structural characteristics and basic functions ascribed to the primary tissues
- appreciate permanency, stability, lability of tissues
- recognise the evidence for plasticity or transdifferential of stem cells/progenitors within primary tissues
- understand that all organs composed of primary tissue types
- identify the structural characteristics and basic functions ascribed to the primary tissues
- appreciate permanency, stability, lability of tissues
- recognise the evidence for plasticity or transdifferential of stem cells/progenitors within primary tissues
- identify the structural and functional basis of communication between cells in tissues
- describe how and why cells communicate at different levels in physiological systems
- discuss the concept of stem cells/origin embryonic germ layers/body plan
- describe the life history of the germ line
- describe the bilaminar and trilaminar germ disc stages of development
- describe gastrulation and neurulation
- identify organ primordial
- understand how one tissue may be a temporary scaffold for the growth of definitive tissue, eg bone
- recognise a gene's program development of shape, orientation, symmetry
- recognise that interactions between cells/tissues contribute to organ growth including clinical examples, eg congenital abnormalities

Immunology (a number of these concepts will be reviewed in your Year A lectures)

Prior to the commencement of Year A, students should be able to:

- describe cells of the innate immune system: macrophages, dendritic cells, polymorphs
- describe cells of the adaptive immune system: T and B lymphocytes, plasma cells
- identify antibody structure and function: Heavy and light chains, Fab and Fc fragments, Fc receptors, complement, antibody effector functions
- discuss the interaction of innate and adaptive systems at initiation and effector phases of immune response
- describe antigen uptake and presentation; Toll receptors
- define clonal selection theory
- describe effector mechanisms; especially opsonisation
- outline the distinction between self and non-self
- provide a simplified account of self-tolerance by clonal deletion during early lymphocyte development
- discuss the mechanism of antigen recognition by B cells and the role of T cells in their activation
- explain the mechanisms whereby T cells recognise antigen
- discuss the various B cell effector mechanisms, including direct binding to toxins and facilitation of phagocytosis by ‘opsonisation’
- recognise the effector mechanisms of both the CD4 (helper) T cells and the CD8 (cytotoxic) T cells
- describe the concept of immunological memory