BWY Diploma Course
Essential Anatomy and Physiology for Yoga
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Section 1

Introduction and the Nervous System
1. General Introduction

1.1. The current level of understanding of the normal structure (*anatomy*) and functioning (*physiology*) of the human body began with the development of the concept of modern science during the Enlightenment period in late eighteenth century Europe. Since then, the availability of more and more sophisticated techniques has allowed us to investigate not only what we can see with the naked eye, but what can only be revealed by higher and higher levels of microscopic magnification coupled with extraordinarily complex laboratory analytical techniques. It is worth appreciating, for example, that the discovery of hormones could not occur until there were practical methods available for detecting specific small molecules present in minute amounts in the blood. These techniques were only developed during the twentieth century so before that the concept of hormones was unknown and diseases caused by hormonal abnormalities (e.g., diabetes) were untreatable and usually fatal.

1.2. Since its beginnings the approach to modern scientific and medical investigation has involved the breaking down of complex concepts and structures into small parts, with the aim of being able to understand how the whole works. It is, after all, a human characteristic to try to break any complex subject matter up into smaller parts in order to try to make sense of it. The body has not escaped this process. One of the first divisions occurred in the eighteenth century, when the physical body became considered as being a functioning *machine*, distinct and separate from any concept of soul, spirit or life force. The machine was complicated, so it became divided up into a number of *systems* (cardiovascular, nervous, etc). This approach allowed much research to take place, leading to many important discoveries, but it has had the disadvantage of encouraging scientists to forget that the body only functions as a whole with all the systems seamlessly interacting, and that an individual is not just a body, but a living entity imbued with life force.

1.3. Yoga practitioners know that the *body and mind are one* – two sides of the one coin – and that whatever affects one will have an effect on the other. The way that asana practice can change the state of mind, and the quietening effects of meditation on the physical body are two examples of this which are self-evident to any regular yoga practitioner. So, while our approach to the structure and functioning of the body on this course is “systems-based”, we
must remember always that the body actually functions as a whole, and is indivisible from the mind.

1.4. The understanding that the body is made entirely of cells and substances secreted by cells came about gradually with the development of light microscopy. This, together with the introduction of the use of aniline dyes to stain tissue (a serendipitous spinoff from the development of these dyes to colour fabrics) enabled 19th century scientists to learn about cells, tissues and organs in a way that had not been possible before. After the Second World War, electron microscopy’s enormous magnifying power opened up the world within the cell, while the rapidly-developing sciences of biochemistry and molecular biology provided ways of understanding the chemical processes happening within cells and the ways in which cells communicate with one another.

1.5. All cells have projecting surface features called receptor sites that allow the “docking” of messenger molecules (hormones, neurotransmitters etc). Once a messenger molecule has “docked”, it passes its message into the cell. It then is either taken up and stored for re-use, or is degraded and removed by enzyme action. Messenger molecules like these are made within the brain, but can also travel to the brain from other parts and affect not only brain function but mood. One family of these molecules that you may have heard of is the endorphins, molecules that are generated in the body (including by physical movement) and which reduce the perception of pain while improving mood. Athletes are well aware of endorphin secretion, which they know produces the “runner’s high”. However, yoga can result in endorphin release in a much more controlled fashion.

1.6. In this part of your Diploma course our aim is to inform you of areas of anatomy and physiology that have direct relevance to your safe teaching and practice. We also hope to infect you with an appreciation of the wonder and magic of the human body, so that you will want to find out more as you progress through your lifetime of yoga study and experience.

1.7 This Unit 1 module is designed as a home study course that together with the assessment takes on average about 30 hours to complete. It is in the form of a guided commentary that you will work through in your own time, and is based on a specific textbook.

The required textbook is

1.8 Please note that the book contains a great deal more information than is required for the Diploma course. It is a general text designed for adults with no scientific training, and has been chosen for this module on account of its
numerous colour illustrations and ready availability. You will be guided through the sections necessary for your learning, but of course if you feel tempted to browse and read further, please feel free to satisfy your curiosity! The relevance to yoga practice and teaching will be pointed out and explained as you work through the study pack.

1.9. The assessment at the end of the module will be done electronically and will be based on reading passages that test understanding. These may include selecting the correct word to make sense of the sentence and/or some multiple choice questions for you to answer.

2 Learning Outcomes

2.1. By studying this section on the Nervous System, you will understand:

1. That nervous tissue consists of neurons (nerve cells) and a population of supportive cells (neuroglia).
2. The structure of a typical neuron (nerve cell), and how it conducts nerve impulses.
3. The basic layout of the brain and spinal cord: the main parts of the brain; the concept of the “three-part” brain.
4. The concept of motor and sensory pathways;
5. The main nerves of the body (cranial and spinal) and a simple description of their distribution.
6. The autonomic part of the nervous system; its sympathetic and parasympathetic divisions, and their main functions; the role of the “FFF” stress response.
7. Nervous system-related conditions that the yoga teacher should be aware of: anxiety, chronic fatigue syndrome (“ME”), depression, epilepsy, migraine, MS, nerve pain, stress and panic attacks, stroke.

2.2. By the time you have completed your study of this section you should be able to explain:

2. How considering the “three-part brain” model can help us to understand how our thoughts and emotions interact, and how they influence the body’s functioning.
3. How asana practice can influence thoughts and emotions by the generation of endorphins and other molecules that affect mood.
4. How a simple understanding of the motor aspects of the nervous system can explain how we learn complex movement patterns, for example yoga asanas.
5. How a simple understanding of the sensory aspects of the nervous system can explain how we develop deeper awareness in asana practice, and why it is important to avoid movement in savasana and during relaxation or yoga nidra practice.
6. Why strongly stretching a muscle will not result in as good a lengthening as gentle stretching because of the activation of the stretch reflex.

Working through the Book

3.1 Now, let’s make a start on the book! See the Introduction (pp. 10-11, unnumbered, but before pp. 12-13). Here (in Levels of Organisation) the authors acknowledge that their approach is to consider the body as a machine. The body consists of cells. Cells with a function in common are organised together into tissues, and different tissues are organised together to form organs. A body system consists of a number of organs with a common purpose, for example the digestive system consists of the stomach, intestines and other organs whose function is to take in, break down and absorb the nutritional components of our diet. Read the sections Anatomy and Physiology.

Pp. 12-13 illustrate modern ways of investigating the body using imaging techniques, have a look at this only if you are interested.

Pp. 14-17 illustrate the main body systems. Look briefly at these. See how different organs make up each system, but do not try to take in all the information at this time.

3.2. Now, before we begin to study the nervous system, please read p. 20, Information Processing. This summarises the functioning of the body’s communication network, consisting of the nervous and endocrine systems. Until about 40 years ago it was considered that these were two distinct systems. The nervous system conveyed messages to cells and tissues by means of weak electrical impulses that travelled along nerves, while the endocrine system produced small message-carrying molecules that used the bloodstream as a means of distribution to their target cells. It then became apparent that the nervous system used message-carrying molecules as well as nerve impulses, so with time the distinction between the two systems has gradually broken down – it is more accurate today to talk of a combined neuroendocrine system. In addition, it is now recognised that most (probably all) cells produce small information-carrying molecules, and that the concept of the term “endocrine organs” as being restricted to the ones that were first recognised as such (eg the thyroid or pancreas) is a bit out of date. Organs such as the heart, lungs and kidneys, which in the past were not thought of as being possible hormone secretors, are now known to be very much involved in this process.

3.3. Pp. 24-25 illustrates how cells come together to form tissues, tissues form organs and organs form systems, as was mentioned above. Have a look at this only if you are interested.
3.4. Now turn to pp. 78-79, and see a diagram of the nervous system. Notice the cable-like nerves all attached either directly to the brain (cranial nerves) or to the spinal cord (spinal nerves). What the diagram does not show is the smallest branches of nerves, as these are microscopic. Identify the sciatic nerve in each leg, and trace it back to its attachments to the lower part of the spinal cord. Compression of the nerve near its attachments to the cord causes the pain called sciatica. Now we need to find out more about the structure and functioning of nerves, so turn to pp. 80-81.

3.5. Pp. 80-81. The nervous system consists of two main populations of cells, plus an excellent blood supply. The two populations are (i) nerve cells, also called neurons, and (ii) a diverse group of supporting cells called collectively neuroglia (L. = “nerve glue”). Neurons produce and conduct electrical impulses, while the neuroglial cells act to support, nourish and otherwise maintain the neurons. Neurons are an odd shape, shown in the main picture on pp. 80-81. Each has a cell body, numerous dendrites and one single axon. The cell body containing the cell’s nucleus is in the forefront of the picture, coloured green.

3.6. Extending from the cell body are several branching tentacle-like projections called dendrites (Gr. dendron = “tree”). The axon, drawn wrapped in yellow coverings, is stretching away from the cell body and goes off the top right of p. 81. Dendrites receive information coming into the neuron, while the axon carries impulses away from the cell body. You can see a second neurone’s cell body at the top left of p. 81, and its axon ending coming to lie close to the cell body of the main neuron shown, in order to convey a message to the main neuron. Great numbers of impulses come into a cell body, and these may result in the cell body formulating an electrical response. This response leaves via the axon to go to another cell. The receiving cell could be another neuron, gland cells or muscle tissue. Neurons in the brain and spinal cord form chains that pass impulses along the chain from cell to cell. These are called nerve pathways.

3.7. Now to explain those wrappings around the axons. Many (but not all) axons are insulated in order to speed up the conduction of impulses along the axon. The “insulation” is a fatty white material called myelin. A type of neuroglial cell provides the myelin, and as each cell can only myelinate a short length of axon, the insulation has a segmented appearance. Myelinated axons conduct impulses more quickly than unmyelinated ones. There are several diseases where the myelin layer becomes damaged - multiple sclerosis (MS) is the commonest. A cross section of a nerve axon with its myelin coating is shown at the bottom right of p.81.

3.8. Look briefly at pp. 81-82. Neurons come in different shapes, as shown in Types of Neuron on p.82. You do not need to know the different shapes, just be aware that although they are not all the same shape they work more or less the same way. An axon is sometimes referred to as a “nerve fibre.”
“nerve” (eg the sciatic nerve) consists of thousands of nerve fibres (axons) bundled together and wrapped in layers of protective connective tissue. This is shown on p. 82, in the section titled Nerves. Don’t worry about any of the names, just see the principle.

3.9 Nerve axons are either carrying instructional messages from the brain or spinal cord to a target gland or muscle tissue, telling it to secrete or contract respectively (motor axons), or carrying informational sensory messages from sensory nerve endings towards the spinal cord or brain (sensory axons). In other words a neuron cannot carry both motor and sensory messages within its axon, it is either motor or sensory in function. Of the thousands of axons in spinal nerves like the sciatic nerve, some are motor and some are sensory, thus spinal nerves are called “mixed” nerves.

3.10 Pp. 84-85 illustrates how a nerve impulse is delivered to its target cell, in this case another neuron. At first glance, the diagram looks complex, so let’s take it bit by bit. In the background on p. 85, identify the neuron cell body and its myelinated axon. The impulse is generated in the cell body and travels along the surface of the axon due to the movement of ions in and out of the axon membrane – but you do not need to understand this in any detail to become a good yoga teacher! In the forefront of p. 84 see the axonal ending, containing little round structures that look like bubbles. It comes close to the target cell surface, but does not touch it. This means that there is a narrow gap between the axonal ending and the target cell. The electrical impulse from the axon cannot jump the gap, so another mechanism swings into action to carry the message across to the target cell – the bubble-like structures (which contain specific messenger molecules) burst at the axonal ending, liberating the molecules which diffuse across the gap and convey the message successfully to the target. The molecules are then either collected up again into new “bubbles” ready for re-use, or are broken down by enzymes, so the effect of that impulse is ended. This area, where a neuron passes its message across a gap using messenger molecules is known as a synapse (Gr. syn- = together, haptēn = to fasten). The messenger molecules here are collectively known as neurotransmitters, and they were the first examples discovered of messenger molecules being employed in the nervous system. Dozens of neurotransmitters have been identified so far.

3.11 Now that we know about the structure of neurons and something about how they work, we can begin to explore the nervous system in more detail. The parts encased in the bone of the skull and spine (the brain and spinal cord) are called the central nervous system, while the parts that lie outside these bones (the nerves) are known as the peripheral nervous system. Be aware that these two components are completely interconnected and work together!

3.12 P. 88-89 illustrate three layers of protective wrappings around the brain. Brain tissue is soft and would sag without support, so it is protected and held in place by these wrappings, collectively known as the meninges. You do not
need to know the Latin names of the three layers, but they are interesting – they all include the term *mater*, which means “mother”, implying a caring protective role. *Pia* means tenderly loving, referring to the way in which the delicate inner membrane enfolds all the surfaces of the brain. *Arachnoid* means “like spider’s web” – an apt description of this cottonwool-like layer, while *dura* comes from the same root as “durable”, describing the strong, canvas-like properties of this supportive and protective outer layer. Latin and Greek terminology is not so daunting when we can relate it to its meaning in English!

### 3.13 Some of the main parts of the brain are shown on p. 90. The most obvious feature is the **cerebral hemispheres**, here seen from the left side. They are subdivided up for convenience into lobes named after the overlying skull bones. At the back, below the hemispheres lies the **cerebellum**, while we can see part of the **brainstem** poking out at the base of the brain. It is continuous with the **spinal cord**.

### 3.14 The **cerebral hemispheres** are very folded, in order to pack as much surface as possible into the confining space within the skull. Humans have more cerebral tissue than any other species on earth. Turn to p. 92 and see a cross-section of the brain that shows the surface layer known as the **cerebral cortex** (L. *cortex* = “rind”): this is made up of **“grey matter”** (it is in life actually a creamy beige), consisting of closely-packed neuron cell bodies. Under this surface lies **“white matter”** (it is white), made up of the myelinated nerve fibres (axons) belonging to those neurons. These fibres form bundles called nerve pathways or tracts. A significant bundle of white matter called the corpus callosum (L. = “tough structure”) can be seen interconnecting the two hemispheres. Note that there are islands of grey matter embedded deep within the white matter- these are clusters of neuronal cell bodies, some of which are labelled (basal ganglia). Others are not visible at this level of cross section.

### 3.15 The **cerebellum** surface (seen from the front on p.92) is also folded in order to fit as much in as possible, but here the folds are small and more parallel to one another. Like the cerebral hemispheres it has an outer cortex of grey matter made up of cell bodies, with their axons forming inner white matter. The cerebellum is interconnected with many other parts of the brain, and is essential for the smooth coordination of complex movements such as walking, writing and asana practice.

### 3.16 The **brainstem** (picture p. 93) consists of three parts – midbrain, pons (L. = “bridge”, from its appearance) and medulla (L. = “marrow”, perhaps from its creamy appearance). It is topped by the thalamus (not technically part of the brainstem), a major relay station for sensory axons ascending from the spinal cord (Gr. *thalmos* = an inner area). Below the thalamus lies the small hypothalamus (L. *hypo-* = below”), also not part of the brainstem. We will return to this.
3.17 The brain is not solid, but has oddly-shaped cavities within. These, called brain ventricles (L. venter = “belly”, meaning a hollow structure) are shown on p. 91. You do not need to know any detail about their shape etc. Turn now to p. 89, which illustrates the circulation of the cerebrospinal fluid (CSF), a watery liquid secreted by certain areas of the ventricles’ lining. It circulates within the ventricles, passes through tiny openings on to the brain surface and circulates within the spider’s web-like arachnoid mater layer of the meninges. From here the CSF is reabsorbed into venous channels within the dura mater.

3.18 Now that we have investigated the overall layout of the brain, we can consider its functions, particularly from the yoga point of view. When considering this it helps to divide the brain up into three main functional areas, remembering always that all areas are interconnected by nerve tracts, so that each area communicates freely with the others.

1. The brainstem and hypothalamus are in evolutionary terms the most primitive part of the brain. The brainstem regulates functions vital to life – it maintains the heartbeat and breathing, and controls blood pressure and body temperature. It initiates the fear response to perceived danger, although this can subsequently be much modified by other areas of the brain. It also contains the vertical nerve pathways interconnecting the spinal cord and the brain. As these tracts run through the brainstem many of them cross the midline, which is why much of the body is controlled by the opposite side of the brain. The hypothalamus is responsible for the regulation of our appetites for food, water and sex. It also directly controls the activity of several (but not all) of the endocrine organs such as the thyroid, ovaries and testes.

2. When we looked at the cross-section of the brain on p. 92, we saw some of the embedded deep grey matter, labelled “basal ganglia” (the plural term “ganglia” is used here to mean a cluster of nerve cell bodies). The neurons in these areas are involved in the control of movement patterns, especially those which we carry out “automatically”, such as walking. There are other clumps of deep grey matter which lie between the cerebral hemispheres and the brainstem/hypothalamus complex. These are represented three-dimensionally (and colourfully!) on p. 94. Together they are referred to as the limbic system (L., limbus = an edge or border) because the 19thC scientist who studied them described the areas as being demarcated from the rest of the brain by a noticeable edge effect. This is the second part of the “three-part” brain. The limbic system is quite ancient in evolutionary terms, although not as “old” as the brainstem and hypothalamus. Do not worry about any of the detail on p. 92, but be aware of the existence of the limbic system because it is very much associated with the processing of emotions and emotional memory – aspects of ourselves that we can access and influence by yoga practice. Notice the pair of green “horns” projecting from the model on p. 94 – these are the
olfactory nerve pathways bringing the sense of smell into the brain from the nose. They are connected directly into the limbic system, which is why the sense of smell can be so emotionally evocative – a fact long made use of by aromatherapists.

3. The cerebral hemispheres, the third part of the “three-part brain, are responsible for the initiation and control of voluntary movement patterns, the decoding and interpretation of sensations (including the special senses of sight, hearing, balance, taste and smell), memory, thinking, language and many of the facets of personality. Much work was done in the last half of the 20thC to identify exactly which areas of the hemispheres control which functions, but more recently it has become clear that the hemispheres work more as an integrated network, rather than as a machine with certain areas responsible for certain tasks. If you would like to learn more about the cerebral hemispheres, turn to pp. 110-111.

3.19 Perhaps the most important development of recent research has been the gradual appreciation of the plasticity of the brain – that is its ability to reconfigure nerve pathways. For many years it was thought that after childhood the brain’s functions were “fixed” and that established pathways could not change. Now it is known that the brain can change its pathways, not only after brain injury, but also through conscious mental effort and visualisation. This is of great importance in the field of rehabilitation after brain injury, for example after a stroke. For us as yoga teachers knowing that brain function (including how we think and feel) can be changed with regular practice can motivate us not only when teaching but in our own practice.

3.20 In yoga practice it is possible to become consciously aware of recurring unhelpful thought patterns, and to replace them with new thought pathways using affirmations such as san kalpa during yoga nidra. New movement patterns that improve general physical posture as well as optimising overall musculoskeletal health can be achieved by regular yoga practice over weeks and months. The more we use specific nerve pathways, the more the chain of neurons forming a pathway become interconnected. “The neurons that fire together wire together”. We can experience this process happening when we learn a new asana – at first we may have difficulty in practising it smoothly, but with time we gradually become more competent.

3.21 The brainstem ends and the spinal cord begins at the well-named foramen magnum (L. “big hole”), the sizeable opening at the base of the skull. However, it is important to realise that the spinal cord is not a separate structure, but rather the continuation of the brainstem that lies within the bony spine. It is shown on p. 98, within its meningeal wrappings. The cord has an inner core of grey matter (neuron cell bodies) and an outer coating of white matter made up of vertically-running pathways made up of myelinated and unmyelinated axons. In cross section the grey matter has an "H" shape. Bundles of nerve axons leave the cord on each side at regular intervals as the
spinal nerves. Each spinal nerve emerges from the cord as small nerve rootlets (coloured green on p. 98), these come together to form the individual spinal nerves which run between adjacent vertebrae (see picture on p. 99) to be distributed round the body. The spinal cord exists as a distinct entity until about waist level, when it breaks up into separate bundles of nerve fibres that form the spinal nerves below this level. Here the cord is well named the cauda equina (L. "horse’s tail") from its visual appearance within the vertebral canal.

3.22 There are 31 pairs of spinal nerves. In addition 12 pairs of nerves emerge directly from the brain – these are called cranial nerves. With one exception that we shall meet below, the cranial nerves supply structures in the head and some of the neck, while the spinal nerves supply the rest of the body. All the spinal nerves are “mixed”, that is they contain both motor axons and sensory axons. Some of the cranial nerves are also “mixed”, but others either contain only sensory axons (eg, the nerves from the eyes and ears), or are predominantly motor to muscles (eg the muscles moving the eyeball). Pp. 102-103 illustrates the cranial nerves, but skip this detail over unless you are particularly interested. Do look at p. 104 though, as this describes the spinal nerves. You will see how the nerves from the cervical (L. cervix = neck) and upper thoracic (L. thorax = chest) spine supply the neck, shoulders and arms. The thoracic spinal nerves run between the ribs to supply motor fibres to the intercostal muscles, plus sensory innervation to the overlying skin, while the lumbar and sacral nerves supply skin, the pelvic organs and the lower limbs.

3.22 Glance at the body maps on p. 105. They show how the cranial and spinal nerves provide skin sensations over the body surface. The area supplied by each pair of nerves is known as a dermatome (L. dermis = skin, tomus = section). Dermatomes are useful in medicine as they help to localise which nerves are causing pain, pins and needles or numbness in the skin. You do not need to know about dermatomes, but you do need to be aware of the importance of skin sensation in yoga practice. We get a great deal of feedback from skin sensory nerve fibres - they tell us about the position of the body, weight distribution over the soles of the feet etc. Much of the sensory information that arrives at the brain remains below the level of consciousness unless we deliberately become aware of it, as we do in yoga practice. In yoga nidra it is important to have the arms away from the trunk and the legs apart, also to remain physically as still as possible throughout the practice. This is because any movement triggers off skin sensory impulses to the brain, disturbing the state of pratyahara that you are aiming to induce.

3.23 The other diagram on p. 105 illustrates a spinal reflex, in this case the stretch reflex, which is very important in asana practice. In the given example the chosen muscle is the quadriceps, but all skeletal muscles behave in the same way. The “quads” (quadriceps) tendon is tapped once just below the kneecap. This action causes the muscle to stretch slightly very briefly, but it is enough to stimulate the numerous sensory nerve endings in the muscle. These
respond by sending back impulses to the spinal cord through the nerve supplying quadriceps (the femoral nerve, formed from three lumbar spinal nerves). The impulses arriving at the spinal cord stimulate the motor neurons whose axons that run with the sensory ones in the femoral nerve to quadriceps. The motor impulses make the muscle group contract, so the knee straightens producing the characteristic “knee jerk”. So, in summary as shown on p. 105, stretching a muscle stimulates it to contract. The contraction happens in a fraction of a second, the time taken for the sensory messages to arrive at the spinal cord and the motor ones to return to the muscle. At the same time as the reflex occurs, other vertically-running sensory nerve fibres in the spinal cord convey the message to conscious awareness, so that we know that the knee has bent – but because these nerve fibres have further to travel, this happens only after the knee jerk has occurred! The importance of the stretch reflex in asana practice is that the more you stretch a muscle, the more it will want to contract. The only effective way to lengthen muscles is to stretch them gently for at least half a minute – this allows the stretch reflex to occur and then die away, after which the muscle will lengthen.

3.24 The section of the nervous system responsible for the motor and sensory nerve supply of skeletal muscles, joints and skin is known as the somatic part (Gr. soma = “body”, referring to the limbs and body wall). The section that is responsible for the motor and sensory nerve supply of the internal organs is called the autonomic part (Gr. “self-governing”, which does not have the same meaning as "automatic"). When the autonomic part was first identified in the early 20thC it was named the sympathetic division (Gr. syn- = together, pathos = feeling), with the meaning of the organs working together in harmony. However, further research showed that the autonomic part of the nervous system was more extensive than had been thought. The newly-recognised component was named parasympathetic, as it works alongside (“parallel to”) the sympathetic.

3.25 Both sympathetic and parasympathetic divisions are controlled by the brain, at levels usually below that of conscious awareness. However, Some highly-accomplished yogis have demonstrated under modern laboratory conditions that it is possible to influence some aspects of its functioning, for example slowing the heart rate or changing the blood flow to various body parts at will.

3.26 Pages 106-107 illustrate the “wiring diagrams” of these two divisions. Do not be put off by these – remember that unless you are an electrician a diagram of the wiring of your home would be really complicated! So take them slowly, remembering that you do not need any of the detail, just the principles. Sympathetic nerve fibres are found in all spinal nerves and are distributed around the entire body. Parasympathetic fibres are found in several cranial nerves and the sacral spinal nerves. They are distributed to the head, neck and trunk, with there being no parasympathetic nerve supply to the limbs. You do not need to know this detail at all, but if you want to know more, read the small print on each page that lists how the sympathetic and
parasympathetic divisions affect the functioning of the body. In general the sympathetic division prepares us for any degree of physical or mental activity, while the parasympathetic is more concerned with day-to-day “housekeeping” functions. However, it is important to understand that both divisions work in harmony together.

Here is a summary of the main functions of each division -

3.27 Sympathetic

- Provides the nerve supply to blood vessels. The vast majority of blood vessels have no parasympathetic supply and rely on the sympathetic for their nerve supply.
- Increases heart rate, the strength of heart contraction and raises blood pressure in response to any degree of physical activity.
- Provides all the nerve supply to sweat glands throughout the body.
- Stimulates the adrenal glands to produce adrenaline, a hormone that augments sympathetic effects.
- Reduces digestive functioning and urine output during exercise.
- Dilates the pupils during exercise and in poor light.
- Constricts skin blood vessels and helps to divert blood to muscles during exercise. (Note: the statement at the bottom of p. 106 that sympathetic nerves dilate muscle blood vessels is incorrect. In general sympathetic nerves cause vessel constriction, and the factors leading to the increased muscle blood flow occurring during exercise are complex, with sympathetic nerves making little contribution).
- Produces ejaculation during sexual activity.
- Gears the body and mind up at times of danger or emotional stress. This is often known as the “FFF” reaction.

3.28 “FFF” reaction

The FFF reaction to a perceived danger or stressful situation does not represent the day-to-day activity of the sympathetic part of the nervous system; it can be considered as the “10 out of 10” response when daily activity results in more like a “2 or 3 out of 10” response. However, the FFF reaction does illustrate what the sympathetic can do – the heart rate increases, breathing becomes quicker and more shallow, blood is diverted away from the gut and kidneys so as to be more available to muscles, the pupils enlarge, the mouth dries and the skin becomes pale. Mentally the mood becomes fearful and anxious. The relevance of this to yoga is that when people are under sustained psychological stress their reaction is chronically more like “5 or 6 out of 10”. This is exhausting, and also it does not take much additional stress to convert this into a full “10 out of 10” FFF response, which in these circumstances is usually referred to as a panic attack. Panic attacks are often made worse by hyperventilation (see the respiratory section of this module). Yoga can help sufferers of stress and panic attacks to understand
what is happening, and gives them the tools to be able to reduce their stress load and gain control over such situations.

3.29 **Parasympathetic**

- Slows the heart when we are at rest.
- Narrows the lung airways to divert air away from unperfused alveoli when we are resting.
- Causes much (not all) of the secretion of digestive juices.
- Is instrumental in producing peristaltic waves of contraction in the gastrointestinal system.
- Causes bladder emptying.
- Constricts the pupils in bright light.
- Produces erection of the penis and clitoris during sexual activity.

**Nervous System Conditions**

3.30 **Anxiety**

Anxiety is classed as a mood disorder. It can be generalised (present all the time) or episodic (occasional). Episodic anxiety tends to be generated by a trigger (phobias) or manifests as panic attacks (see below). Symptoms include fear, worry, palpitations, and often digestive and bowel problems due to sympathetic overactivity. An appropriate balanced yoga practice is very helpful in dealing with anxiety.

3.31 **Chronic Fatigue Syndrome (“ME”)**

A syndrome (Gr. *syn* = together with, *dromos* = occurring) is a collection of signs (what is observed by the examiner) and symptoms (what is complained of by the patient) that together indicate a particular medical condition. Chronic fatigue syndrome (CFS) is classed as a functional disorder, as medical examination and tests do not show any physical abnormalities, however the body and mind obviously are not functioning healthily. The term “ME” (myalgic encephalopathy or encephalitis) is misleading as it does not accurately describe the condition (Gr. *my* = muscle, - *algia* = pain, *encephalon* = brain, *pathos* = suffering in the sense of disease, - *itis* = inflammation. Muscle pain is not a common symptom of CFS, and there is no evidence of physical disease or inflammation in the brain). The main symptom of CFS is absolutely overwhelming fatigue that prevents normal living and produces sleep disturbance, and commonly depression. Yoga can be very helpful, but asana practice has to be carefully moderated for each individual to avoid relapses.

3.32 **Depression**

Depression is a mood disorder, although it can be secondary to physical disease such as thyroid underfunctioning. It can occur alone (unipolar
depression) or in together with episodes of physical and mental overactivity (bipolar disease). Yoga can help in parallel with medical treatment. Asana work usually should be “energising” (but not necessarily strenuous), and long relaxations or extended yoga nidra should be avoided.

3.33 Epilepsy

Epilepsy often is the result of brain damage, although it can occur in the absence of any evidence of this. Seizures (a word preferred now to “fits”) can be major, resulting in loss of consciousness often with loss of bladder control, or minor (“absence” seizures), where consciousness is not lost but the person is unaware of their surroundings and may walk about without being aware of this. Seizure management should be covered in your First Aid training, and teachers should arrange a management plan with any students with epilepsy.

3.34 Migraine

Severe incapacitating headaches, with or without prior visual disturbances. Thought to be the result of inconsistencies in brain blood flow autoregulation (see cardiovascular system section of this module). See p.125. Many migraine sufferers have found complete or partial relief through a balanced yoga practice.

3.35 Multiple Sclerosis (MS)

See p. 127. MS is a demyelinating disease. Yoga can be very helpful, but because the condition is so variable in its effects no specific advice can be given here. The needs of each individual have to be considered, and an appropriate balanced practice devised. It can be most helpful to seek advice from a qualified yoga therapist.

3.36 Nerve pain

Stimulation of somatic sensory pain nerve endings produces different modalities of pain – sharp, burning, aching etc. Localisation on the skin and in the body wall is usually fairly accurate. Stimulation of autonomic pain pathways by injury or disease in internal organs however is poorly localised, and may be “referred”, ie felt in another part of the body – eg gallbladder pain is often felt in the shoulder. Pain caused by compression of spinal nerve roots is felt along the path of the nerve formed from those roots. It is a shooting “electric shock” type of pain, eg sciatica, which is felt along the path of the sciatic nerve.

3.37 Stress and panic attacks

See the section of the FFF reaction above. Yoga practice should be calming. “Non-stimulating” breathing techniques and pranayama practices are
beneficial, as is meditation. An appropriate asana practice that relaxes the body will also ease the mind. People who are very stressed may benefit from not closing the eyes in savasana and yoga nidra, as this can cause too much internalisation or flashbacks.

3.38 Stroke

See p. 124 for the main types of stroke. Research has shown that visualisation techniques help in rehabilitation, while stress reducing practices such as meditation can help with acceptance of any lasting disability.
BWY Diploma Course

Essential Anatomy and Physiology for Yoga

Section 2

The Skeletal System
The Skeletal System

1. Learning Outcomes

1.1. By studying this section on the Skeletal System, you will understand:

1. The general arrangement of bones in the skeleton.
2. The general structure of bone tissue and the structure of a typical bone.
3. The influence of mechanical loading (weight-bearing) on bone structure, and the importance of this.
4. The basic differences between cartilage and bone.
5. The three main types of joint, with examples of each.
6. How synovial joints are classified according to their axes of movement.
7. The structure of the bony spine (including the neck) and its joints.
8. The structure of the pelvis and its joints.
9. The structure of the upper and lower limbs and their joints.
10. Skeletal system-related conditions that the yoga teacher should be aware of – fracture repair, disc prolapse, osteoporosis, ligament injuries, torn meniscus (knee cartilage), osteoarthritis, rheumatoid arthritis, ankylosing spondylitis.

2. Objectives

By the time you have completed your study of this section you should be able to explain:

1. Why asana practice is especially beneficial in helping to maintain bone density in older life.
2. The importance of moving the joints through their full pain-free range of movement regularly in asana practice, and the disadvantages of not so doing.
3. Why the spine does not rotate equally along its length in spinal twists.
4. The importance of maintaining the normal spinal curvatures.
5. Why some people should not take the head back (extend the neck fully) in asana practice.
6. How hypermobile people are at risk in asana practice, and how to avoid this.
7. Why sacro-iliac and knee injuries can occur in asana practice, and how to avoid these.
8. How to identify stiffness in the shoulder joints during asana practice.
3. **Working through the Book**

3.1. To begin your study of the skeletal system, turn to pp. 40-41. Here we see the skeleton. The total number of bones is not important. Rather, look at the pattern of how they are arranged. The skull, spine and ribcage form the long axis of the body – the **axial skeleton**. Attached to this are the upper and lower **limbs**, each connected to the axial skeleton by a **limb girdle**.

3.2. The shoulder girdle consists of two **clavicles** (L. *clavis* = key, because of their shape) or collar bones and two **scapulae** (L. *scapula* = shoulder) or shoulder blades. The pelvic girdle (more often just called the pelvis) consists of two **hip bones** and a **sacrum**.

3.3. Let’s look at the similar pattern of arrangement of the bones in the upper and lower limbs. Each girdle connects its pair of limbs through **ball-and-socket** joints (more of these later). The first limb bone (humerus or femur) is a single long bone (a long bone can be large or small, but is always much longer than it is wide). Each of these long bones finishes at a joint (elbow or knee) where it meets with two long bones more or less parallel to one another (radius and ulna or tibia and fibula). Then we come to another region where several **smaller bones** lie at the wrist or ankle between the hand or foot bones. The hand and foot consist of **five** small long bones (metacarpals or metatarsals), which joint with the finger and toe bones respectively (Gr. *meta* = beyond, L. *carpus* = wrist, L. *tarsus* = foot). Note how the thumb and big toe have each only **two** bones, while the other fingers and toes have **three** bones apiece. Check this out in your own hands and feet, as the diagram is not too clear on the smaller points.

3.4. Although each limb, upper and lower, is designed along this same basic plan, it is of course adapted for its functions – in the foot one of the bones has grown out posteriorly to form the large heel bone or **calcaneus** (L. *calcem* = heel) – a uniquely human characteristic that allows us to walk upright. In the hand the thumb has become especially developed to enable it to **swing round** into the palm and touch the tips of the fingers, allowing us the dexterity that has been an important factor in human development.

3.5. P. 42-43 describes the structure of bones and cartilage. Don’t worry about the text details, but rather familiarise yourself with the picture of a bone. Bones consist of three main components – (a) a background **matrix** of hard concretelike calcium-rich mineral that confers compressive strength, (b) a network of flexible (but relatively non-stretchy) string-like protein fibres called **collagen**, which are embedded within the matrix. These confer tensile strength, as well as resistance to twisting and bending forces, and (c) a population of living...
bone cells that lay down or remove the bone tissue and also maintain it throughout life. Bone tissue is laid down in two main structural formations, and these can be seen on pp. 42-43 – see how the shaft of the long bone shown looks solid, forming what is known as compact bone. The bony ends look more like a honeycomb, well shown at the bottom right of p. 43. This is known as spongy (cancellous) bone (L. cancellus = a lattice). It looks weaker than compact bone but in fact is stronger, because the “lattice” of bone is laid down in such a way as to resist the mechanical forces to which the bone is exposed. Numerous blood vessels penetrate through all bone tissue, supplying nutrition to the bone cells embedded within it.

3.6. It is important to realise that once growth has been completed, although bones look to the naked eye much the same from day to day, they are actually changing dynamically throughout life – every day the mechanical loading that results from weight-bearing activities causes changes in the mineral content of bones. Regular exercise keeps them dense and strong, while lack of weight-bearing exercise results in their gradual demineralisation and weakening. This fact alone should encourage us to maintain a physically active lifestyle, including regular asana practice into old age!

3.7. The external surface of a bone is clothed in a thin adherent membrane called the periosteum (L. peri- = around, osteum = bone). Internal surfaces are lined by a thinner version of this membrane. The periosteum contains a population of dormant stem cells that can be stimulated into activity during growth or when the need for repair or remodelling arises. It contains numerous sensory nerve endings, which are damaged when a bone is fractured (broken) - making such an injury a very painful experience.

3.8. Cartilage is related to bone, having a background matrix with embedded collagen and a population of building, removing and sustaining cells, but the matrix lacks the mineral component that makes bones hard. This means that cartilage is moderately flexible. Unlike bone it does not have a direct blood supply, relying on adjacent blood vessels in surrounding tissues to supply sufficient oxygen and nutrition to meet its needs by diffusion through its matrix.

3.9. Now turn to pp. 44-45, which describes joints. A joint is where two or more (eg. at the elbow there are three) bones meet. There are three main types of joint, distinguished by the type of tissue holding the bones together. Not all joints move freely, although many do. The three types are fibrous, cartilaginous and synovial.

3.10 Fibrous joints are not designed to move appreciably. The bones are “stitched” together by short lengths of collagen that blend with the periosteum on the surface of the bones, forming a strong union. The flat, curved bones
forming the cranium (brainbox) part of the skull are joined by very wiggly fibrinous joints called sutures (L. *sutura* = stitch). This is not particularly well-shown in the bottom left corner of p. 44, but if you are interested turn to p. 49 for a view of these bones that shows their irregular edges.

3.11 **Cartilaginous joints** allow a bit more movement than fibrous joints. Here the bones are held together by cartilage tissue attached firmly to the bony surfaces. The joint between the two hip bones at the front of the pelvis is a cartilage joint called the pubic symphysis, because the right and left pubic parts of the pelvis (see below) form the joint (Gr. *sym-*= together, *phyein*= to grow). This is best seen in the diagrams in the middle of p. 53. The other main cartilaginous joints are the intervertebral discs that lie between the vertebrae of the spine. These will be considered in more detail later.

3.12 **Synovial joints** are the commonest type in the body. They get their name from the appearance of the transparent, viscous, slippery lubricant fluid found within the joint cavity (Gr. *syn-*= together, L. *ovum*= egg) – it looks like raw egg white. With a few exceptions, synovial joints move quite freely. Now look at the diagram of a typical synovial joint on p. 46. The bony ends within the joint are capped with a layer of firmly-attached cartilage called articular cartilage. In a small synovial joint like a finger joint, this layer will be less than 1mm thick, while it is several millimetres thick in the large weight-bearing joints like the knee and hip. This cartilage has three main functions (a) it acts as a shock absorber, (b) it is relatively smooth and thus reduces friction during weight-bearing and (c) cartilage anywhere in the body lacks a nerve supply, thus when the surfaces move against one another there is no discomfort.

3.13 The bony ends in a synovial joint are enclosed in a thin fibrous wrapping called the joint capsule, and this is reinforced by ligaments – strong straps of collagenous tissue that join bones together. Ligaments are important in stabilising joints and controlling their range of movement. They are not designed to stretch significantly, and in yoga practice asana work must avoid overstretched them.

3.14 Because there are many synovial joints in the body, they are sub-classified according to the movements that they permit. The range of movement is related to the shapes of the bony ends making up the joints. Examples of these sub-types are shown on pp. 44-45 – pivot, hinge, gliding, ball-and-socket, saddle and ellipsoidal. Identify one example of each of the given sub-types from these pages, and satisfy yourself that you can tell what sort of movements each will allow by looking at the shapes of the bones involved.

3.15 Consider also what factors other than the shape of the bones will affect range of movement at a joint – the degree of stretchiness of the ligaments (as in
hypermobility), the amount of muscle bulk around the joint, obesity and general stiffness due to lack of movement are all important.

3.16 The commonest reason for overall stiffness in our population is lack of physical activity. This causes the joint capsule to shrink, surrounding ligaments to tighten and muscles to waste. It really is a case of “use it or lose it”! Most of these effects can be reversed by appropriate regular movement within the pain-free range, and yoga is ideal for this. Also, because the mind and body are two sides of the one coin, improving physical suppleness and strength has significant benefits as far as mental and emotional health are concerned.

Spine

3.17 Let us now spend some time studying the spine – literally the “backbone” of yoga practice. It moves during asana practice, and it supports the upper body for seated practices such as meditation. Turn to pp. 50-51, and read the short section headed “Spine Function”. Now look at the examples of typical cervical (L. cervix = neck), thoracic (L. thorax = chest) and lumbar (L. lumbus = loin) vertebrae shown on p. 51. Note how the vertebrae get bigger as you go down the spine, allowing them to carry the increasing body weight. See how each of the cervical, thoracic and lumbar examples shown has some features in common – (a) a body, or main part which is more or less cylindrical, (b) a hole for the spinal cord, (c) projections, including a pair of transverse (side) processes and a single midline spinous process at the back - these are for the attachment of muscles and ligaments. Notice also that the vertebrae from different parts of the spine can be distinguished one from another by slight variations in shape. See below for some comments about the top two vertebrae shown on p. 51, the atlas and axis.

Sacrum

3.18 The sacrum (L. sacros = holy, perhaps because it is not completely destroyed in traditional wooden funeral pyre cremations and thus was thought at one time to be the seat of the soul) is formed from 5 vertebrae that fuse together during childhood to form one solid bone. Notice in the illustration at the bottom right of p. 51 how you can tell that it once was made of separate parts. The tiny coccygeal (“tailbone”) vertebrae connected by synovial joints to the tip of the sacrum represent what would be the tail in other mammals. They are unimportant, unless you fall on to the coccyx and dislocate them - a most painful accident.

Vertebral Joints

3.19 Now consider the joints between the vertebrae (middle right of p. 50) – the bodies are connected by cartilaginous joints called intervertebral discs, with an outer shell made of cartilage reinforced by extra embedded collagen fibres,
while the inner part of the disc consists of a gel centre rather like gel toothpaste. When the spine moves, the gel centre acts like a liquid ball bearing, allowing more range of movement than would be the case if these cartilaginous joints were made of solid cartilage. When we are upright the spine is loaded by the body weight. This causes the side walls of the discs to bulge slightly, similar to the way that the side walls of a car tyre bulge because of the pressure of the air inside the tyre.

3.20 Small synovial joints are found where pairs of projections on the posterior surface of one vertebra overlap with complementary (“matching”) pairs on the vertebra above or below. These are called facet joints, because the articulating surfaces are small (about the size of the little finger nail) and flat. Movements here are small in degree, being gliding or rotational. The orientation of the synovial surfaces is such that they allow only minimal rotation in the lumbar region, which can be experienced as the small amount only through which the lumbar spine (at the level of the abdominal region) will rotate during spinal twists. The thoracic and cervical facet joints are angled to allow more rotation, the neck being able to rotate more than the thoracic region because the ribs exert a “splinting” effect.

3.21 Notice the curvatures of the spine shown from the side on p. 51 – the neck curves forward, the chest region backwards and the lumbar region forwards again. The neck and lumbar curvatures develop during early childhood as the child learns to lift its head and eventually stand. These curvatures develop by the intervertebral discs becoming permanently slightly wedge-shaped, rather than by any shape changes in the vertebrae. The curvatures are affected by the degree of tilt of the pelvis (as in cat pose), and by the pull of attached muscles (eg tight hamstrings will tilt the pelvis back and straighten the lumbar curve in forward bends). They can also be permanently changed as the result of disease (eg increased thoracic curvature in osteoporosis).

3.22 Experiment yourself with the extent of movements of the spine, becoming aware that the spine can move forwards (flexion), backwards (extension), sideways (lateral flexion) and can twist (rotation). All these movements move both the disc and facet joints, and should normally be included when planning a balanced asana practice.

**Neck**

3.23 The top seven vertebrae (p. 51) form the neck skeleton. The first two, the atlas and axis are of untypical shape. The atlas carries the skull, just as in Greek mythology the god Atlas is said to have carried the world on his shoulders. The skull rocks to-and-fro on the atlas, while the skull and atlas together pivot on the axis, producing a rotation of both around a vertical axis, hence the name. Small nodding or head-turning movements move these joints, while to employ all the neck’s disc and facet joints we must use larger movements (chin to chest, chin to ceiling, etc).
3.24 Care should be taken in asanas that take the head back, eg ustrasana (camel) or matsyasana (fish). In some people some of the arteries carrying the blood supply to the brain can be compressed during these movements, producing a sense of light-headedness or even fainting. This can occur at any age, but is more prevalent in older people where the arteries may be already somewhat narrowed by arteriosclerosis. Anyone who finds taking the head back has this effect should of course avoid doing so – it is not a problem that “gets better with practice”. It is also important to know that overstretching arteriosclerotic neck arteries by taking the head fully back can damage their lining. This encourages clot formation and may result in a stroke. As most people over retirement age have some degree of arteriosclerosis, such extreme neck positions are best avoided in this group.

Ribcage and Pelvis

3.25 Now turn to pp. 52-53. This shows the ribs and pelvis. Read “Ribcage” on p. 52, and confirm in the illustration that the ribs are attached at the front as this section describes. We will consider the rib movements further in the Respiratory system section later.

3.26 The pelvis consists of three bones – the two hip bones, right and left, and the midline sacrum. These are shown on p. 53. Read the section entitled “Pelvis”. “Innominate bones” and “ossae coxae” are alternate and unnecessarily complex names for the hip bones. Each hip bone develops by the fusion during childhood and adolescence of three separate bones which are held together by firm but temporary cartilaginous joints before eventually becoming one single bone. The three bones are the ilium (from where we get the term “iliac crest”), the pubis (the two pubic bones are jointed together at the pubic symphysis) and the ischium (from where the “ischial tuberosities or “sitting bones” get their name). The socket for the hip joint (the acetabulum, L. = a small vinegar cup) is made up of equal contributions from all three of these bones. P. 53 demonstrates the sex differences between male and female pelvises, from the yoga point of view these are not important.

Sacro-iliac joints

3.27 Note the joints between the sacrum and hip bone on each side – the sacro-iliac joints. These are synovial joints, but are unusual in that they are designed not to move much. The range of movement produces a slight “nodding” of the sacrum on the hipbones. Because the angle of these joint surfaces is diagonal, the sacrum acts like a keystone, so forward nodding of the sacrum causes the sitting bones to be pushed slightly apart. The counter movement, where the sacrum nods back on the hipbones, allows the sitting
bones to come closer together. In total these movements of the sitting bones are only a few millimetres in either direction, but often they can be felt once your attention is drawn to them – try it in cat pose. In “cat head up” feel the sitting bones move apart, while in “cat head down” they move nearer to one another. Men tend to have less movement here than women, and in some men the sacro-iliac joints actually fuse in older age. Women’s pelvic joints (sacro-iliac and pubic symphysis) are designed to loosen somewhat under the influence of placental hormones during pregnancy. This results in a slight increase in the internal pelvic diameters, which makes it easier for the baby’s head to pass through the pelvis. Some women are left with unstable and painful sacro-iliac joints after pregnancy, while many female yoga practitioners have unfortunately strained and damaged their sacro-iliac joints through inadvisable asana technique (see the section below on “asana practice and the skeleton”).

Upper Limb

3.28 It is time to turn to the limb skeleton, where we need to expand somewhat on the information in the book. We will start with the upper limb. P. 45 (top of page) shows the shoulder region. This consists of the shoulder girdle (two scapulae or shoulder blades, plus two clavicles or collar bones) and the ball-and-socket shoulder joint between the head of the humerus (L. *umerus* = shoulder) and the scapula. Each clavicle (L. *clavis* = key) can be felt under the skin along its length. It is attached to the top of the sternum (Gr. *sternon* = breastbone) by a synovial joint, and wings its way sideways to the acromion or tip of the shoulder (Gr. *acros* = summit, *omion* = shoulder), where it takes part in a synovial joint with the wing-like projection on the scapula (L. *scapula* = shoulder blade). Feel how the clavicle moves like a lever – a small amount at the sternal end and a lot at the acromial end - as you raise and lower your shoulder.

3.29 The head of the humerus bone is like half a golf ball, while the socket for it on the scapula is much smaller and shallow. Movements at the shoulder joint carry the arm forward (flexion), backward (extension) and out to the side (abduction), but only occur to shoulder height or less before the humeral head runs out of articular surface. This limited range of movement at the shoulder joint is compensated for by the considerable mobility of the shoulder girdle. Explore how you can raise, lower, draw together and move apart the scapulae, checking how any scapular movement also moves the clavicles, and passively carries the arms. The scapulae are held against the back ribs only by muscles and thus are freely mobile. When we want to lift the arm above shoulder height the scapula on that side rotates, pointing the socket of the shoulder joint upwards and carrying the arm above the head. Prove this for yourself – place the right hand under the left armpit with the left arm hanging by the side. Feel for the outer border of the scapula behind the armpit with your right hand fingers. Raise the left arm out to the side to shoulder height and note that there is little movement of the left scapula. Now
continue to lift the left arm higher. As you do so, feel the lower corner of the left scapula (which normally points down) moving out to the side and into your right hand as the scapula rotates.

3.30 Be aware of the movements possible at the joint and shoulder girdle. You will observe students in your classes with stiff shoulder joints – because of limited range of movement at the joint they use the girdle early to lift the arm, so that their shoulder region hunches up on that side.

3.31 Turn to p. 44-45. Three bones meet at the elbow joint – the humerus, radius (L. = spoke of a wheel) and ulna (L. = elbow). The upper end of the ulna is large, forming the “point” of the elbow. Its lower end at the wrist is small. This is the opposite to what is found in the radius, which is small at the elbow and larger at the wrist. The humero-ulnar joint is a true hinge, allowing bending (flexion) and straightening (extension) only. The radio-humeral and radio-ulnar joints allow such flexion/extension movements to occur, but also provide rotation of the radius against the ulna. This crosses the radius over the ulna, and carries the hand passively into a palm-down position (pronation). Explore this for yourself – feel the ulna lying just under the skin from one end (the point of the elbow) to the other (the small prominent bump on the little finger side of the back of the wrist). Now rest the back of the left forearm on the right hand, so the supporting fingers lie along the left ulna. Turn the left hand so the left palm faces alternately upwards and downwards (these movements are called supination and pronation, respectively). Confirm that the left ulna is not moving, rather the left radius is crossing over the ulna in pronation. We cannot feel the radius as clearly as the ulna as it is clothed in muscles along its length.

3.32 Now turn to pp. 54-55, where you will see the skeleton of the hand and foot. The wrist region consists of several small bones closely connected together by synovial joints. The lower end of the radius is larger than that of the ulna, and the radius is more involved in the wrist joint – its concave oval lower end makes essentially an ellipsoidal joint (see p. 45) with the adjacent cluster of wrist bones. The oval nature of this joint is why “wrist circles” in asana practice are not very circular!

3.33 The saddle joint that gives the thumb its ability to swing into the palm and allows us dextrous movements is shown on p. 45. Its range of movement is similar to that of a rider astride a saddle – allowing front-to-back and side-to-side movements, but little rotation.
Lower limb

3.34 The hip joints are ball-and-socket in type, reinforced with strong ligaments. The bones make a very good fit that is hard to dislocate. In our Western society however we lose much of the overall range of movement of the hip joints, principally because we sit in chairs and do not squat after toddler life. Western people flex and extend their hip joints to some degree during walking and sitting, but lose most of the full rotational and abductional movements that we are born with.

3.35 Unlike the hip, the knee joint is an example of a poor bony fit. See p. 47, although unfortunately the illustration is not very helpful, you will get a better impression of the shape of the bones involved by looking at the back and front views on p. 41. The shape of the bones would allow too much skidding of the rounded knuckle-like lower end of the femur against the relatively flat tibial surface, and this is avoided by:

(a) four strong ligaments that hold the joint together, limiting movement to within the normal range. The medial collateral ligament runs from femur to tibia on the inner aspect of the knee joint, while the lateral collateral ligament runs similarly from the femur to the fibula on the outer side. A second pair of short but strong ligaments runs from femur to tibia within the joint. They cross one another, hence the names anterior and posterior cruciate ligaments (L. crux = cross). Together these four ligaments prevent skidding of the femur against the tibia.

(b) a pair of curved “C”-shaped cartilage wedges inserted between the bones – these knee menisci (L. meniscus = crescent moon) are commonly known as the “cartilages” of the knee (not to be confused with the articular cartilage layer capping the ends of the bones, found in any synovial joint). P. 59 shows these wedges, though not very clearly.

(c) the muscles crossing the joint also help to stabilise it, especially the four muscles of the quadriceps femoris (“quads”) group. P. 47 shows the white-coloured quadriceps (patellar) tendon connecting the four muscle bellies to the larger of the two lower leg bones, the tibia just below the knee. The patella (L. = kneecap) is embedded in the back of the quadriceps tendon and takes part in the knee joint. Its back surface is coated with a layer of articular cartilage, lubricated by synovial fluid. As the knee flexes (bends) and extends (straightens), the patella glides smoothly against the front of the femur, reducing the friction that would otherwise wear away the tendon.

3.36 The knee is often described as a “hinge”, but this is not an accurate term. It can rotate somewhat when the knee is bent, but when the knee is straight any rotation of the leg comes only from the hip joint, safeguarding the knee region. This ability of the knee to rotate when bent makes it vulnerable to over-twisting in this situation. It rotates when bent because when we are standing, as the bent knee moves through the last few degrees of movement to become
completely straight, the unequal pull of the four ligaments described above causes each femur to rotate slightly inwardly on the tibia. This “screws” the joint surfaces together into a **close-packed position** in which the knee joint acts as if it were completely fused - it will stay straight without any muscle action and will not buckle or “give” unexpectedly. This is an example of the energy-saving design of the body. When we want to bend the knee again, a small muscle in the back of each knee (see p. 67) must first pull the femurs into outward rotation, “unscrewing” the knee joints. This then allows the hamstring muscles to now carry out their normal function of bending the knee.

3.37 The ankle region consists of the ankle (tibia/fibula/talus) joint itself, plus the several foot bones adjacent to it. In the ankle joint the lower ends of the tibia and fibula (L. *fibula* = brooch pin) clasp the sides of the talus (L. *talus* = ankle bone), like a sugar cube held in sugar tongs (identify the talus on p. 55). Movement here is essentially a **to-and-fro hinging one**, with slight rotation only when the toes are pointed. The larger rotational movements that turn the sole in or out (the movements you make when you think you have stepped in something....) are called **inversion** (or supination) and **eversion** (or pronation). They occur between the talus and the sub-talar foot bones, and allow us to walk easily over uneven ground. Over-pronation is seen in **flatfootedness.** Explore how ankle-circling movements in asana practice exercise both the ankle joint and the subtalar joints of each foot.

3.38 Note the strong ligaments connecting the ankle and foot bones together, shown on p. 55, but see how the text wrongly describes ligaments as being “elastic”. They are not significantly stretchy - if they were the whole foot region would be most **unstable**, let alone all the other parts of the skeleton. Books **get it wrong sometimes**.... The material on the rest of this page is not important from the yoga point of view, except that you should explore the way that one can vary the weight distribution over the feet. The right hand side of p. 55 shows how our weight is distributed over the feet during walking. Find out how the body weight can be spread over the feet during standing. Be aware also that through lack of use, many people develop **stiffness** in the metatarso-phalangeal (“ball-of-the-foot”) joints (see “foot bones” illustration on p.55 to locate these), making it difficult to “tuck the toes under” in asanas like adho mukha svanasana (downward-facing dog).

**Asana practice and the skeleton**

3.39 For optimum bone and joint health we should include plenty of **weight-bearing** exercise in our lifestyle, move our joints through their **full pain-free range of movement** regularly, and avoid over-loading by keeping our **weight** within the normal range. Asana practice is an ideal way of doing this, provided that movements are done slowly and with great awareness. This avoids strain and reduces the possibility of yoga-induced injury. The physical benefits of asana practice include the gentle stretching of tight muscles (thus abolishing tension and discomfort), while achieving and maintaining the normal range of
joint movements. They do not include, and **should not include**, the overstretching of ligaments or tendons, as this can lead to joint instability and muscle tears.

3.40 Some people are **hypermobile**, i.e., they have "stretchier" ligaments than usual—in young life they tend to be drawn to activities such as dance, gymnastics and yoga because they can perform them easily, even in advanced forms. Such practitioners need to know that hypermobility carries a high risk of joint wear and tear, and should not attempt to further increase their range of movement much past the normal range in order to safeguard the joints. They should ensure that they have strong muscles—when ligaments are too lax to adequately support the joints, then one must rely on the muscles crossing the joints to do the job.

3.41 It is important to know that pregnant and post-natal women are suppler than when not pregnant, due to the action of placental hormones. These cause the pelvic joints to open slightly, but also have an all-body effect, making all the joints more mobile than usual. Thus generalised over-stretching can occur and should be avoided.

3.42 **Sacro-iliac injuries** commonly occur in asana practice, especially in hypermobile practitioners. **Over-twisting** in spinal twists (especially by the strong use of the arms to lever the trunk around), and the practice of "squaring" the hips in asanas such as trikonasana (triangle), parsvakonasana (wide-legged side stretch) and virabhadrasana II (Warrior II), are the commonest causes of these injuries.

3.43 Be aware too that many yoga-induced knee injuries are as the result of over-twisting the bent knee due to there being insufficient rotational ability in the hip joints. It is important to minimise the chance of bent-knee being over-twisted by being aware that many students will have stiff hips with limited range of movement, and by planning your classes in such a way as to avoid such injuries. During this Diploma course your tutor will stress the important of correct alignment of the knees during asana practice. You will also learn the precautions and modifications necessary to ensure safe practice for those of your students suffering from any of the skeletal problems described below.

**Skeletal System Conditions**

3.44 **Broken bones**

Students may return to class after a broken bone has healed, some even arrive back when still in plaster! Note that a "fracture" is a break—the two words mean the same. Pp. 56-57 show types of fracture, this is only of general interest. The information on p. 57 illustrating how bones heal is reassuring though, as it shows how bones usually do heal strongly after a few months. Once the initial "knitting" of the break has occurred and any hard
plaster or support has been removed, appropriately-paced asana practice can complement physiotherapy in rehabilitating the region back to full strength and range of movement. Immobilisation over several weeks leads to muscle wasting and joint stiffening, which can take some time to recover.

3.45 Disc Prolapse

This is usually called a “slipped disc”, although the disc itself cannot slip as it is firmly attached to the adjacent vertebrae—as you see from reading p.57, what happens is that the outer disc shell splits and the inner gel centre oozes out. This presses on nearby structures, causing pain. Rapidly-developing inflammation further increases pain and muscle spasm around the injury site. If the gel compresses a spinal nerve root where it attaches to the spinal cord, additional pain can be felt along the path of the nerve. If the nerve root is in the lower lumbar or upper sacral part of the spinal cord, the pain is known as sciatica.

3.46 Osteoporosis

Read p. 58 and see how osteoporosis causes the reduction in density of both compact and spongy bone. This weakens the bone, making it more liable to fracture. The commonest sites for osteoporotic fractures are the neck of the femur (“breaking the hip”), the “wrist” (actually usually the lower ends of the radius and ulna) and the vertebrae—the vertebral bodies can collapse under the compression of the body weight, reducing one’s overall height and increasing the thoracic curvature as well as causing pain.

3.47 Ligament injuries

Read the upper half of p. 59. Very common, especially at the ankle region. These can take months to heal, as ligaments have a relatively poor blood supply. Healing is accelerated by regular gentle movement as this stimulates the formation of new collagen. However, healing is delayed if the joint is overused.

3.48 Torn cartilage

Twisting injuries of the bent knee can result in the menisci being ground between the bones at the knee, like in a pestle and mortar. This releases microscopic particles of cartilage into the synovial fluid, and these are very inflammatory—the knee joint swells and is difficult to bend. Minor meniscal injuries can settle with time, but bad tears require “keyhole” surgery when frayed parts of the meniscus can be trimmed away.
3.49 **Osteoarthritis**

Read p. 60, which describes how the articular cartilage coating the bony ends in an affected joint **wears away**, with deformity of the joint surfaces and increasing pain levels. This is the commonest reason for hip or knee replacement. Osteoarthritis (OA) is a common reason for needing modification in asana practice.

3.50 **Rheumatoid arthritis**

A completely different disease from OA, rheumatoid arthritis (RA) is a whole-body **autoimmune** disease, where the body’s immune system mistakenly attacks the joints and other parts (heart, bone marrow, lungs etc). Joint involvement is accompanied by marked inflammation and pain, with progressive joint destruction in the absence of medical treatment. Nowadays treatment is aggressive early on in the disease, in order to **minimise joint damage**. Inflamed joints should not be worked until the inflammation has died down. People with more than mild RA are better catered for in the one-to-one situation, with a teacher experienced in working with this condition.

3.51 **Ankylosing Spondylitis**

This is another **autoimmune disease**, which usually starts with inflammation in the sacro-iliac joints, and then rises progressively up the spine. As the disease burns out, the affected spinal joints **fuse**, resulting in **stiffness** and **increasing thoracic curvature**. Modern treatment minimises the effects of the disease, although the spine usually ends up stiff. Asana practice within the pain free range and featuring gentle back bending and “heart-opening” posture.
BWY Diploma Course

Essential Anatomy and Physiology for Yoga

Section 3

The Muscular System
The Muscular System

1. Learning Outcomes

By studying this section on the Muscular System, you will understand:

1. The general structure of muscle tissue and skeletal muscles.
2. In simple terms, how a muscle contracts, including the principles of nerve/muscle interaction.
3. What is meant by the term “muscle tone” and how yoga practice can influence this.
4. What is meant by the term “proprioception”, and how this sensory information acts as feedback in the control of muscle action.
5. In simple terms, how muscles act to move bones as levers.
6. The concept of core stability and how it relates to asana practice.
7. The basic layout and arrangement of the following muscle groups and their relevance in yoga practice: the muscles of the head and neck, the facial sheet, the trunk, pelvic floor, upper and lower limbs.
8. The following muscular conditions that can be met in a general yoga class: muscle sprains and tears, tendinitis and tenosynovitis, ruptured tendon, carpal tunnel syndrome, cramp, fibromyalgia and myasthenia gravis.

2. By the time you have completed your study of this section you should be able to explain:

1. How muscles contract, the concept of muscle tone, how stress can affect this and how yoga can help.
2. How muscles or muscle groups often work in pairs to produce movements.
3. The effects of moving-with-the-breath asanas and static asanas on muscles and muscle blood flow.
4. How increased awareness in yoga practice can access deeper levels of sensory feedback from the muscles and joints.
5. The importance of maintaining good muscle strength throughout life and how yoga can help with this.
6. Why ligaments and tendons should not be stretched significantly during asana practice.
7. The importance of strong muscles in protecting the joints of hypermobile yoga practitioners.
8. Why good core stability is important in asana practice.
3. **Working Through the Book**

3.1 Muscle tissue consists of cells that are longer than they are wide, and which have the ability to **contract**, becoming shorter. There are three types of muscle tissue in the body, shown on p. 67 – **skeletal** (in the muscles involved in moving the skeleton), **cardiac** (forming most of the wall of the heart) and **smooth** (mostly in the walls of internal organs). The detailed structure of these different types of muscle tissue is unimportant from the yoga point of view. In this section we are going to focus on the skeletal muscles of the body.

3.2 These consist of skeletal muscle tissue, together with blood vessels and nerves, wrapped around and supported by connective tissue (fascia). This connective tissue also attaches muscles to bones, usually through collagenous straps or sheets called **tendons**. On p. 72 you can read about tendons, including how they are connected directly into the periosteal membrane adherent to bone surfaces. Many muscles have a tendon at each end, but in some the muscle fibres are connected to bone through a flat collagenous sheet known as an aponeurosis (Gr. *apo* = from, *neuron* = tendon). Other muscles are attached by their fascial wrapping merging directly into the periosteal surface of the bone.

3.3 Muscle is expected to remain fixed in position during contraction (origin) and Where a muscle connects to bone (whether by tendon or directly) is known as an **attachment**. Observing where any muscle’s attachments are connected to bone can usually allow us to deduce its actions, as the attachments will be pulled closer together when the muscle contracts. Note that the term ‘attachments’ is now preferred to the older terms ‘origin’ and insertion’. These latter designate which end of the which one moves (insertion’), but it is now recognised that many muscles often work ‘either way’; thus the use of the neutral term ‘attachment’ is preferable.

3.4 Like ligaments, tendons are **not** designed to stretch, whether in asana practice or at any other time – because of its strong connection to bone, overstretching a tendon can result in its tearing at the tendon-muscle interface. On p. 72 you can also read about how tendons can be wrapped in a synovial membrane ‘sleeve’, in order to reduce **friction** against bone or other tissues. The tendons of the muscles responsible for extending the fingers and the hand at the wrist are well-shown at the bottom of this page. See if you can feel some of these in your own hands, but do not try to remember the names of the muscles to which they belong.

### Structure of muscles

3.5 On pp. 70 – 71, firstly do not be put off by the complexity of the diagram! We will only take out of it what is useful for our purposes. The deciphering of the mysteries of skeletal muscle’s complicated microscopic structure, which
allowed the development of our current level of understanding of how it functions, was one of the great scientific breakthroughs of the last century. Although as a yoga teacher you do not need to be able to explain this in any depth at all, it is useful to have some idea about how muscles work at the subcellular level, even if only to fill you with the wonder of it all!

3.6. Start at the top of p. 71, identifying the parts of a muscle shown here. The muscle is wrapped around by the outer of a series of three connective tissue layers, this one being called epimysium (the names of these three layers is not important, their function is to carry blood vessels and nerves deep within the muscle). This outer layer can also be called the ‘deep fascia’ of the muscle. See how this typical muscle in cross-section consists of a number of bundles or fascicles each separated by a second layer of connective tissue, here coloured yellow and labelled ‘perimysium’. The term ‘fascicle’ (which also is not important) comes from L. *fasciculus* = a bundle of twigs). Now see how each bundle (one of which has been pulled out a bit from the others) is made up of a number of individual very elongated muscle cells, also called muscle fibres or myofibres (*myo* = muscle). Long before microscopes were invented, people saw that meat (the skeletal muscle of animals) has a fibrous appearance, or ‘grain’, so the term ‘muscle fibres’ came into use then. When we look at meat, what we see as the ‘grain’ are fascicles – the individual myofibres are too small to be distinguished without a microscope.

3.7 Some of these myofibres, wrapped around by the third and finest layer of connective tissue (drawn as a yellow meshwork in the diagram) have been pulled out further and magnified up, snaking into the upper part of p. 70 before curving back into p. 71. Notice the capillaries (labelled) surrounding these myofibres – muscle tissue has an extensive network of nearby blood vessels close to them, as when working it requires lots of nutrition and oxygen. Now see where a single myofibre has been pulled out from the others, it is the cylindrical structure that curves back on to p. 70. Each myofibre consists of an outer cell membrane surrounding the cell’s cytoplasm. In muscle these are given the special names of sarcolemma and sarcoplasm respectively (Gr. *sarcos* = flesh), but you do not need to remember these terms, which appear on p. 71. The cytoplasm of each myofibre is filled with microscopic filaments called myofibrils, arranged in parallel bundles. They are made up of thread-like proteins called actin and myosin, which are arranged in such a way that the myofibres have a striped appearance. You can see this in the centre of p. 71, where the myofibre shown bears more than a passing resemblance to a striped scarf!

3.8 You do not need to read any more about how muscle cells contract (although feel free to do so if you wish). Essentially, it occurs by the actin and myosin proteins inside the myofibre sliding into a close-packed position in the same way that you can ‘close-pack’ your fingers by clasping them together. When all the proteins in a myofibre do this, the overall length of the cell is shortened. Each myofibre in any skeletal muscle (eg biceps in the arm) can only be either
completely close-packed and thus contracted, or else fully relaxed – this is known as the ‘all or none law’ of muscle contraction. The degree to which any individual muscle exhibits contraction depends on what proportion of its total complement of myofibres is contracted at any one time. A typical muscle when contracted can shorten to about one-third to one-half of its resting length. When we hold a muscle strongly contracted for a period of time (eg in a static asana), the individual myofibres within that muscle ‘load-share’, taking it in turns to be contracted for a while and then resting and relaxed while others do the work. This enables the muscle to exert a steady contraction without becoming overly tired. The overall effect is felt as a continuous contraction. Some muscles are designed to work steadily for hours at a time (eg the main back muscles), whereas others (eg most of the hand muscles) will contract quickly and strongly, but tire after a short time.

3.9 Now turn to p. 73 and read the section ‘How Muscles Work Together.’ Many muscles are arranged in pairs or group-pairs, with each member of the pair/group-pair producing the opposite movement from the other member. The example given here is that of biceps and triceps in the upper arm (the prefixes bi- and tri- mean two and three respectively, while ceps = head, referring to the number of muscle bellies present in the muscle). Quadriceps and the hamstrings in the thigh are an example of a pair of groups with opposite actions. During such a movement, the muscle or group actively contracting is called the agonist (derivation), while its opposite number, which is lengthening in a controlled way in order to allow and to control the movement, is called the antagonist. When the arm is flexing (bending) at the elbow (upper diagram), biceps is the agonist and triceps the antagonist. When the arm is straightening at the elbow, triceps is the agonist and biceps the antagonist. However, one must not forget that gravity has a significant part to play in all muscle movements, in fact here triceps though technically the agonist, is being very much helped by gravity while biceps as antagonist is lengthening in order to prevent gravity straightening out the joint too quickly. Much of triceps’ action in the body is helped in this way by gravity, leaving it in most people a relatively weak muscle. To strengthen it further requires repeated contractions to straighten the elbow while moving the body weight against gravity, for examples “gym-style” push-ups, cataranga dandasana(static push-up pose) or adho mukha svanasana (dog head-down).

3.10 The example we have just been considering demonstrates some basic principles of muscle movement. Most movements however are not so simple, and are the result of complex interactions involving numerous muscles. In the example shown, the muscles in the shoulder region would also be contracting during the movement in order to hold the shoulder girdle steady so that the arm is held stable at its attachment to the trunk while the elbow bends. When muscles have this type of stabilising or ‘helper’ action they are known as synergists (Gr. synergos = working together).
3.11 The analysis of muscle movement patterns is a complex science called kinesiology (Gr. kinetikos = moving). This should not be confused with ‘applied kinesiology’, which is a type of alternative therapy. In kinesiology, movement patterns are considered with respect to mechanics, analysing the forces generated and how they act. Most bones act as relatively rigid levers, which move at joints because of the pull of muscles upon them. P. 72, ‘Bones as levers’ gives a flavour of how this can be done. Although it is only of little relevance to yoga teaching, you can see how a thorough understanding of bones as levers would be essential in physiotherapy and in the design of artificial limbs and joint replacements. There are three classes of lever, resulting from the relative positioning of the lever (bone), fulcrum or pivot point (joint) and the force being applied to move the lever (muscle or muscles). Third class levers are the commonest found in the body, the bottom diagram again using the example of elbow flexion. Do not worry about the detail of this short section, but appreciate how the musculoskeletal structures of our body, which we move effortlessly in so many different ways each day are really complex in their design!

3.12 Earlier we saw capillaries lying alongside myofibres (p. 70). Resting muscles require a relatively small blood flow, and many of the capillaries then will be temporarily collapsed and ‘out of action’. When muscles are working, capillary beds progressively open up and the blood flow through the active muscles rises sharply. If a muscle is alternatively contracting and relaxing (eg the leg muscles during walking) the blood flow through it will not be smooth, but intermittent. This is because during contraction the pressure build-up in the muscle temporarily inhibits the low-pressure blood flow through the capillaries. When a muscle contracts and stays contracted, eg as in a static asana (although remember that within that whole ‘contracted’ muscle the individual myofibres are ‘load-sharing’) the overall blood supply to the muscle will be reduced. When the muscle eventually relaxes there will be a surge of blood through it to compensate for the reduced flow beforehand; this can sometimes be felt as a ‘warm’ sensation in the muscles concerned as we release a static asana.

3.13 When skeletal muscles are not actively contracting, they do not become completely relaxed – a small proportion of myofibres will always be contracted at any one time. This produces the phenomenon known as ‘muscle tone’. Muscle tone is important as it supports body structures, eg muscle tone in the pelvic floor supports the pelvic organs and helps to maintain continence, while muscle tone in the small muscles around the shoulder joint keeps the head of the humerus in place against the shoulder socket and helps to prevent shoulder dislocation. Muscle tone cannot be abolished when we are conscious, but it can be temporarily reduced to the bare minimum by deep relaxation techniques like yoga nidra. As anxiety often causes excessive tone in some muscles, practices that encourage deep relaxation will help to change the state of mind as well as be beneficial to the comfort of the body.

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3.14 Skeletal myofibres will only contract when instructed to do so by motor nerve messages coming from the brain or spinal cord. P. 68 shows a myofibre magnified up to show where a tiny nerve motor nerve ending is coming very close to the cell surface, at the region called the motor end plate. Here neurotransmitter molecules released from the motor endings (see the ‘Nervous system’ section) will diffuse across the gap between the nerve and muscle in order to instruct the latter to contract. Note the ‘striped scarf’ appearance of the myofibre. In the absence of motor nerve messages (eg if the nerve is cut or diseased), a skeletal muscle will be paralysed.

3.15 Several types of sensory detector provide feedback about muscle contraction and skeletal movements to the brain and spinal cord. These are all stretch detectors. Skeletal muscles can stretch to about one-and-one-half times their resting length without incurring damage. Small specialised muscle cells called muscle spindles are embedded in the bellies of skeletal muscles. These react when the muscle is being stretched, whereas stretch detectors embedded in tendons will fire when the tendon is being stretched, which is when its muscle is contracting. Stretch detectors in the capsules of joints and in ligaments send back sensory feedback on body movements. This feedback, collectively called proprioception, tells us of the position and overall activity of the musculoskeletal system. Such information is essential to keep the brain and spinal cord informed, and allows us to perform complex movement patterns in a smooth and coordinated way. Although much of it normally remains at subconscious levels, during yoga practice we can tap into this sensory feedback to varying degrees and bring at least some of it to conscious awareness. This helps us to fine-tune the physical aspects of our practice.

3.16 Now we need to look at specific muscles and muscle groups in a way that is relevant to yoga practice. Read the short section on p. 64. Do not remember the number of muscles in the body – facts like these are of no practical use to any yoga teacher! The names and actions of individual muscles (with a very few exceptions, which you will explore later) are also in this category, as few muscles work alone and their actions are best considered in association with their partners. Muscle names (mostly in Latin) usually describe the muscle’s shape, actions or position.

Head and neck muscles

3.17 Muscles of the head and neck are well-shown on pp. 68-69. The head is balanced on the top of the spine in such a way that when we are upright it has a tendency to fall forward. This is resisted by strong vertical muscles in the back of the neck. On p. 68 you can see the right hand half of the great diamond-shaped muscle trapezius (but you will have to turn to p. 66 to see it labelled). Be aware how you can usually work out the action of a muscle by observing the direction of ‘grain’ of its fibres – the upper part of trapezius can pull the scapulae up and towards the midline, while the lower fibres will pull
them down. Trapezius can also pull the head back (extension of the neck), and will also resist the head’s tendency to tip forward under the influence of gravity. In these actions it is helped by the numerous underlying smaller neck muscles shown on the left side on p. 68 (remember, you do not have to learn the names). Psychological or emotional tension causes increased tone in all these muscles, keeping the shoulder girdle slightly lifted as a subconscious defence mechanism – is it any wonder that so many people end up with a stiff and painful neck? Yoga practice can ease these muscles considerably, as well as helping to reduce the mental turmoil causing the problem.

Facial muscles

3.18 The face muscles on p. 69 can be considered as three main groups. Firstly, some fibres are arranged in a circular pattern around the openings of the eyes and mouth. These are sphincter muscles – rings of muscle designed to close an orifice. Gentle contraction will blink the eyes or close the lips, while strong contraction screws up the eyes or purses the lips (try these actions). Secondly, muscles form strips or sheets with the fibres attached at one end to bone and at their other end to the under surface of the skin. Contraction of these produces the various facial expressions – on p. 69 can you identify muscles involved in smiling? Or in wrinkling the forehead in surprise? The muscles of facial expression provide an invaluable component of body language in our communication with others, as their actions clearly reflect our emotional state. The third group of muscles are the powerful chewers – those which bring the lower jaw to meet the upper jaw in biting and chewing movements, and act less forcefully in opening and closing the mouth. See two of these on p. 69 – labelled as masseter and temporalis. The other chewing muscles are inside the jaws and not visible in this diagram.

Trunk muscles

3.19 On pp. 66-67, see two great muscles under the skin of the back on the right side of the diagram. One is trapezius, which we have already met, the other is the broad flat latissimus dorsi (L. “the widest muscle of the back”), often in gyms called the ‘lats’. Note its long vertical attachment to the spine in the midline and how its fibres curve up and out, converging to pass under the arm to attach to the upper humerus from behind. It thus forms part of the bulk of the posterior wall of the armpit, and acts to pull the arm back (extension). If you sit in dandasana with your arms supporting you on the mat behind you, then push up into purvottanasana (upward-facing plank pose, you will be using your latissimus muscles strongly. Now look at the muscles found beneath trapezius and latissimus, shown on the left side of the diagram. In the upper back lie several shoulder muscles which we will consider later, plus the powerful group of vertically-orientated muscles known collectively as erector spinae. This translates as ‘straightener of the spine’, an accurate description of the group’s action. Pay no attention to the individual names shown in the labelling. Erector spinae tirelessly maintains your spine in the upright position.
all day against gravity, and when more strongly contracted will pull it into a back bend. In forward bends it will resist gravity, lengthening gradually to release the trunk forward in a controlled way.

3.20 Deep to erector spinae (but not illustrated here), are numerous short slips of vertically- or diagonally-arranged muscle that span two or more vertebrae. These lack the power of erector spinae, but hold the vertebrae on top of one another to stabilise the spine when it is moving. These deep muscles in the lumbar spine are involved in the concept of core stability, which we shall explore later.

3.21 Now let’s consider the muscles at the front of the trunk. Turn to pp. 64-65, and look at the right side of the diagram (the person’s left side). See the great pectoralis major muscle (‘great muscle of the chest’), attached to the sternum and ribcage and converging towards the armpit. It attaches to the upper humerus. Can you deduce its main action from the direction of its fibres? It pulls the arm forwards (flexion at the shoulder joint), and contributes to all arm-raising movements.

3.22 The spaces between the ribs are filled in by the intercostal muscles (L. costa = a rib). These are not well-illustrated here and will be considered with the respiratory system. Look instead at the abdominal muscles. These consist of three flat overlapping sheets (of which only two can be seen in this diagram), plus the rectus abdominis muscles on either side of the midline (the left one is shown). Firstly, identify the flat sheet muscles – the most superficial one is the external oblique (shown on the person’s left side). It is attached to aponeurotic fibrous tissue in the lower back and passes round the side of the body, its ‘grain’ running forwards and downwards (hence ‘oblique’). In the front it blends with the fascia surrounding rectus abdominis (L. rectus = straight, abdominis is added here to distinguish it from some of the eye muscles that are also called ‘rectus’). Deep to the external oblique is the internal oblique sheet, shown on the person’s right side on pp. 64-65. The attachments of this muscle are similar to those of the external oblique, but the ‘grain’ is at right angles to it, running forwards and upwards (more so than this diagram actually suggests). It is a pity that the third and innermost sheet is not shown, as it is important in core stability – it is transversus abdominis, and its fibres run more or less horizontally across the lower abdomen deep to internal oblique. More of it later.

Pelvic floor muscles

3.23 Turn back to p. 53. The hole down the middle of the pelvis, seen here, is closed by a hammock-like sheet formed of several small skeletal muscles. Collectively, these are known as the pelvic floor group. This is not well-illustrated in this book, but you can get an idea of its structure by clapping your hands palms up, to form a concave ‘hammock’. Imagine this hammock filling in the hole in the middle of the pelvis, the edges of the hammock being
attached to its inside walls. Now look at pps. 256-257, where the pelvic floor muscles are shown cut in midline section. See how in this view they appear as a sheet attached in front to the pubic symphysis (grey, labelled) and pass backwards to the tip of the coccyx. Their functions are to (a) support the pelvic organs, cradling them in the ‘hammock’ – identify from front to back the bladder, uterus and rectum, and (b) to help maintain continence. Find the three tubes passing in the midline from these organs to the outside of the body – the urethra, vagina and anal canal. As they pass through the pelvic floor the muscle fibres exert a ‘nipping’ effect to help to keep them closed. Faecal continence is also reinforced by additional sphincter muscles around the anal canal. Although both sexes have a pelvic floor, problems are much commoner in females: during the reproductive years oestrogen has an overall muscle-strengthening effect, which is lost at the menopause, while some women also suffer pelvic floor damage in difficult childbirth.

Core Stability

3.24 This term derives from Pilates, but the principle was built into asana practice long before this. In simple terms, certain muscles cooperate to stabilise and support the lumbar spine during physical movements. These are sometimes referred to as a ‘muscular corset’, but it would more accurate to describe it as a close-fitting pair of shorts – the ‘corset’ has a gusset! Three main groups of muscle contribute to these ‘shorts’ (although other muscles help) – the abdominal wall muscles (particularly transversus abdominis, known in Pilates as ‘TA’), the small deep stabilisers of the lumbar spine and the pelvic floor muscles. The nerve supply to these three groups is interwired, so that contracting any one will reflexly contract all three. Maximal contraction is not required (and indeed would interfere with one’s normal breathing pattern). In Pilates one is advised to engage TA or the pelvic floor (few people would have any awareness or control of the deep lumbar stabilisers) about 30% of maximal – and this is about right for yoga too. In asana practice, the use of moola bandha, and/or a gentle engagement of the TA muscle (known in the astanga viniyasa tradition as uddiyana bandha) ensures that core stability is switched on and the lumbar region protected while the spine is free to move.

Limb muscle pattern

3.25 Look at the overall arrangement of muscles in the upper and lower limbs. Their arrangement is similar in both limbs, but with differences that reflect the specific functions of each. Consult pp. 64-67 as you read this section, and see if you can identify the basic layout without getting bogged down in names. Afterwards, we shall examine a few specific muscles in more detail. At the shoulder and hip we find powerful muscles that flex (forward movement), extend (backward movement), abduct (moving away from the midline) and adduct (moving towards or across the midline) the whole limb. Their attachments run between the trunk and the limb bones. Deep to these lie a group of smaller muscles that rotate the humerus or femur at the shoulder or
hip joint respectively. At the shoulder this group also stabilises the humeral head against its shallow socket, preventing skid as the overlying more powerful muscles move the arm. During embryological development the lower limb rotates through 180° compared to the upper limb (which is why the ‘inside’ of the elbow faces forward while the crook of the knee faces backwards), thus the muscles that flex (bend) the elbow, wrist and fingers are found clothing the front of the upper arm and forearm, while those flexing the knee, ankle and toes lie along the back of the thigh and in the calf. There is little room at the wrist and ankle, so the muscles for the fingers and toes have long thin tendons that convey their power into the hand and foot without bulk. In addition to these powerful muscles, each hand and foot contains around twenty smaller ones that are involved in movements of the fingers, thumbs and toes.

Upper limb muscles

3.26 The powerful muscles that move the shoulder include three we have already met – trapezius (moves the shoulder girdle), *pectoralis major* (moves the shoulder joint) and *latissimus dorsi* (extends arm at the shoulder joint). Now meet a fourth – *deltoid*. A triangular muscle (Gr. *delta* = ‘D’, written ‘Δ’), deltoid is attached to the clavicle and scapula and passes down like a cap sleeve over the shoulder to attach to the humerus. It is a very versatile muscle, contributing to flexion and extension movements as well as being the main *abductor* of the arm.

3.27 Deep to these muscles lie several smaller ones attached to the scapula. Four of these attach to the head of the humerus by tendons that blend with the shoulder joint capsule. This group is known as the *rotator cuff*. Three can be seen on p. 66 (the person’s right side) – supraspinatus, infraspinatus and teres minor, the names only being mentioned here so that you can identify them. They are shown again (unlabelled) on p. 68. Supraspinatus, a common site of tendinitis (see below), is better shown on p. 74. The fourth member of the group (subscapularis) is attached to the front of the scapula and is not visible in these diagrams. The actions of the rotator cuff muscles are to *stabilise* the humeral head against its socket during arm movements, and to *rotate* the arm at the shoulder joint.

3.28 We have already met biceps and triceps. Biceps is actually more correctly termed ‘biceps brachialis’, (L. *brachium* = arm) to distinguish it from another biceps muscle, biceps femoris in the thigh (one of the hamstrings). This pair of arm muscles is involved in flexion/extension movements at the elbow. In addition, biceps is a powerful supinator, contracting to turn the hand palm upwards. It is not necessary to know the detail of any of the muscles of the forearms, and you have already looked at examples of the tendons passing through the back of the wrist into the hand (p. 72.) See here how a band of collagenous tissue (the extensor retinaculum) straps them down to prevent them ‘bow-stringing’ when the wrist is extended – you do not need to remember this name. There is a similar strap holding down the tendons of
muscles passing down in the front of the wrist, and we will meet this later when we consider carpal tunnel syndrome.

**Lower limb muscles**

3.29 Turn to pp. 64-67. Only some of the muscles that move the limb at the hip joint can be seen. The hip flexor ilio-psoas (actually two muscles that converge to share a tendon) can be glimpsed in part on pp. 64-65. Of these, **psoas** (the “p” is silent, it is pronounced “soh-ass”) deserves a bit more of a mention as it crops up sometimes in yoga books. More accurately called psoas major, to distinguish it from its adjacent little cousin psoas minor, psoas is a long cylindrical muscle tapered at both ends. (Apologies to vegetarians, but the pig psoas can be seen in a butcher’s as a pork **fillet**). Psoas is attached to the lumbar vertebrae and passes down to meet the fibres of **iliacus** (a muscle attached to the inner surface of the ilium). The combined iliopsoas tendon descends through the groin (see diagram on p. 65) to attach to the upper part of the femur. It cannot exert great leverage on the limb because it is attached near the top of the femoral shaft. If called upon to work strongly against gravity (eg in supine leg lifts) the core stability and abdominal muscles are recruited to stabilise the trunk – if they are weak, psoas will pull excessively on its lumbar attachment, which may **strain** the lower back.

3.30 The main hip extensor, **gluteus maximus** (pp. 66-67) is the strongest muscle in the body. The powerful group known as the **adductors** form a bulky mass along the inside of the thigh – their individual names are not important. You can feel the sharp-edged tendon of one of these (adductor longus) at the top of the inner thigh, where it attaches to the pelvis. The **adductors** gluteus medius and minimus (which also help to rotate the limb inwards) are deep to gluteus maximus – medius can be seen peeking out above gluteus maximus on p. 66 (the person’s right side), clinging to the outside of the ilium part of the hip bone, while on the person’s left it has been removed to show minimus underneath medius. The details of these does not matter, but now you know why the buttock is so fleshy under any covering fat!

3.31 In much the same way as the flexors and extensors of the elbow clothe the front and back of the humerus, so the flexors and extensors of the knee clothe the femur (but remember the effect of the lower limb’s rotation during embryological development referred to earlier). At the front lie the four powerful muscle bellies making up **quadriceps**, sometimes referred to as the ‘quads’ (L. *quad* = four, *ceps* = head). Their individual names are not important. Three are attached directly (ie not by a tendon) to the periosteum of the front and sides of the femur, while one (rectus femoris, shown on p. 65) is attached in the more orthodox way by a tendon to the front of the hip bone – this attachment across the hip joint means it can contribute to hip flexion. It also means that in asanas that require lengthening of the quadriceps such as *suptavirasana* (reclining hero) or *natarajasana I* (dancer), a tight rectus femoris will pull on the front of the pelvis, increasing the lumbar curvature. All
four bellies converge to a single strong tendon that crosses the knee joint to attach to the front of the upper tibia. Remember that the patella is embedded in the back of this tendon to reduce friction during knee movements. Quadriceps is the powerful extensor (straightener) of the knee, and tends to be strong (and tight...) in people who walk a lot or play ball-kicking sports.

3.32 The **hamstrings** are three long powerful muscles that flex (bend) the knee. They also rotate the lower leg at the knee joint when the knee is bent. Although they are shown on p. 67, you can see them better on p. 74. They each attach to the ischial tuberosity (sitting bone) of the pelvis and pass down the back of the thigh. Here they diverge, with one attaching to the top of the fibula, the other two to the inner aspect of the upper tibia. The names of the hamstring muscles are not important. One (biceps femoris, which we came across earlier) has an additional attachment to the back of the femur.

3.33 Can you feel the tendons of these three muscles in the back of your knee? On the inner side of the knee one overlies the second one, which can be felt beneath it.

3.34 Below the knee, the extensor muscles of the ankle and foot/toes clothe the **front** of the lower leg, while the flexor muscles lie in the **calf**. Remember not to worry about any of their names, just explore the principles. The extensor muscles to the toes are easily seen and felt under the skin of the top of the foot (p. 65, the person’s left side). Note how, like the flexor tendons at the wrist, they are held against the foot by a strap of collagenous tissue (another retinaculum, here unlabelled). On p. 67 (the person’s right side) identify the powerful flexors forming the bulk of the calf, gastrocnemius and soleus. These two share an attachment through the **Achilles’ tendon** into the heel bone, and are important in contributing to ‘push off’ during walking or running.

*In Greek mythology, when Achilles was a baby his mother dipped him in a sacred river in order to make him immortal. She held him by the heel, which unfortunately did not get wet. Later he was killed by a wound to the heel, his only point of weakness.*

3.35 Under these superficial muscles (p. 67, on the person’s right) lie the hidden but powerful deep flexors of the toes. Their long tendons run behind the inner ankle bone (lower end of tibia) to pass into the sole en route to the toes. They help to support the **arches** of the foot as well as pointing the toes and contributing to ‘push off’ in walking.

**Conditions of the muscular system**

3.36 Some of the common muscular problems are well-described on pp. 74-75, so please read these now. Use the diagrams to help you to understand the topics.
3.37 **Muscle strains and tears**

See p. 74. The connection between a tendon and a bone is so strong that it is uncommon to tear a tendon away from the bone - it is much more likely that the softer **muscle belly** will tear if too strong a force is applied. A torn hamstring (illustrated here) is unlikely to result from asana practice, but it can occur – apparently BKS Iyengar suffered from this injury once as a consequence of performing hanumanasana (splits) when insufficiently warmed up!

3.38 **Tendinitis and tenosynovitis**

See p. 74. Inflammation of the supraspinatus tendon as it passes under the acromion to attach to the head of the humerus (shown here) is a common shoulder problem. Like the other rotator cuff muscles, supraspinatus helps to stabilise the humeral head. Unlike them though it does not contribute to rotatory movements of the arm, but is the important initiator of **abduction** movements: contraction of supraspinatus ‘kick starts’ abduction, positioning the arm so that deltoid can take over to complete the movement. Thus, any supraspinatus inflammation will cause pain during abduction. Acute inflammation of any of the rotator cuff muscles can be so painful as to prevent all shoulder movement, producing a **frozen' shoulder**. The diagram of the foot on p. 74 shows the **synovial sleeves** that surround most tendons where they are at risk of frictional irritation. These delicate membranous wrappings are lubricated within by synovial fluid, allowing the tendons to move easily against nearby structures. Inflammation of these sheaths (tenosynovitis) not only is acutely painful at the time, but can result in long term discomfort due to tendon sheath damage. Inflamed tissues need to be rested until the inflammation has died down, after which they should be gently encouraged to regain their full painfree range of movement.

3.39 **Ruptured tendon**

See p. 75. Not a likely yoga injury for most practitioners, but tendon rupture through trauma from another cause (mostly **sports injuries** or falls) is a serious event. Most cases require repair surgery followed by immobilisation during healing, especially in the case of the Achilles’ tendon shown here.

3.40 **Carpal tunnel syndrome**

See p. 75. The lower ends of the radius and ulna together form a concavity on the inner side of the wrist. The carpal tunnel is formed by this being bridged by a band of fibrous tissue (the flexor retinaculum). See in the diagram on p. 75 how the several tendons and the median nerve pass through the tunnel under this bridge. The **median nerve**, being softer than the tendons, can be compressed. This causes ‘pins and needles’, pain and other unpleasant sensations in the hand, and can result in **muscle weakness** in the longer
term. If necessary, surgical intervention is simple and usually completely effective – the flexor retinaculum forming the ‘roof’ of the carpal tunnel is divided. Scar tissue rejoins the gaping cut edges, making the strap wider and thus making more room in the tunnel.

3.41 Muscle cramps

Muscles often work by alternately contracting and relaxing, for example in the leg muscles during walking. We have already discussed how the capillaries supplying oxygen and nutrition to the myofibres are temporarily compressed during muscle contraction. When the muscle relaxes there is a marked increase in blood flow in order to compensate for the reduction in flow during contraction. Cramp occurs when a muscle’s myofibres all contract and then refuse to relax. The increased pressure generated within the muscle reduces its blood supply for long enough to allow the build-up of metabolic waste products normally removed by the circulation. This causes the characteristic pain of muscle spasm, otherwise known as cramp. The answer to the problem is to stretch the muscle in order to encourage the contracted myofibres to relax. It is unclear why cramps are so common in some people, especially at night, although there seems to be an association with stress. The commonly-suggested cause of magnesium deficiency is actually quite uncommon. Quinine sulphate seems to reduce their incidence, and can be prescribed as tablets, but some GPs recommend a quinine-containing tonic water at night instead (adding gin to it is optional....).

3.42 Fibromyalgia

‘Fibromyalgia’ is a term that is purely descriptive – ‘fibro’ = connective tissue or fascia, ‘my-’ = muscle and ‘algia’ = pain. In other words, ‘pain in muscles and their associated connective tissue’. Fibromyalgia used to be called ‘fibrositis’ or ‘muscular rheumatism’. It is currently classed as a ‘functional disorder’ – one of a group of conditions where medical examination and investigations can at present find no abnormality such as inflammation present, but where the patient complains of symptoms. Here these are of muscular pain that is resistant to painkilling medications, sleep difficulties, tiredness and (often) depression. The condition is common. It seems to be related in some ways to chronic fatigue syndrome, but with pain rather than debilitating exhaustion the primary symptom. As no physical cause has been identified, treatment is based on symptom control rather than cure – a combination of medication, cognitive behavioural therapy and gentle exercise helps a proportion of sufferers.

3.43 Myasthenia gravis

This is a rare auto-immune disease, where the immune system attacks the endings of motor nerves and destroys their ability to release the neurotransmitter that tells muscles to contract. The symptoms are progressive
muscle weakness and tiredness. Treatment is by medications designed to block the actions of the immune system and improve neurotransmitter release at the nerve endings.
BWY Diploma Course

Essential Anatomy and Physiology for Yoga

Section 4

The Cardiovascular System
Cardiovascular System

1. **Learning outcomes**

1.1. By studying this section on the Cardiovascular System, you will understand:

1. The composition of blood.
2. The structure of the heart and the path taken by blood flowing through it.
3. The coronary circulation (the heart’s own blood supply).
4. The cardiac cycle, being the sequence of events during one heartbeat.
5. How the heartbeat is controlled and varied according to need.
6. What is meant by the term “blood pressure”, and how it varies with exercise and with change of bodily position.
7. The following cardiovascular conditions that can be met in a general yoga class: arteriosclerosis, coronary artery disease (CAD), heart attack, deep venous thrombosis (DVT), stroke, heart valve replacement, arrhythmias, high and low blood pressure and varicose veins.

2. **Objectives**

2.1. By the time you have completed your study of this section you should be able to explain:

1. How the heart works, how exercise and stress can affect its functioning and how yoga can contribute towards heart health.
2. How an appropriate asana practice can benefit someone with coronary artery disease (CAD), or in rehabilitation after treatment for CAD.
3. Why all people at or over middle age with diabetes (insulin-dependent or not) should be considered in yoga class as if they have CAD.
4. What is meant by “blood pressure” (BP), how this varies around the body when we are lying flat, upright, or practicing an inverted asana, such as sirsasana (headstand).
5. How in people with normal BP the body maintains the blood flow through the brain within the normal range despite the increase in BP in the head during inverted asanas such as sirsasana.
6. Why people with high BP should be advised not practice strong static asanas.
7. The differing effect on the BP of practicing static asanas and “moving with the breath” asanas (eg sun salutations/surya namaskar).
8. Why people on anticoagulant therapy should be advised not to practice strong inverted asanas or stay long in “head down” asanas.
9. Why people with low BP should not stay long in static standing asanas and why they should take time moving from lying or sitting into a standing position.
10. The effects of “moving with the breath” asanas and static asanas on muscles and muscle blood flow.

2.2 The cardiovascular system consists of a series of tubes containing blood under pressure. The pressure driving the blood around the system is provided by the rhythmic contraction of the heart. The blood vessels vary their diameter in order to direct blood round the body according to need – eg more to the muscles during exercise, or more to the gut during digestion. This distribution is controlled by the combined influences of nerves, hormones and local byproducts of metabolism.

3. Working through the Book

Blood

3.1 Turn to p. 148 and read the section ‘What is Blood?’ Note that we have about five litres of blood in the body, and visualise this in terms of milk or juice cartons to get an idea how much there is. Notice that the fluid content of blood, the plasma, makes up about half its total volume. Plasma contains a lot of water, plus proteins (several of which are mentioned, but this detail is not needed), glucose, hormones etc.

3.2. Note the cell content of the blood. The book is incorrect in saying there are three main cell types in blood, as there really are only two – platelets (shown on pp. 148-149) are not individual cells, but rather are multiple tiny fragments budded off from a very large cell type that lives in the bone marrow. Platelets are involved in blood clotting. Red blood cells (the alternative name of ‘erythrocyte’ from Gr. erythros = red and cytos = cell is not important) are biconcave discs that are unique in that they have no nucleus. This frees up internal space to allow them to contain as much haemoglobin (the iron-containing compound that binds oxygen) as possible. Red cells transport oxygen and carbon dioxide in the blood. See some red cells on pp. 148-149. White blood cells (‘leucocytes’, from Gr. leukos = white), which do have a nucleus, come in several varieties. Find some on pp. 148-149. They are part of the immune system, and spend most of their time out in the tissues, using the blood only as a means of transport from one body part to another.

3.3. Now read the sections describing arteries, veins and capillaries on p. 149. You do not need to know any detail of their structure except that arteries have relatively thick flexible walls containing some muscle, in order to both withstand the pressure of the blood within them and to be able to vary their diameter in order to distribute blood selectively to where it is needed at any
time. The **sympathetic nervous system** controls most of this process, helped by the action of locally-acting substances produced by the vessel walls themselves. Veins are thinner-walled because they carry blood at low pressure and most have valves to encourage one-way blood flow. Capillaries are microscopically tiny vessels, with very thin walls that allow gases and other small molecules to diffuse through their walls.

### Structure of the heart

3.4. Now turn to pp. 150-151, as we start to explore the structure of the heart. Begin by drawing a simple pencil diagram for yourself – a triangle with the apex pointing down and the corners rounded (similar to the outline of that shown in ‘Cardiac Skeleton’ on p. 150). Divide it into two halves by a vertical line. Imagine that this heart on your page belongs to someone standing in front of you, and label its right and left sides (the side on your left is the person’s right side, etc). Now divide each side into two by a horizontal line. You now have a heart diagram with four chambers, so label these – the upper two are the **right atrium** (RA) and **left atrium** (LA), the lower two the **right ventricle** (RV) and **left ventricle** (LV). ‘Atrium’ and ‘ventricle’ both come from Latin words meaning ‘a chamber’, or ‘a space’. Rub out enough of the line dividing each atrium from the ventricle below it to make an opening (atrio-ventricular, or AV, opening) between the two on each side.

3.5 Now we are ready to begin to explore the one-way system of blood flow through the heart. This is most easily done by considering the heart as not one pump, but as **two pumps** - a right and a left, situated side by side. Each pump has a **collecting chamber** (the atrium), while the ventricle below is its **ejecting chamber**. Blood is delivered into the atrium and is directed through the AV opening into the ventricle. The ventricle contracts, forcing blood out of the heart. Valves prevent any back flow; we will see more of these later. Drawing arrows on to your diagram, indicate the direction of blood flow in the atria and ventricles – draw an arrow through the wall to indicate blood entering the atrium and leaving the ventricle on each side.

3.6. Commonly blood is referred to as being either “oxygenated” or “deoxygenated”, which could be taken to mean that “deoxygenated” blood contains no oxygen. This is incorrect - the true situation is that “deoxygenated” blood just contains less oxygen than “oxygenated” blood, because it has given up some (not all) of its oxygen content to the tissues of the body.

3.7. The RA receives **deoxygenated** blood from all of the body except the lungs. It passes through the right AV opening into the RV. The RV sends this blood out to the **lungs**, where it is “topped up” with oxygen and releases surplus carbon dioxide. This **oxygenated** blood returns from the lungs to the heart, into the LA. It passes through the left AV opening into the LV, from where it is sent out **around the body**. Once having been round the body, it returns again
to the RA. Now we have to add the ‘plumbing’, by finding out which blood vessels convey blood into the atria and which take it away from the ventricles. We will also use the diagram on p. 153 (the section labelled ‘double circulation’) to see if you have followed all the above. Firstly, notice that, unlike the heart you drew, the heart does not sit in the body with its point (apex) facing vertically down – it is actually tilted so that the apex faces to the left as well as downwards. Identify the four chambers in the diagram on p. 153. As the chambers are not labelled in this diagram check that you have correctly identified all four of them by looking at the diagram on p. 152, where they are labelled. Now back to p. 153, starting at the RA.

3.8 See two vessels bringing ‘low oxygen’ blood into this chamber, one from above the heart (superior vena cava) and one from below it (inferior vena cava) – ‘vena cava’ is Latin for ‘sizeable vein’. Now follow the blood as it flows through the right AV valve into the RV, from where it turns upwards to exit through the pulmonary artery (labelled). The pulmonary artery (which is also known as the pulmonary trunk, but not in this book) splits at a ‘T-junction’ to form a pulmonary artery branch to each lung. Follow the blood into and through the lung capillary networks, seeing how the colour changes to indicate the ‘topping up’ with oxygen of the blood in the lungs. Now see how vessels from each lung deliver the blood into the LA. There are actually two pairs of these pulmonary veins, one pair on each side. These are better shown and labelled in the diagram on p. 151. From the LA blood flows through the left AV opening into the LV. Trace it as it is ejected into the aorta, to then be distributed either to the regions of the upper body or the lower body. Here see the colour change in the capillaries that indicates the blood giving out some of its oxygen content and picking up surplus carbon dioxide before being returned via the two vena cava veins back to the RA. Congratulations! You have completed both one circuit of the blood through the lungs (the pulmonary circulation) and back to the heart, and one around the rest of the body, supplying all the body systems (the systemic circulation) and back to the heart. You may like to repeat this exercise a few times, to make sure you understand it – it really is just like a one-way traffic system through a town.....

3.9 Note that all Arteries carry blood Away from the heart, and all veins carry it towards the heart. It is not true to say that all arteries carry oxygenated blood and all veins carry deoxygenated blood, as there is one exception to each of these statements. Can you identify what these exceptions are? The answers can be found on p. 149 (‘arteries’) and p. 153 (diagram).

3.10 Four valves in the heart ensure one-way flow. There are two each of two different designs. One design closes the AV openings, while a different design guards the artery carrying blood out of each ventricle. If you are interested, read more about valve structure on p. 150, but this is optional. The AV valves have fibrous cords (the ‘heartstrings,’ that tether the free edges of the valve cusps (flaps) to prevent them turning inside out. The left AV valve is
sometimes referred to as the 'mitral' valve because its two cusps have a resemblance to the 'mitre', or hat, worn by some bishops.

3.11 Now we can appreciate better the structure of the heart. The lower diagram on p. 150 shows the swirling arrangement of the **cardiac muscle fibres** making up the bulk of the heart wall. Cardiac muscle is somewhat similar to skeletal muscle in structure, but unlike skeletal muscle it has the characteristic of being able to contract **without** a motor nerve supply – more of this later. The four heart valves are each supported by a **fibrous ring**, shown in this diagram. The illustration on p. 151 shows how the LV wall is thicker than the RV wall, enabling the LV to contract strongly to provide the great pressure boost needed to convey the blood around the systemic circulation. The pulmonary circulation round the lungs is a much **lower-pressure** system as the lungs are next door to the heart. You can also see some of the ‘heart strings’ of the AV valves, as well as a view from below of the aortic and pulmonary valves.

**Coronary Circulation**

3.12 The heart wall has its own blood supply, to provide nourishment to the hard-working cardiac muscle fibres. This is called the coronary circulation, as it encircles the heart like a king’s crown (L. *corona* = crown). Look now at the upper diagram on p. 150. It shows a cast made by filling the blood vessels of the coronary circulation with a plastic resin and then dissolving away the surrounding tissue. There are **two coronary arteries**, right and left, here coloured red and white respectively. Each at its widest is no thicker than a drinking straw. Both arteries come off the beginning of the aorta and branch repeatedly until they become capillary networks that supply the muscular wall. Blood from these capillaries is drained into the RA via numerous small veins. Circulation through the coronary artery network is **intermittent** as the arteries are designed to fill only between heartbeats. This is because when the heart is contracting the small bloodvessels in its walls are squeezed shut. Coronary arteries can become narrowed or blocked either by **degenerative changes** in their walls (see arteriosclerosis, later) or by **spasm** which can be caused by severe stress or emotional trauma.

**Cardiac cycle**

3.13 Pages 153-154 explain in quite a bit of detail how each heartbeat occurs. You do not need to work through all the information on these pages, it is enough to know the following. The two sides of the heart (the two pumps) work in **synchrony**. Each atrium fills with blood, and as it does so most of the blood flows on through the A-V opening into the ventricle below. The atrium then contracts to ensure complete filling of the ventricle before the ventricle itself contracts to empty into the pulmonary artery (RV) or aorta (LV). When ventricular contraction occurs the A-V valves close to prevent backflow into the atria. Now the whole cycle (called the cardiac cycle, or a ‘heartbeat’).
repeats itself. When the heart relaxes and starts to fill again the pulmonary and aortic valves snap shut to prevent backflow of blood into the ventricles.

3.14 Atrial contraction occurs such a short time before ventricular contraction that to the naked eye the whole heart appears to contract as one. The phase when the heart is contracting is called \textbf{systole} (Gr. = contraction), pronounced ‘SISS-toll-ay’, while the relaxation phase when the heart is filling is \textbf{diastole} (Gr. = expansion), pronounced ‘die-AS-toll-ay’. These words are important as they are used with reference to blood pressure (see below). The ‘lub dup’ sounds heard with a stethoscope during the cardiac cycle are caused not by blood flow through the heart (which is normally silent), but by the \textbf{snapping shut} of the heart valves – ‘lub’ is from the two A-V valves closing in synchrony during systole and ‘dup’ is the pulmonary and aortic valves doing likewise as diastole begins.

\textbf{Control of the heartbeat}

3.15 Because cardiac muscle cells are individually able to contract without a nerve supply, there needs to be a system in place to impose control, so that all contract at the right time in the cardiac cycle. This system, called the \textbf{conducting system}, consists essentially of a small cluster of “bossy” heart muscle cells in the wall of the RA. This region, known as the \textbf{sinus atrial} (or \textbf{SA} node), is the natural \textbf{pacemaker} of the heart. It imposes control over the rest of the heart, sending out electrical messages through the heart wall to ensure co-ordinated and synchronous contraction of the atria and ventricles for each heartbeat. The SA node itself is controlled by two sets of autonomic nerves, the \textbf{parasympathetic vagus nerves} and the \textbf{sympathetic cardiac nerves}. The node’s own inbuilt programming causes it to instruct the heart to contract at about 100-120 beats/min, and in the absence of any nerve supply to the node this is the speed at which the heart would beat. Parasympathetic nerve fibres to the SA node act to \textbf{slow} this inherent rhythm down to resting levels of around 70-80 beats/min (less in the physically very fit). When a faster heartbeat is required for any degree of physical activity (or as a reaction to psychological stress) the combination of a \textbf{reduction} in the frequency of parasympathetic impulses, coupled with the generation of new \textbf{sympathetic} nerve impulses to the SA node via the cardiac nerves cause the node to instruct the heart to contract more quickly.

\textbf{Blood Pressure}

3.16 Now we need to augment the book’s content with some information about blood pressure. As blood travels around the systemic circulation the pressure within the blood vessels \textbf{drops} because pressure is used up in pushing the blood through the miles of tubing involved. Pressure is \textbf{highest} in the aorta and large arteries. It drops markedly as it passes through the smallest arterial channels, the \textbf{arterioles}, so that by the time it reaches the narrow thin-walled capillaries it is flowing slowly at \textbf{low pressure}. This allows time for the
transfer of gases and other substances through the capillary walls without pressure damage to these delicate vessels. By the time the blood is delivered back to the RA it has hardly any inherent pressure left. Thus, measurements of pressure in the systemic system will show different results depending on where you measure. In order to avoid confusion, and to be able to produce data that can be compared with previous readings either in an individual or within populations, measurements of ‘blood pressure’ (BP) are made using a main artery, usually in the upper arm or at the wrist. Other arteries can be used when necessary.

3.17 The blood flow in arteries is not uniform but pulsatile, reflecting the fact that the heart fills the aorta only during systole. BP readings reflect this pulsatility, each heartbeat producing a high reading (the maximum pressure in the artery) and a lower reading (the minimum pressure recorded). The higher reading occurs as the heart empties into the aorta during systole, thus this reading is known as the systolic BP. The lower reading is called the diastolic BP as it occurs during the filling phase of the heartbeat. BP readings are recorded as two numbers, the systolic and diastolic values, written with the systolic above and the diastolic below a horizontal line, eg 120/80 units. The units are millimetres of mercury, as the original BP measuring devices contained mercury. Modern digital measuring devices (mercury-free) are still calibrated using the same scale.

Exercise and the Cardiovascular System

3.18 At rest muscles require a relatively low blood flow. Exercising muscles require a much greater blood flow than resting ones. They have an increased need for oxygen and generate significantly greater quantities of carbon dioxide. During exercise the blood flow to the kidneys and gut is significantly reduced, freeing up blood for redirection to the muscles. The BP and heart rate both rise in order to send the body’s five litres of blood around the circulation more quickly. These changes are due partly to autonomic nervous system activity and partly to the effects of the increased amounts of carbon dioxide and other metabolites generated by the working muscles.

3.19 During exercise the brain receives feedback via sensory nerves coming from baroreceptors and chemoreceptors. Baroreceptors are small sensory structures lying in the walls of blood vessels in the neck and in the aorta. They monitor changes in BP. Chemoreceptors are related structures in the brain, neck and aorta that measure the carbon dioxide content of the blood, plus changes in the blood pH (a measure of the acidity/alkalinity balance of the body).

Effects of Exercise on BP

3.20 All exercise, even getting up from a sitting position or walking across a room, raises the BP from resting levels. Mental stress involving any degree of fear
will also increase it. In physiological terms, exercise can be described as being of two kinds – static and dynamic. Static exercise requires muscles to contract and to remain contracted in order to maintain a particular bodily position, while in dynamic exercise muscles are alternately contracting and relaxing. Note that the term “dynamic” in exercise physiology does not necessarily imply physically challenging (as it sometimes does in yoga); some dynamic exercise can be very gentle (eg wrist circles). Non-yoga examples of exercise are holding a heavy weight up off the floor (static) and walking (dynamic). In yoga practice, asana work can be static (“held” postures, eg vrksasana (tree balance)) or dynamic, eg sun salutations (surya namaskar). Most people would consider an iyengar-style practice to be predominantly static and a Desikachar-style (Viniyoga) one to favour dynamic work. Some asanas can be practised in either a static or a dynamic way.

3.21 Dynamic exercise increases the systolic BP slightly while the diastolic changes very little from resting values. Static exercise tends to increase both systolic and diastolic readings, with the values rising in proportion to the effort required for the task. This is because more force is needed to push blood through the capillary beds of the constantly-contracted muscles. Also the contracted muscles generate more metabolites that increase BP.

3.22 Interestingly, after both types of exercise the raised BP falls, not only to resting values but somewhat below resting values, and it does not return to resting values for several hours. This BP-lowering effect of exercise occurs both in people with normal BP and in those with high BP, and is the reason that people with high BP are encouraged to employ short periods of exercise spread through their day, rather than all done in one session.

3.23 Exercises working the arms raises the BP more than those using the legs, due to the higher resistance to flow in the smaller arm blood vessels. The significance of these facts will be discussed in the section on hypertension below.

Effects of gravity on BP

3.24 Gravity can affect the blood pressure readings. When we lie flat there will be no significant difference in BP readings taken from arteries in the head, at the level of the heart or in the feet. However when we stand up, quite a bit of the pressure in the arterial blood is used up in pushing it up into the arteries above the heart. Thus the BP measured in the head will be lower than at the level of the heart. Conversely, the BP in the foot arteries will be significantly higher than at the heart because of the weight of the column of blood pressing down on the foot arteries. In order to avoid these gravity effects BP measurements are conventionally taken at the level of the heart, whether the person is lying down or upright. Conveniently the midpoint of the main artery in the upper arm lies at the level of the heart, which is why this site is so commonly used for BP measurements. To obtain accurate results from a wrist cuff device the
arm should be supported with the arm resting on a table so that the cuff is level with the heart. For every 13 cm above or below heart level both the systolic and the diastolic BP will be 10 mm Hg lower or higher respectively than a reading taken at the level of the heart.

Inversions and BP

3.25 As explained above, when we are upright the gravitational effect causes the BP in arteries above the heart to be lower than that at the level of the heart, while BP below heart level will be higher. Conversely when we practise inversions, because the feet are now above the heart the BP in the feet falls and because the head is below the heart the BP in the head rises compared to the BP reading at heart level. This is why the feet become pale and the face reddens during the inversion.

3.26 It is essential to life to maintain an adequate blood flow to the brain at all times. In order to help to ensure this, the arteries in the brain regulate the flow by changing their diameter. When we move from lying flat to an upright position the cerebral arteries widen in order to make flow easier. If we turn upside down they constrict and prevent any increase in flow despite the increased BP in the head. This sophisticated system of autoregulation of blood flow by the brain arteries operates well when the overall BP is within the normal range, but it breaks down when the BP falls to abnormally low values (causing unconsciousness and death) or if it is abnormally high (where the result may be rupture of blood vessels in the brain and/or cerebral oedema).

3.27 Remember also that as inversions are usually practised as static asanas, both the systolic and diastolic BP measured at the level of the heart will be significantly raised above resting levels by the constant muscle contraction needed to maintain the asana. This means that the BP-raising effect of gravity inside the head (10 mm Hg for every 13 cm distance below heart level) will be increased from a baseline reading at the level of the heart that is already considerably higher than if the person was at rest. The significance of this will be explained when we consider whether people with high BP should practise inversions.

3.28 Some yoga practitioners suggest that stimulation of the neck baroreceptors (see above) by the increased BP during inversions results in a reflex fall in BP sufficient to control the rise of BP in the head. Some also claim that inversions will “reset” the baroreceptors of people with high BP and thus that inversions are beneficial to this group. These claims should be viewed with caution as the significant increase in BP that can occur due to the effect of gravity during inversions is too great to be significantly offset by any BP-lowering effect due to baroreceptor feedback.
Conditions of the cardiovascular system

3.29 Arteriosclerosis (atherosclerosis)

Arteriosclerosis, also known as atherosclerosis or “hardening of the arteries” is so common as to be almost universal in Western society. Turn to p. 157, where the condition is well described. With increasing age our artery walls become damaged, with fatty cholesterol-rich deposits (“plaques”) being laid down under the artery lining. This roughens the lining and pushes it inwards, reducing blood flow through the vessel. The artery walls become damaged and brittle, and this makes them more likely to split with time. Risk factors for developing arteriosclerosis include genetic makeup, smoking, high saturated fat diet, high blood cholesterol and diabetes.

3.30 Coronary Artery Disease (CAD)

This term describes arteriosclerosis in the coronary arteries supplying the muscular wall of the heart. The arteries, which are small to start with, can narrow until insufficient blood can flow along them to meet the needs of the heart wall. Muscle fibres deprived of blood send pain signals to the brain – coming from the wall of the heart this pain is felt in the chest region and is called angina (Gr. ankhone = strangling). Read about angina on p. 156. Angina occurring during exercise is a warning that the heart wall is being insufficiently supplied with oxygen and nutrients needed when it is working harder than at rest.

Middle-aged and older people with diabetes have a high risk of CAD because the condition is associated with accelerated arteriosclerosis. This applies to all older diabetics, not just those taking insulin. As diabetes can damage sensory nerve endings, including in the heart, diabetics may not experience angina pain if the heart wall is insufficiently perfused with blood – so-called “silent angina”. It is nowadays recommended that yoga teachers should consider all older diabetics in class as if they have CAD, as the chances are they do, even if they have no symptoms.

Investigations of suspected CAD will include an angiogram, a procedure where radio-opaque dye is directed into the coronary arteries. This outlines them on a video screen and shows up any narrowed or blocked sections. Further treatment may include angioplasty (widening the affected section of artery and inserting a small metal coil-like structure called a stent to keep it open) or a coronary artery bypass graft (CABG), where narrowed or blocked coronary artery branches are bypassed by sewn-in lengths of blood vessel. Angioplasty is done under local anaesthesia and is rather like keyhole surgery, while CABG requires a general anaesthetic, a midline chest incision and “open heart” surgery. The pieces of blood vessel used for the graft procedure are taken from superficial veins under the skin of the arm(s) or
leg(s) – how many pieces are required depends on the number of narrowed or blocked sections of artery showing up during the angiogram.

3.31 Coronary Thrombosis (heart attack)

Blockage of an artery or vein by a clot is called thrombosis (L. thrombus = a clot). Clots can occur in an artery or in a vein, for different reasons. If an arteriosclerotic coronary artery branch either spasms or becomes blocked by a clot, the blood supply to the part of the heart wall that it supplied is interrupted. This causes severe angina chest pain as the wall of the heart reacts to oxygen lack. If the situation is not speedily remedied, the section of heart wall will die over the next few hours (a myocardial infarct or MI). Some myocardial infarcts are fatal – 50% of sufferers of MI do not survive 24 hours. If the person survives, the damaged section of wall will be replaced by a scar which is detectable during subsequent cardiological tests such as an ECG. There is now firm evidence that prolonged mental and emotional stress can be associated with the development of a heart attack. Now read about heart attacks on p. 156.

Yoga and CAD

3.32 People with CAD are medically advised to exercise, so an appropriate asana practice can be a helpful complement to this. Dynamic exercise should be favoured, with static asanas being held only for a short time. They are also advised to reduce stress and make lifestyle changes. Quietening pranayama practices and relaxation/visualisation/meditations should feature significantly in the design of yoga sessions, as they help with these, also with the fear engendered by all serious forms of heart disease.

Yoga and open heart surgery

3.33 Patients after CABG surgery can have long arm and/or leg skin incisions for vein harvesting, plus a cut and bruised ribcage. Both are very painful during healing. It is no surprise that even months later their posture is often slumped forward, with rounded shoulders – it takes time and tact on the part of the yoga teacher to overcome the subconscious guarding of the “heart centre” that results from the intrusive surgery that they have undergone.

3.34 Deep venous thrombosis

Clots occurring in an artery are usually the result of arteriosclerotic damage to the vessel wall. Clots occur in veins for different reasons – veins do not suffer the same degenerative changes as occur in arteries. The commonest cause of thrombosis in veins is stasis of the blood flowing through them. This occurs most often in the deep vein of the legs.
Limb veins are of two types – **superficial** and **deep**. Superficial veins lie just under the skin, where they are visible in many people. Deep veins run through the muscles of the limb. Superficial and deep veins are interconnected, and in the legs the flow tends to be from deep to superficial, and from superficial upwards towards the heart. The deep veins empty into the superficial ones because of the rhythmic compression of the deep veins as the result of muscle contraction, eg during walking, aided by the presence of numerous **one-way valves**. If we are immobile for long periods blood can pool in the deep veins to such an extent that flow in these vessels practically stops. Slow-flowing blood is liable to clot (L. *thrombus* = clot), forming a **deep venous thrombosis** (DVT) that can be several centimetres long. This produces local pain, swelling and inflammation, but is only dangerous if the clot becomes dislodged. A clot that moves from its site of origin like this is called an **embolus** (Gr. *embolos* = stopper). If the DVT dislodges, the embolus will be effortlessly swept towards the heart through ever-wider veins. It will pass into the right atrium and through the right AV opening into the right ventricle. Now it will pass into the pulmonary artery branches, which are branching and becoming progressively narrower – so it will **stick**, blocking part of the pulmonary circulation and forming a **pulmonary embolus** (PE). A large PE will be fatal, whereas small ones cause breathlessness, chest pain and sometimes coughing up blood.

Now read about embolism on p. 158, noticing in passing that emboli can be formed from materials other than blood clots and can occur in arteries or veins, with different results.

### 3.35 Stroke

In a stroke the blood supply to part of the brain becomes insufficient to keep that region of brain tissue alive, similar to what happens in the heart during a heart attack. This commonly happens through one of two events – either a clot blocks an artery carrying blood to part of the brain (a **thrombotic stroke**), or the artery bursts or leaks, interrupting the normal blood flow (a **haemorrhagic stroke**). In the latter, the situation is made worse by the build up of pressure within the brain due to the escaping blood. Thrombotic strokes are more common in older people, while haemorrhagic strokes (sometimes called a **brain haemorrhage**) can happen at any age. In older life both types of strokes are associated with arteriosclerotic damage to the arteries, while haemorrhagic strokes in younger people usually occur in relation to a weak-walled or otherwise abnormal bloodvessel present since birth. The effects of stroke in any sufferer are determined by where and how much brain tissue is destroyed by the event.

### 3.36 Valve disorders

Any of the four heart valves can become diseased. Commonly they either do not close properly (**incompetence**) or do not open fully, **stenosis** (narrowing).
Modern treatment of these conditions usually involves replacing the affected valve(s) with metal and plastic artificial ones. This involves an “open heart” technique similar to that mentioned above with respect to CABG surgery, and with the same attendant problems of posture as have already been described. Following valve replacement it is common to be on anticoagulant medication (see below). Now read p. 157 “Valve Disorders”.

**Yoga and anticoagulant therapy**

3.37 Anticoagulant drugs, commonly (if inaccurately) referred to as “blood thinning” medication, are often prescribed to people with various heart or cardiovascular problems, including being at high risk of stroke or heart attack. Low-dose aspirin is the commonest one given. Heparin is very quick-acting, but not normally used outside hospital as it has to be injected. Warfarin is in tablet form, but needs to be regularly monitored to establish and maintain the optimum dose. Strong inversions and static “head down” postures run the risk of inducing troublesome nosebleeds. Strong inversions (head stand and shoulder stand) may also carry an increased risk of eye haemorrhage or stroke.

3.38 Arrhythmias

Now turn to p. 159 and read about Arrhythmias. “A-“ in front of a word usually gives it the opposite meaning. “Arrhythmia” describes the situation when the heart is not beating at normal speed or with normal rhythm. Anxiety and fear can produce a simple sinus tachycardia more usually called “palpitations” – many of us have experienced this at some time, and it does not indicate the presence of any heart disease. Reading p. 159 you have the opportunity to revise your knowledge of the natural pacemaker of the heart, the SA node. Sinus tachycardia is shown in the left hand illustration on p. 159). Despite its rather off-putting name (sinus = SA node, tachycardia = fast heartbeat, from Gr. tachys = swift), this is the heart’s normal response to exercise, anxiety and fear.

3.39 Atrial fibrillation (AF) on the other hand (seen in the middle illustration) is potentially dangerous as it can lead to clots forming in the atria. These can be swept out into the circulation as emboli, with possibly disastrous consequences. Thus people with persistent AF are often on anticoagulant therapy (see above). Arrhythmias may be treated by medication and/or implanting an artificial pacemaker, a small computerised box, below the collarbone. No special precautions in yoga practice are needed for people with an artificial pacemaker.

3.40 Hypertension (High BP)

BP is said to be abnormally raised at or over around 140/90 mm Hg. This value is obtained by repeated readings taken at the level of the heart when the
person is at physical and mental rest. Hypertension is never diagnosed on the basis of a single reading. If necessary, a portable 24-hour BP-measuring device can be worn. This is valuable as it shows if the BP continues to be raised at night when the subject is asleep, this is an abnormal finding. The printout from such a device can be seen on p. 159. See how the BP varies with activity during waking hours. Hypertension has no symptoms unless it is very severe indeed — although commonly thought to be associated with high BP, a red face, nose bleeds and dizziness are not symptomatic of the condition. Most people with high BP are unaware that they are at risk. Treatment to control the BP and to deal with attendant risk factors (smoking, excess alcohol, obesity and stress) is important in order to reduce the associated risk of stroke and heart attack.

As a yoga teacher you may well have people in your class with undiagnosed high BP, and there is little that you can do about this. People with known high BP are usually on medication to control it. Sometimes this is effective, sometimes not. Even when it is, and the BP is controlled, it is important to remember that older people with hypertension have usually got damaged arteries due to arteriosclerosis. The capacity of their brain arteries to autoregulate the cranial blood flow in inversions will probably be significantly reduced, so they may lack this normal protective mechanism — as a teacher you should be aware of this when assessing whether they should practise strong inversions.

3.41 Low Blood Pressure

There is a normal range of resting BP within the population, but it is generally agreed that around or below 90/60 qualifies as low BP. The main problem with this condition is that when upright there may not be sufficient BP to push blood up to the brain against the normal effects of gravity described above. People with low BP have a tendency to feel lightheaded or even to faint when standing up from lying or sitting. Fainting may also occur from standing still for too long — this is because blood pools in the leg veins when the calf muscles are inactive, reducing the venous return to the heart.

Yoga teachers should advise students with low BP to come up slowly from a lying or sitting position, to alternately contract and relax the calf muscles when standing still and to avoid long holds of static standing asanas.

3.42 Varicose veins

The superficial leg veins can become chronically dilated, forming uncomfortable twisted varicosities. Long periods of standing still, pregnancy (if the womb compresses the pelvic veins) and other factors can increase the BP in these veins and cause the condition. Varicose veins can be removed surgically or treated by injection so that the walls stick together. Yoga positions that cause discomfort should be avoided.
Respiratory System

1. **Learning Outcomes**

   1.1. By studying this section on the Respiratory System, you will understand:

   1. The general layout of the parts of the respiratory system, and the functions of each.
   2. The structure of the lungs, including the airways and alveoli.
   3. How gases are exchanged within the lungs and in the tissues.
   4. The mechanics of breathing, during rest and with exercise.
   5. The factors involved in the control of breathing, and how they operate.
   6. The following respiratory conditions that can be met in a general yoga class: upper respiratory tract infections (colds, ‘flu and acute bronchitis, sinusitis), hyperventilation, asthma, chronic obstructive pulmonary disease (COPD), lung cancer, cystic fibrosis.

2. **Objectives**

   2.1. By the time you have completed your study of this section you should be able to explain:

   1. Why it is preferable to breathe through the nose.
   2. In physiological terms, why the two nostrils often are not equally “open”, and how this finding might relate to the concept of the ida and pingala nadis.
   3. Why the concentration of salt used is important if using the technique of jala neti.
   4. How the diaphragm and ribcage contribute to breathing.
   5. Why deeper breathing will not increase the oxygen content of the blood.
   6. The role of carbon dioxide in the body.
   7. What hyperventilation is and why people might hyperventilate in yoga class.
   8. How mental/emotional state can influence breathing patterns and vice versa.
   9. How an appropriate yoga practice can help people with respiratory disorders.

   2.2. Some aspects of yoga practice are intimately associated with the breath. Asanas are usually practised at least with **breath awareness**, and often with a specific breathing technique such as ujjayi. Pranayama practices use the breath in many ways to effect changes in the **mind**, as well as to
strengthen the breathing muscles. That the term “pranayama” is used to describe these practices indicates their traditional role in connecting the individual with the life force, “energy” or the Divine through the breath.

3. Working Through the Book

3.1 To begin our exploration of the respiratory system please turn to pp. 162-163, where the component parts are displayed. In essence, the respiratory system consists of two main parts – (a) many thousands of small thin-walled alveoli or air sacs where gas exchange takes place, and (b) a system of tubes or air passages that convey air in and out of the alveoli and prepare the air so that it is suitable for exposure to the delicate lung tissue. The diaphragm, ribcage and associated muscles, although technically part of the muscular and skeletal systems of the body, provide the movements essential for breathing, and will be included in this section.

3.2 Now read the paragraph on p. 162 that begins “Air enters the body....” and in the diagram on these pages identify the nasal cavity, pharynx, larynx, trachea, bronchi (primary, secondary and tertiary), bronchioles, right and left lungs and the diaphragm. Read each of the short descriptions given for each of these. The larynx is stated to be involved in speech (which it is), but the text on p. 162 fails to mention its most important function – it guards the tracheal opening, preventing food and drink from “going down the wrong way”, and thus safeguarding breathing.

3.3 See how the tubes within each lung (the pulmonary arteries, pulmonary veins and the bronchi) resemble three trees that have grown too close together, their branches intertwining. We can breathe through either the nose or the mouth. Normally we breathe in and out through the nose, but when speaking, chanting, singing, coughing or sneezing we breathe in through the nose and out through the mouth. Breathing in through the mouth and out through the nose usually is confined to certain swimming strokes and the pranayama techniques of sitali and sitkari (the cooling breaths). Breathing in and out through the mouth occurs during strong exercise and when the nose is blocked, eg by a cold.

3.4 Although the nose is not shown in any great detail in the vertically-sectioned view on p.162, you can see the outer wall of the right nostril here – the mid-line partition between the nostrils has been removed. Notice that you can see three structures (unlabelled) projecting in from the lateral sidewall of the nostril. These are three more-or-less horizontal bony shelves, one above the other, with the longest shelf being the lowest one. The shelves (called conchae) are covered over with the mucous membrane that lines the nasal cavities (the term “mucous membrane” here means a wet lining surface). Microscopic examination of this lining reveals several features that explain how the nasal lining prepares the incoming air so that it is suitable for the lungs.
(i) The free surface of the lining cells has numerous microscopic projections. These are commonly described as being “hair-like”, but although they might look like hairs they are not hairs. They are each far more complex structures called a **cilium** (L. = eyelash). The plural is cilia. Cilia have the inherent ability to **beat rhythmically**, all in one direction, here towards the back of the throat. The tips of the cilia are embedded in an overlying layer of sticky **mucus**, and as the cilia beat they push the mucus sheet progressively towards the back of the throat, from where it can be swallowed (or, if copious, spat out). Dust, pollen and germs (bacteria and viruses) carried into the nose with the breath sticks to the mucus sheet and are carried towards the throat for disposal. Thus the incoming air is **cleaned**. Swallowed mucus is disinfected and broken down by the acidic stomach juices. The mucus sheet is **replaced** continuously by mucus-secreting glands that lie within the nasal lining.

(ii) Mucus has a high water content, and evaporation of this water, together with that of the tears that drain from the eyes into the nasal cavities, plus other secretions **humidifies** the air so that it does not dry the lungs out.

(iii) Finally the incoming air is **warmed** by the radiation of heat from a complex network of thin-walled veins within the nasal lining.

**Paranasal sinuses**

3.5 Now turn to p. 48 and read the section entitled “Sinuses”. These paranasal (“alongside the nose”) cavities in the skull bones are lined by a similar membrane to that of the nasal cavities, but without the well-developed network of veins used to warm the incoming air in the nose. The lining of each sinus produces **mucus**, and cilia beat rhythmically to carry it towards the opening of a narrow drainage duct. The other end of the duct opens into the nostril on that side, under the lowest concha shelf.

3.6 At any time, one nostril may be more “open” (or **dominant**) than the other nostril, which feels somewhat blocked. This is due to the swelling of the nasal lining of the “blocked” nostril, caused by congestion within the lining’s venous network. The congestion brings increased numbers of white blood cells into the lining. These mobile immune cells squeeze out of the veins and move through the lining tissue seeking out and destroying invading germs and generally cleaning the lining. This process usually takes around a couple of hours, after which time the congestion subsides, the lining shrinks to normal thickness thus “opening” the nostril and the process begins in the other nostril. It is probable that when the yogis in ancient times noticed this phenomenon of “**nasal laterality**” or alternating nasal dominance it prompted them to develop the concept of the **ida and pingala nadis** as a way to explain their experiences.
Jala neti

3.7 Yoga practitioners who choose to use the nasal washing technique of jala neti should be aware that the nasal lining cells are very delicate and can be damaged by exposure to either too high or too low concentrations of salt in the washing water. Water alone should never be used. Users of the practice are advised to use a saline solution of similar salt concentration to that found in the blood and interstitial fluid (the fluid surrounding cells). This can be made using 10 gm (2 level tsp) salt per litre of water. There is some clinical evidence that slightly stronger salt solutions may be more effective in removing nasal mucus and temporarily shrinking a congested nasal lining (though this will interfere with the natural nasal laterality described above). No attempt should be made to force water into the paranasal sinuses as this can result in infection and sinusitis. In addition it is important to be aware that jala neti may remove valuable antibodies from the nasal lining.

Lungs

3.8 We will now study the lungs in more detail. Turn to pp. 164-165 and read the paragraph starting “Air enters the lungs....”. The term “hilum” given here is borrowed from botany and originally referred to the scar on a bean or pea where it was attached to the pod. Here it means the area on the inner side of each lung where the blood vessels and airways enter and leave.

3.9 Each lung has an upper slightly pointed apex that lies behind the collarbone. The wider lung bases sit on the diaphragm. The right lung has three lobes and the left two (this leaves room on the left for the heart). The lobes are not separate from one another, but only partially separate – each lung is like a loaf of bread cut incompletely through, making a deep fissure between the parts.

3.10 Each lung is covered by a thin adherent membrane like “cling film” and the pleural cavity in which it lies is lined with the same type of membrane (pleural membranes). The lung fills its pleural cavity completely, so that the two layers of membrane are held in contact with one another by a small vacuum. This means that the lungs are pulled into expansion when the pleural cavities expand. A small amount of slippery fluid is secreted by these pleural membranes and this acts as a lubricant, allowing each lung to move easily against the walls of its containing cavity.

3.11 Now examine the diagram of alveoli on p. 164 and read the paragraph above it. The smallest airways (respiratory bronchioles) each terminates in a cluster of alveoli, tiny hollow spheres each with a very thin wall. Identify the elastic fibres arranged around the outer surface of the alveoli, like so many rubber bands. Each consists of fibres of stretchy elastin protein. As the alveoli fill with air and swell during inhalation the elastic fibres stretch. During the exhalation they naturally recoil back to their resting length, causing to alveoli to be compressed and the air to flow out. Now see the network of capillaries.
applied closely to the outer surface of the alveoli in the centre of the diagram (the elastic fibres would lie under these capillaries, but are not shown here). Blood is brought to the capillaries by a small branch of the pulmonary artery (here colour-coded purple-blue) and drained from it by a small pulmonary vein (coloured red). As deoxygenated blood passes through this capillary network, it is topped up with oxygen. At the same time its surplus carbon dioxide is released, diffusing through the alveolar wall to be breathed out. We need to explore this topic of gas exchange in more detail now, so turn to p. 166-167 and begin by reading the paragraph beginning “Oxygen is drawn into the body...”. We will now make sense of these pages by moving through the numbered sections 1 to 9. The first four sections illustrate gas exchange in the lungs, while 6-9 describe what happens in the tissues elsewhere in the body.

3.12 (1) shows a high magnification of a small portion of the wall of an alveolus, plus an adjacent capillary. Identify the red blood cells, parts of which can be seen on the right of the diagram. Trace the oxygen (red arrow) and carbon dioxide (purple-blue arrow) diffusing through the thin capillary and alveolar walls (labelled). (2) Oxygen diffuses into the blood plasma and (3) binds to haemoglobin in the red cells, while carbon dioxide diffuses in the other direction (4). In (5) we follow the reoxygenated blood as it leaves the heart via the aorta en route to the tissues. Now read the paragraph on p. 167 headed “Exchange in the body tissues”. (6) shows red blood cells in an arteriole, which empties into a network of capillaries.

3.13 One of these capillaries is illustrated curving along the bottom of p. 167 in close contact with tissue cells (the whitish transparent structures). By this time the blood cells are flowing slowly and in single file, making the conditions ideal for gas exchange. The process is shown at higher magnification in (7-9), so make sure that you understand that here oxygen is diffusing out of the blood and carbon dioxide is diffusing into it – the opposite to what happens in the lungs. Finally, the deoxygenated blood (colour-coded purple-blue) flows into venules and small veins (not shown) before being returned to the heart via the inferior vena cava.

Oxygen Saturation

3.14 Note that deep breathing does not increase the amount of oxygen in the blood – that it does is an “old wives’” tale. The reason that it does not is because all red blood cells are designed to normally carry as much oxygen as they can possibly bind in the lungs. When they leave the lungs each red cell is carrying as much oxygen as possible, so exposing it to more oxygen has no effect – the blood is said to be “fully saturated” with oxygen.
Breathing

3.15 Turn to p. 168 and read the paragraph headed “breathing”. Here and on p. 169 we will consider the **muscles** involved in breathing, and after that we will explore the **air pressure** changes involved. Familiarise yourself with the structures labelled in the diagram on this page. The only muscle names you should try to remember are the **external intercostals** and the **diaphragm**, the others are less-important “helper” muscles that are recruited when needed for forceful inhalation. Read the paragraph headed “Inhalation”. The external layer of intercostal muscles pulls the ribs up and out, while a little more needs to be said about the diaphragm as it is the principal muscle of inspiration. The two chest X-rays shown side-by-side on p. 168 are meant to show the different position of the diaphragm in inhalation and exhalation, but the picture has been cropped too severely and the diaphragm is out of view during inhalation (left picture)! All that can be seen are the transparent air-filled lung fields and the central heart shadow. The right hand X-ray does show the right dome of the diaphragm rising up, but the left one has been cut off. It is difficult to see any difference in the size of the pleural cavities in the two pictures, although this should have been evident in the illustration.

3.16 Read the paragraph headed “Exhalation”, and examine the diagram. The different shapes of the **diaphragm** as it contracts during inhalation and relaxes in exhalation are quite well seen here and in the illustration on p. 167 – flattening down on the in-breath and resuming its relaxed domed shape on the out-breath. The paragraph mentions the effect of the stretching of the elastic fibres wrapped round the alveoli – how the lungs shrink due to **elastic recoil**. Breathing out at rest is passive, while when a more forceful exhalation is required muscles such as the **internal intercostals** (which lie deep to the external ones) and the **abdominals** can be recruited to shift the air out more quickly.

3.17 Read the paragraph at the top of p. 170 “Volume and Pressure”. You do not need to remember the values stated, except it is useful to be aware that the average resting breath moves about **500 ml** of air in and out of the body, a fraction of the maximum possible amount. This is normal, we are not meant to “over breathe” as this can induce **hyperventilation** (see below). The upper diagrams on p. 170 show the way that the diaphragm and **external** intercostal muscles (not just “intercostal muscles” as stated in the paragraph at the top of the page) cause the ribcage to expand on the resting in-breath, and how the elastic recoil of the stretched lung tissue passively causes exhalation without any muscle effort being expended. The lower diagrams show the air pressure changes induced by respiratory movements during breathing.

“Sectional” breathing

3.18 Breathing in expands the pleural cavities in **all directions** – from top to bottom, side to side and front to back. The diaphragm is responsible for the
increase from top to bottom, while the orientation of the joints between the ribs and the vertebrae at the back and the breastbone or costal margin at the front causes the ribcage to expand from side to side (lower ribs) and front to back (upper ribs). Beginner students usually have very little awareness of their breathing. Teachers often use the technique of “sectional” breathing to help them to become more in touch with their breath. “Abdominal”, “middle chest” and “upper chest” breathing are terms often used to describe the movements of the diaphragm, lower ribs and upper ribs respectively.

3.19 When the abdomen is fully relaxed (as in lying semi-supine, with the knees bent and feet on the mat), inhalation results in the diaphragm flattening and moving towards the feet. This compresses the abdominal organs, and in order to make room for them the abdominal wall expands. On the exhalation the diaphragm relaxes and moves back up towards the heart, so the abdominal wall sinks back to its resting position. However, when we are upright the situation changes – the core stability muscles should now be engaged to support the lumbar spine, so that the lower abdomen is held gently still and now does not expand outward on the inbreath. This results in the lower ribs compensating by flaring out to the sides on the inhalation.

3.20 The “middle chest” (lower) ribs expand out to the sides with inhalation, while the upper ribs (“upper chest”) move to push the breastbone forward and up. The “yogic breath” or “complete breath” uses all these movements in sequence, reinforcing one’s awareness of the breath and also inducing a calm relaxed mental state.

3.21 P. 171 gives information on speech, respiratory reflexes and the larynx (the latter with a mostly unhelpful diagram) – you can skip this page or study it, as you prefer.

Control of breathing

3.22 Breathing is ultimately controlled by a region of the brainstem called the respiratory centre. This maintains breathing as an involuntary subconscious activity, and keeps us breathing during the day (including the adjustments required for periods of exercise), during sleep and if unconscious for any reason. Higher centres in the cerebral hemispheres can exert voluntary control on the breath, over-riding the brainstem centre to some degree and allowing us to consciously change our breathing patterns, for example during pranayama practice.

3.23 The brainstem controls the nerves that activate the breathing muscles. These are the somatic (i.e. not autonomic) spinal nerves to the diaphragm (the phrenic nerves from C3, 4 and 5) and those to the intercostal muscles (intercostal nerves, T1 – 12). Although we can control the breath to some extent by the use of the conscious will, in the end the brainstem will
overcome this and take over control, for example when we hold the breath for too long.

3.24 Although most people think that the amount of oxygen in the blood is the prime factor in controlling the breath, this is not actually the case. Carbon dioxide concentration is far more important. The body breaks down much of our food intake into the small sugar molecule called glucose. Our cells take in this glucose and in the presence of oxygen break it down progressively into water and carbon dioxide, liberating large quantities of energy from the glucose during the process. If the carbon dioxide builds up too much in the blood (i.e. when we exercise or hold the breath) it acts on the brainstem centres to impel us to breathe more forcibly, while conversely if we breathe out more carbon dioxide than the body’s cells are producing at the time, this will induce the state known as hyperventilation. Hyperventilation occurs when the amount of carbon dioxide in the blood is falling. This causes the cerebral arteries to constrict, reducing the blood flow to the brain and resulting in light-headedness, tingling in the fingers and feelings of panic. It often accompanies anxiety and panic attacks, due to the tendency to “overbreathe” in these circumstances. The only yoga practices in which slight hyperventilation is deliberately induced is kapalabhati and bhastrika (which are not suitable for everyone), and in neither of these should light-headedness occur - if it does the practice is being carried out much too strongly, producing far too much hyperventilation.

Body/Mind influences and Breathing

3.25 We all know that our emotional or mental state influences our breathing. If we observe a baby (or even the family dog!) sleeping, we see a perfect example of diaphragmatic breathing with the abdomen fully relaxed and the mental state quiet. Conversely, if we are emotionally upset or psychologically disturbed, the breath changes to be shorter and shallow in nature. It is also true that our breathing can influence our mental state, and yoga practice conclusively demonstrates how quietening pranayama practices like nadi shodhana (alternate nostril breathing) will result in peace of mind and reduction in mental stress. Conversely stimulating techniques such as kapalabhati and bhastrika will lift the mood and increase overall energy levels. These effects only go to confirm the saying that mind and body are two sides of the one coin, and that you cannot affect one without changing the other.

Respiratory system conditions

Colds and ‘Flu

3.26 These are not particularly relevant to yoga classes – one hopes that students suffering from either of these viral conditions will stay away from class! However, for general information, look at pp. 172 and 173.
Sinusitis

3.27 Each paranasal sinus has a drainage duct lined by ciliated cells. Infection can track up these ducts from the nose, resulting in inflammation and swelling of the lining of both the sinus and its duct. Duct swelling can temporarily close the duct, with secretions and pus accumulating within the cavity. This increases the pressure in the sinus, causing the aching headache pain of sinusitis. Treatment usually involves decongestants to shrink the lining and re-establish drainage, plus antibiotics where needed. Head down positions and anything that increases pressure in the nasal area (eg kapalabhati and bhastrika) should be avoided during attacks.

Asthma

3.28 Read the section on p. 173. See how the condition causes (i) episodic narrowing of the smaller airways, making it difficult to breathe (ii) inflammation of the airways, resulting in thickened walls and (iii) increased mucus production. Be aware that stress (including the stress of having the condition in some cases) makes asthma worse. Most asthmatic people coming to class will carry and self-administer any necessary medication.

Chronic obstructive airways disease (COPD)

3.29 This “umbrella” term covers the two conditions chronic bronchitis and emphysema, as they often co-exist, and it can be difficult to know which is more significant in many patients. Read p. 175 where the two are described. A history of smoking is the commonest cause of COPD, although long term exposure to some lung irritants such as coal dust can have a similar effect.

Lung cancer

3.30 Read p. 174 for general interest. This condition is most often linked with a smoking history, but be aware that some rarer lung cancers are not connected with smoking at all. Also, it is important to know that the lungs are a common site for the development of secondary cancer deposits that have seeded off from a pre-existing tumour elsewhere in the body, eg in the breast. These tumours are not at all connected with smoking.

Cystic fibrosis

3.31 As more people with cystic fibrosis survive into adult life due to improved medical management the possibility of them coming to yoga classes increases. This inherited condition results in the body’s mucus being too thick, so that it clogs the lungs. In addition digestion is inefficient, leading to the poor absorption of nutrients. The latter can be adequately treated with enzyme supplementation, and it is the lung problem that is most dangerous. Excess mucus harbours chronic infections and
leads to progressive lung damage that can threaten life unless a heart-lung transplant is possible. Inversions can be useful in some cases for helping to drain mucus from the lungs, provided the individual can practise them without strain or other adverse effects. Kapalabhati may also be helpful for encouraging secretions in.
APPENDIX

AREAS FOR CAUTION

ADVICE FOR YOGA TEACHERS
AREAS FOR CAUTION
ADVICE FOR YOGA TEACHERS

Yoga by its very nature is both health-giving and beneficial, but like any other activity there are areas where care needs to be taken. The following appendix is a non-exhaustive list of conditions commonly encountered in yoga teaching, rather than a definitive list of conditions. Areas where caution might be advisable, plus some suggestions for appropriate modifications in yoga practice also are provided in this section.

Yoga teachers need to be able to observe and listen to their students so that they can adapt each individual’s practice accordingly. They also should have sufficient knowledge of the common medical conditions encountered in class to be competent in providing the advice and modifications that allow all students to get the maximum possible benefit from their practice.

Yoga practice is not designed to replace medical advice and treatment, but it can supplement prescribed medical treatment for many common conditions. If in doubt, ask the student to seek their doctor’s advice before joining the class.

In asana practice, students should not strain to “win”, or to try to achieve a specific end result. A balanced asana practice should move all the joints through their full painfree range of movement.

Students should never “run out of breath” in any breathing/pranayama practice - this raises anxiety levels and produces the opposite of the quiet mind that yoga is designed to induce. They should proceed at a pace that is comfortable for them.

Be aware that misguided attempts to adjust students in postures can cause injury – if verbal instruction does not help, the least possible physical indication should be used (eg a light touch on the shoulder to indicate that it should be rolled back). Always ask a student’s permission before touching him/her.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Areas for Caution</th>
<th>Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-coagulant medication</td>
<td>See hypertension/coronary artery disease (CAD) below</td>
<td>See hypertension/CAD below</td>
</tr>
<tr>
<td>Anxiety</td>
<td>Fast-breathing practices such as kapalabhati and bhashrika</td>
<td>Use quietening breathing practices</td>
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<tr>
<td></td>
<td>No asana prohibitions except if claustrophobic, then avoid pose of a child</td>
<td>Encourage slow, easy breathing to include use of diaphragm to diffuse anxiety</td>
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<td></td>
<td>or similar “closed” postures</td>
<td>If closing the eyes provokes anxiety in an individual, say to the whole</td>
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<td>class that they may stay softly open</td>
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<td>Arthritis</td>
<td>Inflamed joints should not be worked, but should be rested until inflammation</td>
<td>Try padding under knees, or kneel with folded blanket under shins so</td>
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<tr>
<td></td>
<td>dies down</td>
<td>kneecaps are projecting just clear of blanket edge and weight is being</td>
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<td></td>
<td>Work only in the painfree range of movement</td>
<td>taken on shins</td>
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<td></td>
<td>No weightbearing on painful joints</td>
<td>Place heels of hands on rolled blanket if wrists uncomfortable on hands and</td>
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<td></td>
<td>No taking the head back in people with rheumatoid arthritis (risk of neck</td>
<td>knees</td>
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<td></td>
<td>dislocation)</td>
<td>Moving-with-breath asanas better than strong static ones, but limit number</td>
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<td></td>
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<td>of repetitions so as not to cause more inflammation</td>
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<td></td>
<td></td>
<td>Support hips in cross-legged poses if needed, with cushion under thigh(s)</td>
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<tr>
<td>Condition</td>
<td>Avoidance and Adaptations</td>
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<tr>
<td><strong>Asthma</strong></td>
<td>Avoid focusing on the breath (increases anxiety in asthmatics)</td>
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<td></td>
<td>Asthmatic students usually manage their own condition (carrying and using an inhaler when needed)</td>
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<tr>
<td></td>
<td>No specific asana prohibitions</td>
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<tr>
<td><strong>Carpal tunnel syndrome</strong></td>
<td>Asanas on hands and knees – try hands further forward on floor rather than directly under shoulders. Try rolled blanket under heels of hands – both modifications reduce wrist extension (painful in CTS)</td>
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<td></td>
<td>If weight-bearing is not possible at all in asanas on hands and knees, support forearm(s) on 4 stacked blocks. Use elbows against wall for wall back stretch instead of dog head down</td>
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<tr>
<td><strong>Coronary Artery Disease</strong></td>
<td>See Hypertension</td>
<td></td>
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<tr>
<td><strong>Depression</strong></td>
<td>Avoid over-long relaxations, visualisations or yoga nidra. (these can pull mood down further)</td>
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<td></td>
<td>Satyananda teachers can use longer yoga nidras as they have had additional training in this practice</td>
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<td></td>
<td>Avoid long static asanas</td>
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<tr>
<td><strong>Detached retina</strong></td>
<td>As for Hypertension (see below)</td>
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<tr>
<td>Condition</td>
<td>Specific Asanas Prohibitions</td>
<td>Additional Advice</td>
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<tr>
<td>Diabetes</td>
<td>No specific asana prohibitions, but see below re risk of CAD</td>
<td>Insulin-dependent class members usually manage their own condition (carrying glucose if needed) Be aware of the cardiovascular risk in all diabetics past first youth – high incidence of coronary artery disease (CAD) and arteriosclerosis, so avoid any physical or mental stress in practice</td>
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<td>As for Hypertension (see below)</td>
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<tr>
<td>Faintness</td>
<td>Avoid long periods of standing still Advise students to eat a small snack not less than one hour before class Do not ask student to put the head between the knees – fainting can still occur in this position</td>
<td>Advise the student to lie completely flat. Raise legs above heart if props are available (this is not essential) Advise that the student remains flat until feeling well, and then comes up very slowly from lying down</td>
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<tr>
<td></td>
<td></td>
<td>As for Hypertension</td>
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<tr>
<td>Glaucoma</td>
<td>As for Hypertension</td>
<td>As for Hypertension</td>
</tr>
<tr>
<td>Heart Attack</td>
<td>See Hypertension</td>
<td>See Hypertension</td>
</tr>
</tbody>
</table>
| Hiatus Hernia | Avoid positions that take head level with or below stomach  
Prone postures may be uncomfortable for some  
Avoid strong twists and inversions  
(All the above encourage acid reflux and therefore heartburn or upper abdominal pain) | Supine postures – raise head and upper body above stomach level using cushions etc  
Legs-up-the-wall may be a suitable inversion if head/upper body raised as above  
Standing forward bends, take the hands to a chair |
| Hip Replacement (Total Hip Replacement) | Avoid bringing knee to chest (or chest to knee) more than 90 degrees unless the student can do this easily without strain.  
Avoid operated leg crossing the midline  
Avoid turning operated leg toes markedly in | Use ardha uttanasana (halfway standing forward bend) rather than the full asana  
Sitting forward bends – use a belt round the foot/feet and lift spine rather than folding forward  
In garudasana (eagle) use vrksasana (tree) leg position  
In ardha matsyendrasana (Lord of the fishes twist) do not take the operated bent-kneed leg across the straight one  
In trikonasana (triangle) keep the operated leg toes pointing forward. |
<p>| Hip resurfacing (“Birmingham Hip”) | Once the post-operative rehab period is completed, the student can return to class with few restrictions | Advise the student to work within their comfortable range of movement |</p>
<table>
<thead>
<tr>
<th>Hypertension (High blood pressure)/Coronary Artery Disease (CAD)/Angina</th>
<th>Avoid strong static work</th>
<th>Favour moving—with-the-breath asanas over static ones (do not forbid static asanas, but only stay in them a short time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid holding arms above head for long periods</td>
<td>Arm-raising is OK if done as part of moving-with-the-breath work</td>
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<tr>
<td>Avoid head below heart for long periods</td>
<td>Head below heart is OK if done in moving-with-the-breath work</td>
<td></td>
</tr>
<tr>
<td>Avoid headstand and shoulderstand. This also applies to people whose high BP is controlled by medication, unless under 30 yrs (in older people the high BP is usually associated with arteriosclerosis, which makes arteries more vulnerable to damage, including in the brain. This can increase the risk of stroke)</td>
<td>Substitute legs up the wall, with restful breathing</td>
<td></td>
</tr>
<tr>
<td>Coronary artery disease and angina – avoid strong increases in BP by following advice re high BP above. Physical practice should not result in angina pain – if it does it is too strong for the individual</td>
<td>As for Hypertension above</td>
<td></td>
</tr>
<tr>
<td>Students on warfarin (anti-coagulant medication) should avoid inversions and sustained head down positions as these increase the risk of troublesome nose bleeds and might raise risk of stroke. Warfarin can be prescribed after heart valve replacement or DVT, and for some heart arrhythmias (eg atrial fibrillation)</td>
<td>Legs up the wall instead of other inversions</td>
<td></td>
</tr>
<tr>
<td>Any student who has had “open heart” surgery (valve replacement, coronary artery bypass etc) may have subconscious fear of postures that “open the chest/heart”</td>
<td>Dog head down – use a chair or the wall</td>
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<td></td>
<td>Child pose – cup chin in hands, elbows on floor</td>
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<td>Be aware of use of language – don’t say “chest/heart-opening postures” as the phrase has a literal meaning to this group....</td>
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<tr>
<td>Hyperventilation and Panic Attacks</td>
<td>Have an “open door” policy – inform the class that students are always free to leave the room and return whenever necessary, for any reason. Avoid strong pranayamas like kapalabhati and bhashrika when working with anxious or nervous students. Avoid focusing on the breath if this encourages hyperventilation.</td>
<td>Instruct a hyperventilating student to “pause the breath” for as long as is comfortable, then to breathe for a few moments, then repeat. Or use slow abdominal breathing. Ujjayi is helpful if the student knows how to do it before the attack. Encourage awareness of “the witness within”, i.e. become able to observe what is happening to the body in an objective way. Take a private opportunity to explain to the student how the “FFF” reaction affects the body and mind, and that in a panic attack this otherwise normal response to danger is being triggered inappropriately by a (usually subconscious) thought. Understanding what is happening can defuse the attacks.</td>
</tr>
<tr>
<td>Hypotension (Low blood pressure)</td>
<td>Avoid standing still for any length of time (risk of fainting). Avoid coming from lying to sitting/standing, or from sitting to standing too quickly (risk of lightheadedness or fainting).</td>
<td>Instruct student to rhythmically contract and relax calf muscles in static standing asanas (helps maintain venous return to the heart). Advise pausing for a couple of breaths half way when coming up from a standing forward bend. Advise the student to move slowly from lying or sitting position to standing.</td>
</tr>
<tr>
<td>Health Issue</td>
<td>Recommendations</td>
<td>Modifications</td>
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<tr>
<td>Knee problems</td>
<td>Avoid movements that cause any pain</td>
<td>Place block(s) between hips and heels in vajrasana</td>
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<tr>
<td></td>
<td>Avoid kneeling if not possible to modify comfortably</td>
<td>Try a folded blanket under shins with knee caps projecting over edge</td>
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<td></td>
<td></td>
<td>(see modifications for arthritis above)</td>
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<tr>
<td>Knee Replacement</td>
<td>Most replacements do not allow full flexion (bending). Avoid sitting back on the heels or full vajrasana (thunderbolt pose)</td>
<td>Some students may be able to sit back with two or more blocks between the hips and the heels</td>
</tr>
<tr>
<td></td>
<td>Some replacements do not allow kneeling on the operated side</td>
<td>Some students may be able to use the modifications described above in “knee problems”. If not, have an alternative asana ready that the student already knows when the class is using a kneeling posture</td>
</tr>
<tr>
<td>Lower back problems</td>
<td>Prolapsed (herniated) disc – avoid forward bends for 3-6 months</td>
<td>Gentle backbends can be helpful, but need to be explored gently</td>
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<tr>
<td></td>
<td>Avoid any movements that cause pain</td>
<td>Bend knees to release stretch on sciatic nerve</td>
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<tr>
<td></td>
<td>Avoid straight leg raising if sciatica is a problem</td>
<td>For students diagnosed with nonspecific back pain a general balanced practice is often helpful</td>
</tr>
<tr>
<td>Menstruation</td>
<td>No prohibitions</td>
<td>Inversions are not advised against for any physiological reason. But if the flow is heavy it may cause embarrassing “flooding” when coming out of the posture. Also, energy levels are low at this time so it is normal not to wish to practise strong asanas</td>
</tr>
</tbody>
</table>
| Neck conditions, Spondylosis ("wear and tear"), Arthritis Whiplash | Avoid strong inversions – headstand and shoulderstand  
Avoid any postures that cause pain  
Students with rheumatoid arthritis should avoid taking the head back – unstable neck joints  
Students with Down’s syndrome – avoid all full neck movements – upper neck joints are unstable  
Whiplash – soft tissue injury in neck region – can leave long-standing emotional “guarding” of the area. Avoid mentioning “neck” as sufferers are too aware of it | Spondylosis (wear and tear) in the neck – sufferers should use the full painfree range of movement regularly  
Keep head in line with trunk in postures where the head is normally taken back  
Keep head in neutral position as much as possible  
Remind whole class to relax shoulders, face- ie areas surrounding neck, with time the neck will relax also, releasing muscular tension |
|---|---|---|
| Obesity | Avoiding strong inversions is probably good advice for most obese people | Legs up wall as a substitute for other inversions  
Folded blanket under ribcage (not under breasts) in prone position helps those with large breasts  
Belt around knee(s) if supine student cannot bring knee(s) to chest  
Child pose – cup chin in hands, elbows on floor if head closer to floor impedes breathing  
Folded blanket under midriff (solar plexus area) helps to relieve pressure on large breasts in prone postures |
<table>
<thead>
<tr>
<th>Condition</th>
<th>Advisements</th>
<th>Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Osteoporosis</strong></td>
<td>Avoid headstand and shoulderstand, strong twists, jumping into/out of postures.</td>
<td>Use legs up wall instead of stronger inversions.</td>
</tr>
<tr>
<td></td>
<td>Care with all neck movements.</td>
<td>Use gentle twists, forward bends to a chair, or use a belt around foot/feet.</td>
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<tr>
<td></td>
<td>Avoid full forward bends and strong spinal twists as these load high compressive forces on vertebrae.</td>
<td>Use gentle twists, forward bends to a chair, or use a belt around foot/feet.</td>
</tr>
<tr>
<td><strong>Pacemakers (implanted)</strong></td>
<td>No specific precautions</td>
<td>No specific modifications.</td>
</tr>
<tr>
<td><strong>Pregnancy</strong></td>
<td>Although there is no evidence that any yoga practice increases miscarriage risk, most teachers do not accept new students into class until about 14 wks, after which miscarriage risk is lower.</td>
<td>Recommend that all pregnant students go to a special pregnancy yoga class where appropriate practices and props will be available.</td>
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<td></td>
<td>Avoid lying supine after about 26 wks – womb weight can impede venous return to heart.</td>
<td>Prop head and upper body up against beanbag at the wall or similar.</td>
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<tr>
<td></td>
<td>Avoid strong static asanas and prolonged standing at all stages of pregnancy – risk of fainting.</td>
<td>Favour flowing work, moving with the breath.</td>
</tr>
<tr>
<td><strong>Recent abdominal surgery</strong></td>
<td>Do not return to class until at least 2-3 months after surgery.</td>
<td>Avoid postures needing strong abdominal work for about 6 months, eg navasana (boat pose), any supine straight leg raising, etc.</td>
</tr>
<tr>
<td><strong>Upper back problems</strong></td>
<td>Avoid strong back bends in permanently kyphotic spines, and in students with ankylosing spondylitis (an inflammatory arthritis of the spine).</td>
<td>Place block or padding under head and neck region if chin lifts towards ceiling when supine.</td>
</tr>
<tr>
<td><strong>Kyphosis</strong></td>
<td></td>
<td>Gentle backbends are helpful for ankylosing spondylitis.</td>
</tr>
<tr>
<td>Varicose veins</td>
<td>Avoid sitting positions that are uncomfortable (varies with individual and which veins)</td>
<td>Avoid virasana/suptavirasasa</td>
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</table>