Applied Anatomy & Physiology of Yoga

yogasynergy

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Important note to readers

Every effort has been made to ensure that the information in this publication is as up to date and accurate as possible however the subject matter is complex and readers are advised to seek expert advice when faced with specific problems. This work is intended as a guide to the subject and should not be used as a substitute for professional advice and treatment.

Reviews and Comments on 'Applied Anatomy and Physiology of *Yoga'*

'Applied Anatomy and Physiology of *Yoga*' is highly recommended to *yoga* teachers, physical therapists, occupational therapists and *yoga* practitioners. As a physical therapist and a long time Iyengar *yoga* practitioner myself, I searched for a book that would help me analyse *yoga* postures anatomically, biomechanically and therapeutically. When I was introduced to an earlier version of this book I was amazed at its accuracy and application to therapy; but the improvements made in this current edition make it an even more effective reference book. As a physical therapist I own many other anatomy and physiology books, which I use when researching a topic. When cross-referencing information in 'Applied Anatomy and Physiology of *Yoga'* I found the accuracy and comprehensiveness to be excellent compared with other yoga anatomy books currently on the market, which include many inaccuracies. The book is also a great reference source for physical therapists and others that have an interest in yoga.

Dalia Zwick PT PhD Physical Therapy Supervisor, The Women's Center, Premier HealthCare, New York, NY

The depth of information and knowledge in 'Applied Anatomy and Physiology of *Yoga'* is breath taking. This book explores the effects of *yoga* on each part of the body through the use of *asanas*, *bandhas*, *mudras* and *kriyas* while minimising the risk of injury. This book explores the ability of *hatha yoga* to develop both strength and flexibility and at the same time to use *yoga* as a therapy for healing musculoskeletal injuries. If detail and knowledge is your thing, you will not be able to go past this text. Rarely has the use of *bandhas* integrated with the *asanas* been so well explained and with such detail and clarity. Highly recommended.

International Yoga Teachers Association Journal: International Light, October – December 2005

'Applied Anatomy and Physiology of *Yoga'* is an invaluable resource for both teachers and students wanting to take more responsibility for their own practice. In reading the text, it seems obvious that the authors are expert *yoga* practitioners and teachers, not just proficient in anatomy and physiology. Most injuries in *yoga* did not occur because a posture or movement was inappropriate for a student, but rather because a teacher did not understand the body well enough to teach the exercise safely. This book provides *yoga* teachers and students with clear explanations and instructions which they can use in their own teaching and practice. The information comes in a clear well-illustrated and engaging way that does not overcomplicate and succeeds in making anatomy and physiology relevant to the actual practice of *yoga*.

Liz Bennett BAppSc(Physiotherapy) (University of South Australia)
Yoga Teacher and Physiotherapist

'Applied Anatomy and Physiology of *Yoga'* makes a unique contribution to the *yoga* community. The anatomy and physiology of the human body is presented in a way that is accessible to all and the application of this to the practice of *yoga* is clearly defined. For *yoga* practitioners, the book provides clear explanations of why the positioning in each *asana* and the use of *bandhas* and *mudras* are important in ensuring a safe and effective practice. It will help *yoga* teachers to understand the technical aspect of *yoga* from a western scientific point of view as well as from a *yoga* physiology point of view, and help them to give clear explanations to their students. For those interested in *yoga* therapy, this book serves as a valuable resource which demonstrates how, with knowledge of applied anatomy, *yoga* can be used effectively as a therapy.

Melanie Gallagher BSc(Physiotherapy) (Curtin University, Western Australia)
Physiotherapist

'Applied Anatomy and Physiology of *Yoga'* provides the missing link between east and west. You can't learn *yoga* without doing it, and you can't do *yoga* without learning it. If you are going to put your body on the line to explore *yoga*, then you had better learn how to protect it if you are going to survive the journey. This book teaches the *yogi's* 'suit-of-armour', the nine *bandhas* or body locks that take the danger out of *yoga*. Once you are so aligned it is safe and effective to apply seven powerful pumps described in the book for moving energy around your body. Then hang on for the ride of your life!

Jon Gould
Yoga teacher and Director: Yoga Alchemy

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Foreword to the 2005 Edition

Applied Anatomy & Physiology of *Yoga* is intended to be used by *yoga* teachers, *yoga* practitioners and also anyone who uses stretching, strengthening, breathing and other *yoga*-like exercises as part of their health regime. It can be read on its own as a whole or may be used as a reference text.

This book was designed as the main text for our course ***YOGA SYNERGY* Applied Anatomy & Physiology of *Hatha Yoga*: Course for Teachers & Students**. Our full course is run annually in Sydney from May to August. Shorter forms of the course are run throughout the year in other cities and overseas on the invitation of other yoga schools. This book has evolved from a series of notes we created in India in 1994 to supplement the first year of our course. While attendance at the course is encouraged for those who can do it, this book aims to stand alone and does not require course attendance.

This book and its related course include a study or revision of the basic anatomy and physiology required to understand *yoga*, but the main emphasis is on the practical or applied aspects of anatomy and physiology theory. In other words, the main purpose of this book is to use an understanding of basic anatomy and physiology to:

- enhance one's yoga practice
- improve one's ability to increase strength, flexibility, cardiovascular fitness and inner wellbeing
- minimise the risk of injuries as a result of *yoga* practice
- help to use *hatha yoga* to recover from a variety of musculoskeletal injuries and medical conditions.

Applied Anatomy & Physiology of *Yoga* has three main components spread throughout the book. The first component is theoretical (non-applied) anatomy and physiology. This information is mainly presented in the first half of each chapter. Those who have already studied basic anatomy and physiology may not need to read these sections fully or may wish to use these sections of the book as a reference only. Although this theoretical information is important and will be new for some readers, it will be revision for other readers, and has therfore been presented in a slightly smaller font to delineate it from the applied information. Some of the tables and diagrams have been compiled from a variety of difficult-to-access material and are therefore useful references.

For those wishing to gain further understanding of basic anatomy or physiology, we recommend *The Anatomy Colouring Book* (3rd Ed. by Kapit, W. and Elson, L.M. (2001) New York: Addison Wesley) (ACB) and *Bodyworks* (by Francine St George. (1999) Sydney: ABC Books).

The second component of this book is the practical application of the anatomy and physiology theory to the practice of *yoga* or, more specifically, *hatha yoga* (physical *yoga*). This subject is mainly discussed in the introductions and in the second half of each of the chapters of this book. In these applied sections the various aspects of *hatha yoga* are demonstrated and discussed in relation to the theoretical component. The aspects of *hatha yoga* examined include *asanas* (static postures) and *vinyasas* (dynamic exercises), *pranayama* (breath-control) and *dhyana* (meditation). Much emphasis is also placed on the role of *bandhas* [Section 1.7.3], which are discussed on a physical level as the co-activation or simultaneous tensing of opposing muscles around joint complexes [Section 1.5.3]; and *mudras* [Section 1.7.2], which are muscle control exercises or gestures that effect the flow of energy within the body and can tension (stretch) nerves and acupuncture meridians. Throughout the book there are also special shaded boxes entitled APPLICATION TO YOGA, which come directly after the basic statements on anatomy and physiology and help to make these statements relevant to the *yoga* practitioner. Intelligent use of anatomy and physiology theory can enhance all aspects of *hatha yoga* as well as other exercise forms. Readers are invited to attempt the various postures and exercises using this information but all caution must be taken. **Please note that all care must be taken if attempting any of the exercises discussed in this book, as not every exercise will be safe for everyone in its full form. In addition, it is sometimes useful while learning theory and exercise together to carefully attempt a less safe or less correct version of a pose to see its effects in a controlled situation. People should not make such attempts if they have specific problems in related parts of the body.**

The third component is concerned with safety in *yoga* classes and practice. This involves learning how to appropriately adapt the *yoga* to suit individual students. By knowing the anatomical and physiological limitations that the human body has, one has tools to safely modify *hatha yoga* exercises for individuals with musculoskeletal problems or those with special medical conditions. This also serves as an introduction to the concept of *yoga cikitsa* (*yoga* therapy) [Section 1.8], in which a teacher may use *hatha yoga* to facilitate and perhaps assist in the recovery from an illness or heal a musculoskeletal injury or may, instead, see the wisdom of referring students with difficult problems to other health practitioners. By appreciating the anatomical and physiological potential that the human body has, one can safely take each student to their personal maximum in order to challenge their mind while further improving their levels of strength, flexibility and cardiovascular fitness.

The traditional way to impart the teaching of *hatha yoga* has been for teachers to teach individuals on a one-to-one basis. Today, however, the most common method of teaching yoga is in large group situations. Therefore, an anatomical and physiological understanding of potential benefits or risks of each *yoga* exercise allows one to more safely teach a large class of heterogeneous students. With such an understanding, a good teacher can give one set of instructions to everyone in a large mixed class in such a way that each student is directed along a systematically arranged and anatomically safe pathway to arrive at their own safe yet effective versions of each posture.

In this book we have endeavoured to help readers understand *yogic* applied anatomy and physiology by simplifying the material in several ways. Common everyday words are usually included in brackets adjacent to technical and *Sanskrit* terms. Technical terms are usually underlined to help the reader mentally note that it is a technical term and, if necessary, to check the meaning of the word in the glossary [Appendix E] or index (for clarity, words are not underlined in titles and tables). *Sanskrit words are kept in italics* to help the reader mentally note that it is a *Sanskrit* term and, if necessary, to check the meaning of the word in the glossary [Appendix F] or index. Where possible concepts and terms are cross-referenced to other Sections, Figures or Tables using small font and square brackets, eg *bandhas* [Section 1.7.3]. Abbreviated references to other texts and source material are also noted in the text using small font and square brackets, eg [Iyengar, 1966], with the full references shown where possible in the Reference list [Appendix G].

In this book there are a series of small photos of *yoga* postures and body parts that are not included in the list of Figures but are placed within the text to help clarify the *Sanskrit* names of poses used and their many variations. An asterix (*) next to a pose in this book denotes the pose as being a more complex or difficult version of the pose. Note also the naming of postures is generally along the lines of B.K.S. Iyengar's *Light on Yoga* [Iyengar, 1966], with the exclusion of the numbering of postures with the same name and the inclusion of descriptive *Sanskrit* terms, eg *virabhadrasana II* in *Light on Yoga* is written here as *parsva virabhadrasana*.

This book describes some practical applications of anatomy and physiology theory to hatha yoga that are unique to the Yoga Synergy style. This is the case especially in relation to bandhas and mudras. Bandhas [Section 1.7.3], which are often thought of as internal locks, are described in this book as co-activations (simultaneous tensing) of antagonistic (opposing) muscle groups around the nine main joint complexes. In this book we have described nine bandhas in their locked (ha-bandha) forms and their unlocked (tha-bandha) forms. Most texts only refer to the three central bandhas: mula uddiyana and jalandhara. B.K.S. Iyengar [1966] describes these as 'the three main bandhas', thus implying the existence of other bandhas without actually naming them. Our understanding of how to generate the six peripheral bandhas is based on the teaching and inspiration of B.K.S. Iyengar. Mudras [Section 1.7.3] are usually described in this book as the tensioning (stretching) of nerves and acupuncture meridians and their associated nadis (subtle channels). Much of the information in this book regarding the bandhas and mudras is previously unpublished and is derived from the personal research of the authors. If intelligently applied this information can be a useful addition that can enhance the safety and effectiveness of all forms of hatha yoga.

Yoga is an ancient science and art but it probable that much information has been lost in time. With the current interest in yoga lost information is being slowly rediscovered. Hence, we consider this book to be a work in progress. Many of the sections will be eventually expanded and other sections added in later editions of this book. Should you wish to provide any feedback or point out mistakes that may not yet have been picked up, please email us at yoga@yogasynergy.com.

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***Simon Borg-Olivier & Bianca Machliss*, 1 November 2007**

Figure 1.1 Skeletal system: bones and joints in anatomical position

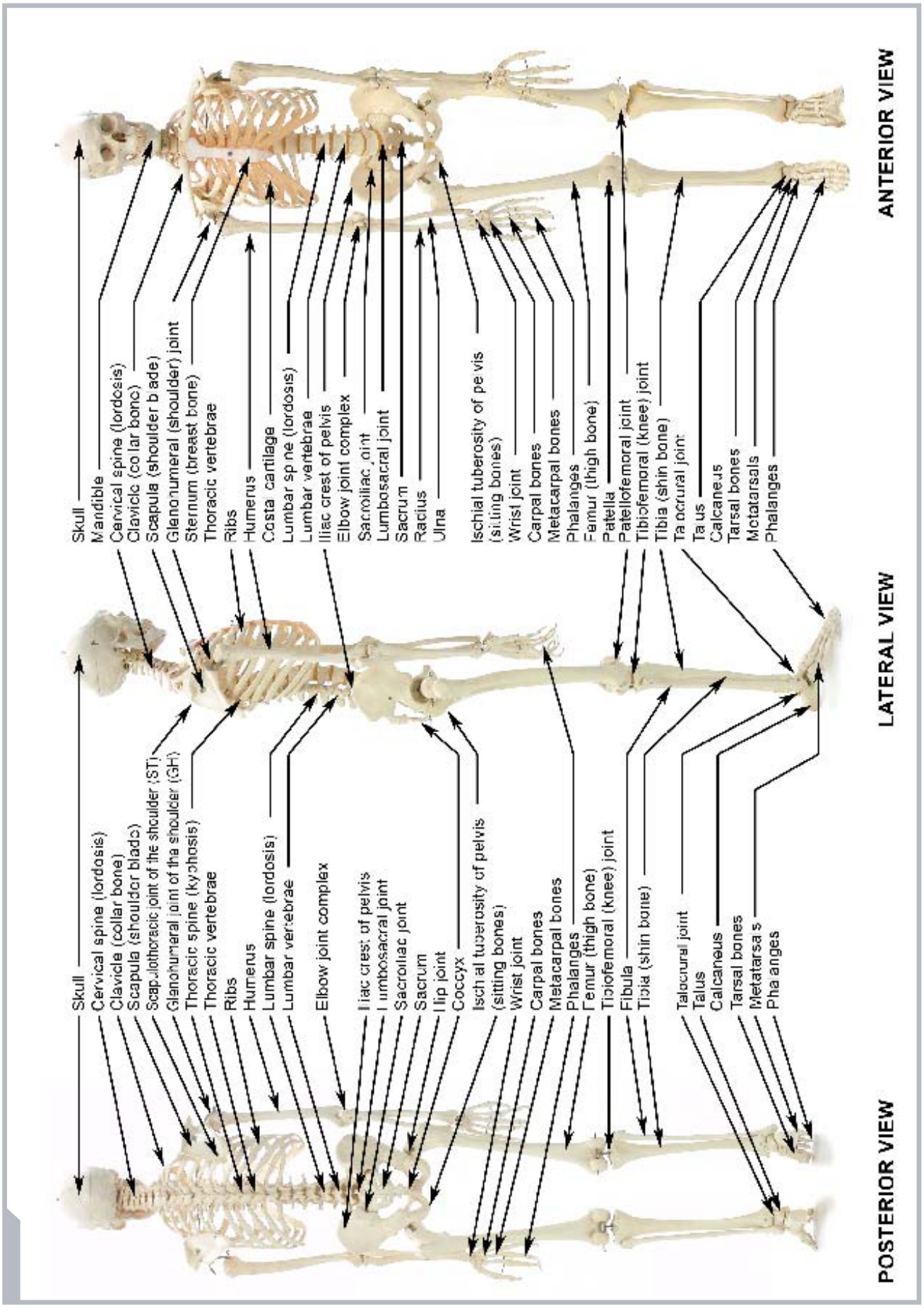


Figure 1.2 Main muscles of the body as seen in anatomical position

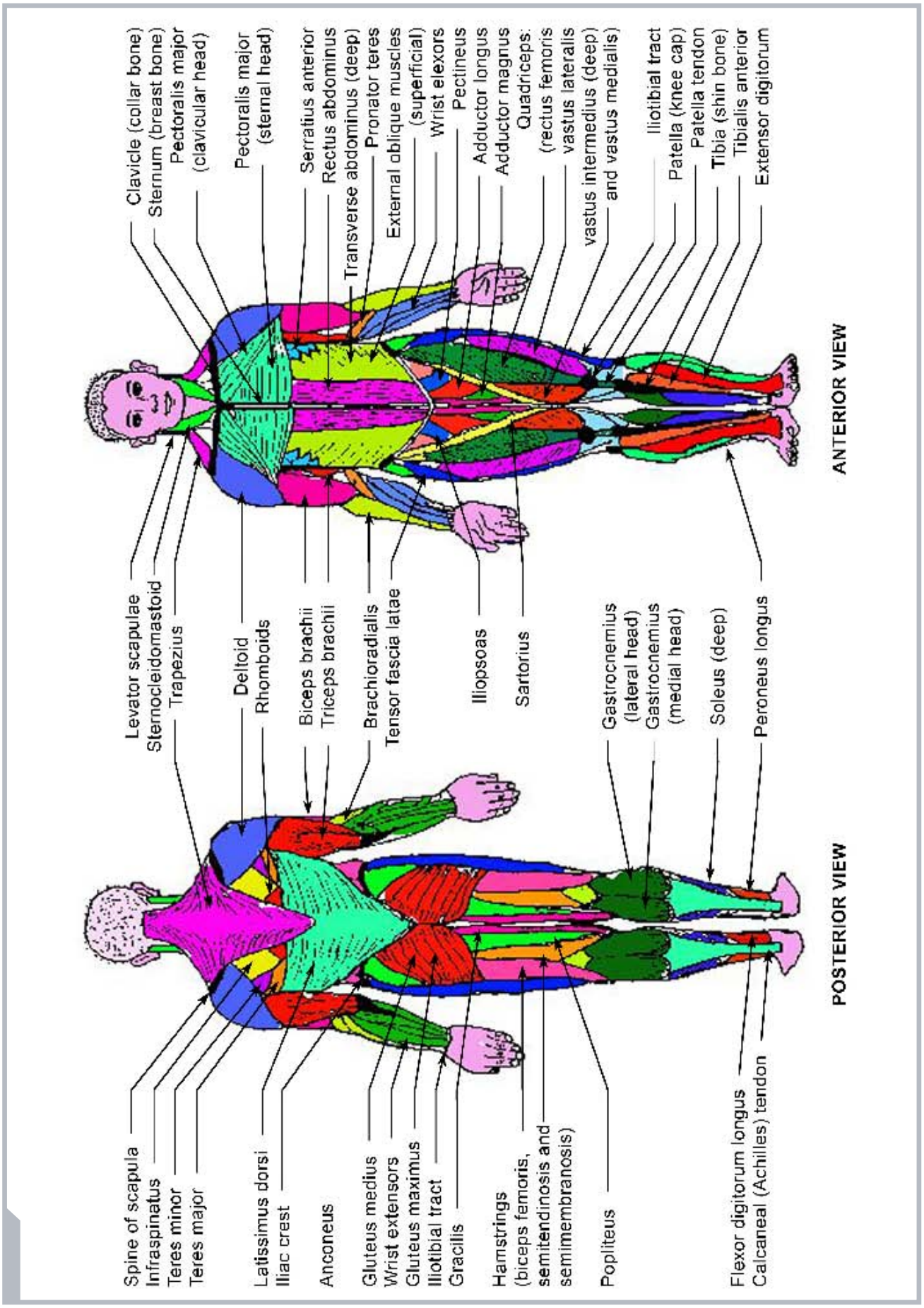


Figure 1.3 Surface anatomy: main muscles of the body & surface markings, in anatomical position

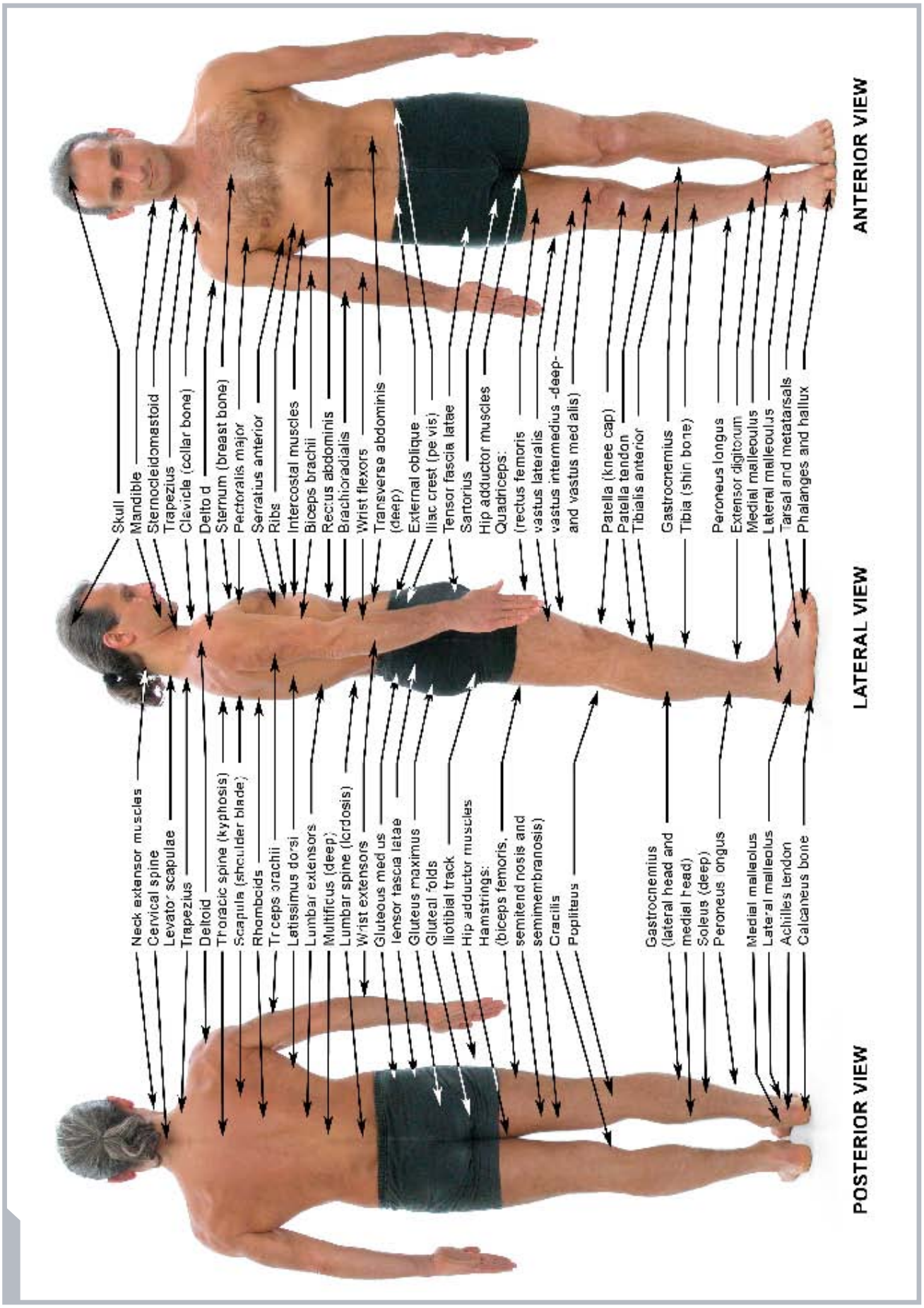
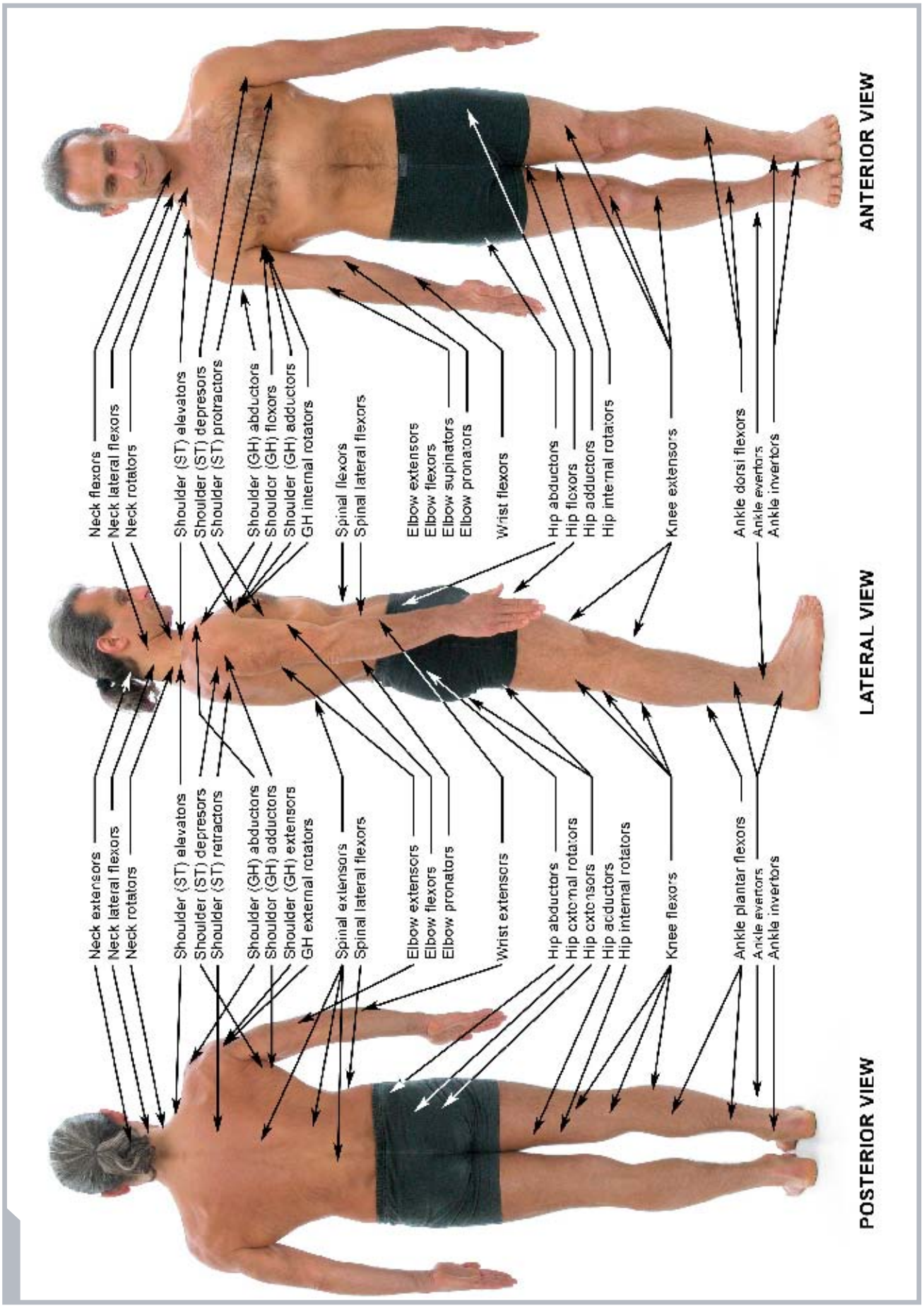


Figure 1.4 Surface anatomy: main muscle groups of the body in anatomical position

(The approximate region of each muscle group is indicated. See Figures 1.2 and 1.3 for individual muscles. Abbreviations: ST = Scapulothoracic Joint; GH = Glenohumeral Joint)



CHAPTER 1
INTRODUCTION TO THE APPLIED ANATOMY & PHYSIOLOGY OF HATHA YOGA

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1.0 INTRODUCTION TO THE APPLIED ANATOMY & PHYSIOLOGY OF *HATHA YOGA*

The word *yoga* means union, joining, or to link together as one whole. *Yoga* is the art and science of resolving the inherent opposition in all things to create a union of body, mind and soul. Meditation is an integral component and the essence of *yoga*.

Yoga is literally a holistic system. Iyengar [2001] describes *yoga* as **"…the path, which integrates the body, senses, mind and the intelligence with the self"**. Feuerstein [1996] describes the *yoga* approach as simplifying one's consciousness and energy to the point where we no longer experience any inner conflict and are able to live in harmony with the world. In India, *yoga* is traditionally thought of as a means to understanding the relationship between one's individual self (*jivatma*) and the universal self (*Paramatman*). In the dualist *Samkhya* philosophy, on which classical *yoga* was originally based, *yoga* is the result of joining *jivatma* with *Paramatman*. In the non-dualist *Vedanta* and *Tantric* philosophies, which modern *yoga* has absorbed, *yoga* is the process of realising that the *jivatma* and the *Paramatman* are in fact the one same entity.

The paths to achieve *yoga*, or to realise *yoga,* are many. Hence, there are many types of *yoga* and each type of *yoga* has many styles. Essentially all the activities of *yoga* can be divided into two parts that can be referred to as physical *yoga* and non-physical *yoga*. Physical *yoga*, which consists of physical exercises (*Asana*) and breath-control (*Pranayama*), is often thought of as a static or slow-moving type of stretching and relaxation. However, it can also include strenuous exercises that tone muscles, tension (stretch) nerves and stimulate the cardiovascular system [Raju et al., 1994]. Physical *yoga* can be very fast and may include repetitive exercises that resemble Western style callisthenics and gymnastics. Physical *yoga* can manipulate internal organs [Kuvalayananda, 1925] and modify blood chemistry [Miyamura et al., 2002]. Non-physical *yoga*, which consists of ethical disciplines and meditative practices, can help to expand one's mind, explore one's emotions, and develop the relationships between oneself and the rest of the world.

Classifying the systems of *yoga* is problematic as there is considerable overlap between the various types of *yoga*. Table 1.0 shows the relationship between the traditional eight limbs of *astanga yoga* and the functional divisions of *yoga*. All eight limbs can be applied to most types of *yoga* including *hatha yoga* and *raja yoga.*

Table 1.0 Practical divisions of *yoga* based on the *astanga yoga* system

FUNCTIONAL DIVISIONS OF THE ACTIVITIES OF *YOGA*	EIGHT LIMBS OF ASTANGA YOGA	FUNCTIONAL DIVISIONS OF THE ACTIVITIES OF *YOGA*
Non-physical *yoga*	1. ***Yama*** (our attitudes towards our environment)	**Ethical disciplines** (which include the essence of *jnana yoga*, *bhakti yoga* and k*arma yoga*)
	2. ***Niyama*** (our attitudes towards ourselves)	
Physical *yoga*	3. ***Asana***	**Physical exercises** (which include *asanas*, *vinyasas*, *bandhas*, *kriyas* and *mudras*)
	4. ***Pranayama***	**Breath-control**
Non-physical *yoga*	5. ***Pratyahara*** (meditative sense-control)	**Meditative practices** (which include techniques of *raja yoga, mantra yoga*, *yantra yoga* and *laya yoga*)
	6. ***Dharana*** (meditative concentration)	
	7. ***Dhyana*** (meditative contemplation)	
	8. ***Samadhi*** (meditative absorption)	

1.0.1 The History of *Yoga*

The history of *yoga* and meditation is the subject of much controversy. Conventional belief is that *yoga* originated in India at least 5,000 years ago [Feurestein, 1996; Ghosh, 1999], but traditional Indian belief is that *yoga* itself is far older and was practised all over the world. Artwork depicting images of people or gods in advanced *yoga* postures are dated at 2,700 BCE [Desikachar, 1998]. *Buddhist yoga* arose out of Indian *yoga* in about the fifth century BCE and slowly spread into the rest of Asia. Indian *yoga* came to China around 500 CE and developed into *Taoist yoga*. Modern *yoga* has evolved and blended from two distinct and possibly unrelated sources, *Vedic yoga* and *Tantric yoga*.

1.0.1.1 *Vedic yoga*

Vedic yoga is one of the six interrelated systems of classical Indian philosophical thought that draws on interpretations of reality based on the *Vedas*, which most authors believe are Indias most ancient texts. *Vedic yoga*, formalised in the *Patanjali yoga sutra*, is based on the dualist Samkhya School that teaches all things arise from two ultimate realities, spirit (*purusa*) and matter (*prakrti*).

Vedic yoga includes *jnana yoga* (*yoga* of self-knowledge), based on the non-dualist Vedanta school, which says there is only one ultimate reality (*Brahman*) making its appearance to our senses as an illusion (*maya*), and that all things are one, only appearing to be separate.

1.0.1.2 *Tantric yoga*

Tantric yoga is based on an important non-classical school of Indian philosophy called *Tantra. Tantric* texts (*Tantras*) are based on ancient texts called *Agamas*, which may predate the *Ved*as [Shah, 2001]. *Tantra* is non-dualist like *Vedanta,* but is polarity based. In *Tantra*, everything consists of opposite and attracting forces, such as male and female. *Tantra* is the base for most *yoga* and meditation practised today. *Tantric yoga* embraces all aspects of life. *Tantric yoga* is often misunderstood and misrepresented and thought to deal only with sexual activity and black magic. However, *hatha yoga, Buddhist yoga* and *Taoist yoga* all have significant *Tantric* influences.

1.0.1.3 *Karma yoga*, *jnana yoga* and *bhakti yoga*

The first main written mention of *yoga* is in the *Bhagavad Gita*, which was written about the fifth century BCE, and which extols the virtues of *yoga* [Desikachar, 1998]. The *Bhagavad Gita* discusses the three great paths (*margas*) of action (*karma marga*), knowledge (*jnana marga*) and devotion (*bhakti marga*) [Iyengar, 1993]. *Karma yoga* is the *yogic* path of action or the *yoga* of work. *Jnana yoga* is the *yogic* path of self-knowledge. *Bhakti yoga* is the *yogic* path of devotion.

1.0.1.4 *Astanga yoga*

The second major extant text on *yoga* is the *Patanjali-yoga-sutra*, which was written about the second century BCE. The *Patanjali-yoga-sutra* explains that the means to achieve *yoga* are by following an eight-limbed (*asta-anga*) path to the ultimate state of meditative absorption (*Samadhi*). Most *yoga* can be classified in the terms of *astanga yoga*.

The eight limbs (*angas*) of *astanga yoga* [Iyengar, 1988; 1993] are:

- *Yama* (our attitudes towards our environment)
- *Niyama* (our attitudes towards ourselves)
- *Asana* (physical exercises)
- *Pranayama* (breath-control)
- *Pratyahara* (meditative sense-control)
- *Dharana* (meditative concentration)
- *Dhyana* (meditative contemplation)
- *Samadhi* (meditative absorption).

The first two limbs of *astanga yoga*, *Yama* and *Niyama*, are the *yogic* ethical disciplines; a set of universal truths about one's attitude to oneself and to one's environment. Encompassed in these two limbs is the essence of *karma yoga, jnana yoga* and *bhakti yoga* [Iyengar, 1993].

The second two limbs of *astanga yoga*, *Asana* and *Pranayama*, can be termed physical *yoga*. In its most basic form, physical *yoga* is simply sitting in a comfortable posture (*Asana*) and being aware of one's breathing (*Pranayama*).

The last four limbs of *astanga yoga, Pratayahara*, *Dharana*, *Dhyana* and *Samadhi,* are the meditative practices. These meditative practices are equivalent to the generic term meditation as it is used in Western literature.

The main types of *astanga yoga* are *mantra yoga*, *hatha yoga*, *laya yoga* and *raja yoga* [*Prana*vananda, 1992]. Each of these *yogas* involves the application of ethical disciplines (*Yama* and *Niyama*), physical exercises (*Asana*), breath-control (*Pranayama*), and meditative practices (*Pratayahara*, *Dharana*, *Dhyana* and *Samadhi*).

1.0.1.5 *Mantra yoga*

Mantra yoga uses chanting of sounds and phrases (usually in *Sanskrit*) to induce a meditative state. Chanting can be audible or mental, and with or without breath-control. *Mantra yoga* techniques are used in traditional *hatha yoga*, Transcendental Meditation (TM) and many *Buddhist* meditative practices.

1.0.1.6 *Hatha yoga*

Hatha yoga (*yoga* of physical forces) is what most people in the Western world think of as *yoga* as it contains physical exercises (*Asana*), breath-control (*Pranayama*) and meditative practices. *Hatha yoga* was first described in the 2000-year-old text *Yoga yajnavalkya samhita*. Better known texts on *hatha yoga* include *Siva-samhita*, *Gheranda-samhita* and *hatha pradipika*, which are relatively recent writings of between 400 and 900 years old. The *hatha yoga* texts appear to be copies of earlier works of *Tantric* origin. *Hatha yoga* is in essence a type of *Tantric yoga* with four physical stages, namely *Sat-kriya* (cleansing processes), *Asana* (physical exercises), *Mudra* (energy-control), and *Pranayama* (breath-control); and three non-physical or meditative stages, namely *Pratyahara* (meditative sense-control), *Dhyana* (meditative contemplation or visualisation) and *Samadhi* (meditative absorption). Although *hatha yoga* is typified by a series of exercises that are used to generate and manipulate physical and subtle forces in the body, its main aim is the same as every other form of genuine *yoga*, namely self-realisation. The *Gheranda samhita* states that the sole reason to learn *hatha yoga* is as a path to *raja yoga* [Pranavananda, 1992].

Iyengar [2001], a foremost modern exponent of *hatha yoga*, describes *hatha yoga* as sighting the soul through the restraint of energy. *Hatha yoga* is a physical method that uses an awareness of the breath to link then unify the various aspects of the body and mind, allowing them to behave as one functional unit.

In practice, some, or all, of the elements of *hatha yoga* listed below may be performed concurrently. For example, a *yogin* can do any exercise with an ongoing meditative awareness and concentrated control of the body. Some muscles may be stretching, some tensing, and others relaxing; one part of the body kept static and another part moving; while at the same time there is an ongoing meditative contemplation (*Dhyana*) and meditative absorption (*Samadhi*) on breath-control (*Pranayama*) and meditative sense-control (*Pratyahara*).

1.0.1.7 *Laya yoga*

Laya yoga is a type of *astanga yoga* that involves deep absorptive concentration. *Laya yoga* has assumed an intermediate position between *hatha yoga* and *raja yoga*. The complicated processes of *hatha yoga* posture and breathing, and the advanced and difficult *raja yogic* processes of concentration are simplified in *laya yoga* [Goswami, 1979]*. Laya yoga* also includes the essence of *mantra yoga*. The final stage of *laya yoga* involves an advanced stage of visualisation (*yantra yoga*) that stimulates the flow of energy through the body in a profound way. This final stage is termed *kundalini yoga*.

1.0.1.8 *Raja yoga*

Raja yoga, the royal path to the ultimate meditative state (*Samadhi*), is what most people think of as meditation and is considered the most difficult type of *astanga yoga* [*Prana*vananda, 1992]. *Raja yoga* is considered the non-physical approach to achieve *yoga*. *Raja yoga* is essentially about controlling the mind and unifying one's intelligence with one's consciousness [Ghosh, 1999]. The main emphasis of *raja yoga* is the meditative practices, which are advanced techniques of meditative sense-control (*Pratayahara*), meditative concentration (*Dharana*), meditative contemplation or visualisation (*Dhyana*), and meditative absorption (*Samadhi*). *Raja yoga* has little emphasis on physical work beyond sitting in a stable posture (*Asana*) with an erect spine. However, the physical exercises (*Asana*) of *hatha yoga* can help prepare one for the challenge of sitting comfortably for a long time in the *raja yoga* meditative state.

1.0.1.9 *Buddhism*

Buddhism arose out of *yoga* about fifth century BCE and slowly spread across Asia. The Buddha was a dedicated *yogin* (*yoga* practitioner) with a passion for meditative absorption [Feuerstein, 1996]. *Buddhist yoga* includes the use of such techniques as posture (*Asana*) and control of the life force (*Pranayama*). *Buddhist* texts, as in Hindu schools of *yoga,* emphasise erect body posture. However, in constrast to the Hindu schools of *yoga, Buddhist yoga* does not advocate breath retentions. Instead practitioners follow the breath with the mind. *Buddhist yoga* often incorporates *mantra yoga, yantra yoga* and *mudras* (energy-control gestures) in order to facilitate meditative practices. *Buddhist yoga* was derived from *Vedic yoga* in India, but is now prevalent throughout Asia.

1.0.1.10 *Taoist yoga*

Yoga was introduced to China about 500 CE and developed into *Taoist yoga*. Qi-gong is the main type of *Taoist yoga. Taoist yoga* is used by Shaolin monks to tone and flex their bodies, to gather *chi* energy (*chi* in *Taoist yoga* is the equivalent of *prana* in *hatha yoga*), and to prepare for meditation. In *Taoist* training, breath has four levels. Windy-breath is noisy and usually present upon physical exertion. Raspy-breath can be heard by others and is usually due to disturbed emotions or sickness. Qi-breath is so quiet that one cannot even hear one's own breath. Resting-breath is the ultimate Qi-gong state of breathing when one cannot tell whether one is breathing or not [Liu, 1991]. The contemporary Qi-gong master Sat Chuen Hon [2002] writes of breathing in *Taoist yoga* in exactly the same terms that breathing is described in the ancient Indian texts.

> **"It is only when one achieves the level of breathing of total smoothness of resting-breath that one can consider to have really attained the beginning level of Qi-gong practice …. very few practitioners can practice with Qi-breath and only a few great masters have demonstrated the ability to maintain a flowing state of Resting-breath while practising Tai-ji or Qi-gong forms. One experiences Resting-breath more readily when doing seated meditation. Once one has reached the level of deep theta brain-waves or the deep *Samadhi* state, the sound of one's own breathing disappears and one no longer notices whether one is breathing or not."**

1.0.1.11 History of *yoga* as a therapy

In the twenty-first century, *yoga* is used to develop and maintain physical and mental health. The concept of using *yoga* as a therapy for the body and the mind is not new. *Yoga* as a therapy had its first probable mention in the *Yoga yajnavalkya samhita*, which dates to the second century BCE. More recent *hatha yoga* texts such as the *Hatha pradipika* also mention the various therapeutic benefits of *yoga.*

Yoga made its first main impact on the West when **Swami Vivekananda** (1863–1902) spoke on *jnana yoga* at the Parliament of Religions held in Chicago in 1893. In 1920, **Paramahansa Yogananda** (1893–1952), who wrote *Autobiography of a Yogi* [1946], arrived in Boston and established the Self-Realisation Fellowship. In 1924, **Swami Kuvalayananda** (1883–1966), founded the *Kaivalyadhama Yoga* Research Institution in Lonavala India, which contributed greatly to modern scientific studies of *yoga* in India, and which are mostly published in the quarterly journal *Yoga Mimamsa* from 1924.

In the same period, **Swami Sivananda** (1887–1963), an Indian medical doctor, studied, practised, and taught *yoga* in its many forms. Sivananda authored over 200 books including *Kundalini Yoga* [1994] and founded the Divine Life Society, an *ayurvedic* pharmacy, the *Yoga Vedanta* Forest Academy, and an eye hospital.

Another great yogi of this era was **Swami Yogeshwarananda** (1887–1985), who founded the *Yoga Niketan* Trust, and travelled the world extensively. Yogeshwarananda wrote an important book on the deepest states of meditation called *Atma Vijnana* – Science of Soul [1959], and he wrote a definitive early book on *hatha yoga* called *Bahiranga Yoga – First Steps to Higher Yoga* [1970].

Shyam Sundar Goswami (1891–1979) was a pioneer of the scientific exposition of *yoga* in the West. He was a master of *hatha yoga* and his treatise on *laya yoga* [Goswami, 1980] is regarded as the best on this subject.

Probably the finest *hatha yogi* and *Astanga yogi* of the twentieth century was **Sri Tirumalai Krishnamacharya** (1888–1989). As a youth, Krishnamacharya studied for seven years with Sri Ramamohan Brahmachari, who was one of last great Himalayan *yoga* masters. Krishnamacharya travelled extensively throughout India in the 1930s lecturing on *yoga* and demonstrating *yoga-siddhis,* (*yogic* special powers) in order to create a resurgence of the dying *yoga* tradition. These demonstrations included suspending his pulse, stopping cars with his bare hands, performing difficult *asanas*, and lifting heavy objects with his teeth [Ruiz, 2001]. Krishnamacharya was a great scholar with seven PhDs, who used his vast knowledge of the ancient texts to synthesise an excellent system of *yoga* therapy. Krishnamacharya was the teacher of the four most influential *yoga* masters of the modern age, namely Indra Devi, K. Patabhi Jois, B.K.S. Iyengar, and T.V.K. Desikachar.

Indra Devi (1899–2002), author of the first bestseller on *yoga* called *Forever Young, Forever Healthy* [1953], was Krishnamacharyas first Western student, and first female student, in 1937. She founded the first modern school of *yoga* in Shanghai China, where she taught Madame Chiang Kai-Shek. In China, she also taught Russian-born Michael Volin, who subsequently took over Devis school, then came to introduce *yoga* to Australia in the 1950s. Devi convinced Soviet leaders that *yoga* was not a religion and brought her *yoga* to the Kremlin in her native Russia, where it had been illegal. In 1947, she opened a school in Hollywood and became known as the 'First Lady of *Yoga'*, and taught actresses like Marilyn Monroe, Greta Garbo, Elizabeth Arden and Gloria Swanson, and also taught Richard Hittleman who presented *yoga* to a large audience in his long-running television show in the United States during the 1970s [Ruiz, 2001].

Sri K. Patabhi Jois (1915–), author of *Yoga Mala* [1953], was instructed by Krishnamacharya from age twelve to teach what is now referred to as *Astanga-vinyasa*. *Astanga-vinyasa-yoga* includes five physically demanding sequences of postures that have become very popular in the West in the past ten years. While these sequences can be effective for some people, they are quite inaccessible for many, and even dangerous for untrained people who have predisposing medical conditions or musculoskeletal problems. This smooth flowing practice emphasises a type of dynamic meditation with focus on breathing in a particular fashion, gazing at particular spots (*dristhis*), while maintaining firmness in the abdomen (*bandha*). The continual flow of this practice develops a tremendous amount of heat that tends to allow an increase in flexibility but does not allow much time to adjust body alignment or consider all issues of safety. While the *Astanga-vinyasa* system can be a therapy for those who are already reasonably healthy, it does not generally allow enough modification of the exercises to allow a broad range of people to take up the practice.

Sri B.K.S. Iyengar (1918–), author of *Light on Yoga* [1966], teaches a very exacting and methodological style of *yoga*, referred to by his students as *Iyengar yoga*, which often modifies postures with the use of props such as chairs, blankets, belts and blocks. Iyengar has researched and experimented with *yoga*-therapy for over 50 years with tens of thousands of students. He has successfully applied *yoga* to a large variety of musculoskeletal injuries and medical conditions. Iyengar has regularly used *yoga* to help people with problems such as knee ligament ruptures, shoulder and hip pain, wrist and ankle sprains, paraesthesia, paralysis, inter-vertebral disc bulges and other spinal injuries. He has used *yoga* to treat people with conditions such as asthma and bronchitis, constipation and diarrhoea, epilepsy, polio, muscular dystrophy and AIDS [Raman, 1998]. Postures taught in Iyengar-style classes are fundamentally the same as those taught in *Astanga-vinyasa-yoga* classes, but they are usually held for a longer time, and often a rest period is given, during which time various aspects of the posture are intellectually examined and safety issues are discussed. Specific guidance on how to effectively do each posture are given throughout most classes. However, while being a demanding yet relatively safe approach to physical *yoga*, this style of teaching may be perceived by some yoga practitioners to compromise the meditative flow of the practice, and can cool the body down.

T.V.K. Desikachar (1938–), author of *The Heart of Yoga* [1995], is the son of Krishnamacharya. The teaching of Desikachar, termed *vini yoga*, is more congruent with the evolved way that Krishnamacharya was teaching in the later half of his life. Students are usually taught on an individual basis, with each student being prescribed specific sequences of postures, with specific breath-control (*Pranayama*) for each.

Modern *yoga* has also been influenced by the teaching and writing of several other important teachers. Three prominent students of Sivananda were Swami Vishnu Devananda (1917–1993), who wrote *The Complete Illustrated Book of Yoga* and translated the *Hatha Yoga Pradipika* [1987]; Swami Satyananda (1923–), who wrote *Kundalini Tantra* and *Asana Pranayama Mudra Bandha* [1966]; and Swami Satchidananda (1914–2002), who founded Integral *Yoga*, which has been adapted successfully by Dr Dean Ornish to treat heart patients [Ornish et al., 1990].

Many of the worlds alternative therapies and physical therapies are *yoga*-based. Techniques resembling *yoga* and often derived from *yoga* are often used for therapy in the world today. Many people who teach and practise these techniques may not realise they are *yoga*-based. Physical and psychological therapists often use relaxation and meditation techniques derived from *yoga*. Many of the exercises that are taught as exercise based physiotherapy are derived from *yoga.* Pilates is a *yoga*-based form of physical training that is especially popular as a therapy in the dance community. Pilates instructors and exercise-based physiotherapists even teach some concepts that are directly from the heart of traditional *yoga*. One example is the concept of core stabilisation, which is described in *yoga* texts as *bandha*, but which is often neglected or not known by many modern *yoga* teachers.

1.0.2 The Scientific Validity of *Yoga*

A MEDLINE literature search on *yoga* reveals that there are 726 scientific articles relating to *yoga* written from 1965 to March 2005. These articles claim the benefits of *yoga* range from improvements in strength [Madanmohan et al., 1992], flexibility [Ray et al., 2001], aerobic ability [Balasubramanian & Pansare, 1991], to improvements in muscle tone, rheumatoid arthritis, lung function, concentration, poor eyesight, obesity, indigestion, back pain, hypertension, various respiratory diseases, sinusitis, arthritis, diabetes (I and II), as well as anxiety, nervousness, attention deficit and memory loss. Many of these articles make interesting reading and may be perfectly correct in their claims regarding *yoga*, but very few present valid scientific proof of the benefits of *yoga*. Only 54 articles were based on randomised, controlled trials on *yoga,* and some of these report that either *yoga* has no effect [eg Kroner-Herwig et al., 1995] or that the effect is not significant [Shaffer et al., 1997].

Similarly, a MEDLINE search on meditation reveals that there are 1031 scientific articles regarding meditation written from 1965 to March 2005. Of these, only 63 were based on randomised, controlled trials.

Randomised, controlled trials of *yoga* have shown that *yoga* is effective in increasing joint flexibility [Ray et al., 2001], management of coronary artery disease [Manchanda et al., 1980], increasing regression of coronary atherosclerosis [Manchanda et al., 2000], coping with exam stress [Malathi & Damodaran, 1999] management of hypertension [Patel & North, 1975], management of stress in epilepsy [Panjwani et al., 1995], relief in hand osteoarthritis [Garfinkel et al., 1994], the ability to perform complex tasks [Manjunath & Telles, 2001], long-term management of bronchial asthma [Nagarathna & Nagendra, 1985], and reduction of medication in asthma [Singh et al., 1990]. A randomised controlled trial of specialised breath-control (unilateral nostril breathing) was found to increase spatial memory [Naveen et al., 1997].
While there is not much valid scientific research published on *yoga*, there are many well researched papers on the scientific elements of *yoga*. The main scientific components or the elements of *yoga* are:

- Stretching
- Isometric strengthening
- Isotonic strengthening
- Isokinetic strengthening
- Joint range of movement exercises
- One-legged exercises
- Cardiovascular (aerobic) conditioning
- Breathing
- Unilateral nostril breathing
- Sense control

- Concentration
- Relaxation
- Visualisation
- Meditation.

MEDLINE searches on the topics such as those following can reveal many research articles or papers, which provide tangible evidence regarding the benefits of *yoga*: isometric exercise [eg Monteiro Pedro *et al*., 1999], breathing exercise [eg Yan & Sun, 1996], stretching [eg; Herbert & Gabriel, 2002], relaxation [eg Weber, 1996], posture [eg Cholewicki et al., 1997], one-legged exercises [eg Kannus et al., 1992], antagonistic muscle co-activation [eg Glasscock et al., 1999], aerobic conditioning, unilateral forced nostril breathing [Naveen et al., 1997], Valsalva [Bazak , 1990] and Mueller manoeuvres [Gioia et al., 1995], visualisation [Kominars et al., 1997], and mental imagery [eg Hudetz et al., 2000].

However, to justify the validity of *yoga* with such a reductionist approach goes against the very nature of *yoga* as a time-honoured holistic science. The best evidence available in support of *yoga* comes from the millions of people around the world who have practised *hatha yoga* throughout the ages, and who continue to practice because of the positive benefits that can be obtained.

1.0.3 Why Study the Anatomy and Physiology of *Yoga?*

Hatha yoga may be learnt by practising *yoga* postures and exercises until they are perfected, without having any knowledge of anatomy and physiology. However, in some cases, incorrect practice or unsafe technique can aggravate a practitioner's pre-existing medical problems or it can actually create new problems. A practitioner who learns *yoga* without an understanding of anatomy and physiology may become very adept at understanding their own body, but may not be able to relate to the individual differences in other peoples bodies.

_No 1.1_ Apply the principles of anatomy and physiology to improve your *yoga*, your health and your ability to communicate with or teach others

A sound understanding of human anatomy and physiology and how it is applied to the *hatha yoga* postures and exercises can help to:

- Improve levels of cardiovascular fitness, strength and flexibility
- Minimise the risk of exercise-related (or *yoga*-related) injuries
- Improve ability to recover after injury or a medical condition
- Deepen understanding of other peoples bodies and help improve their bodies with a safe and effective teaching style
- Liaise and communicate with other medical practitioners.

The *hatha yoga* described in this book is based on the style developed and taught at the Sydney-based school, *Yoga Synergy*. The teaching at *Yoga Synergy* represents a synthesis between traditional *hatha yoga* as passed down from Sri T. Krishnamacharya and his main teachers and exercise-based physiotherapy. Although aspects of *Synergy-style yoga* are rarely used in other yoga styles, it is not our aim to develop a new style of *yoga*. We see *Synergy-style yoga* as traditional *hatha yoga* adapted for the Western body by the systematic applications of the principles of anatomy and physiology.

The three most important, and relatively novel, aspects of the *Synergy-style yoga* and the contents of this book, which have all been developed through a thorough examination of both traditional *hatha yoga* teaching and scientific research, are:

- A gradual build-up for each *asana* (static posture) or *vinyasa* (dynamic exercise), from the simplest or easiest first stage version of a posture to the most complex or hardest version of a posture. Each stage incorporates various amounts and intensities of the main elements of each pose, but always with an inherent balance between strength and flexibility.

- The incorporation of the nine main *bandhas* of *bandha-hatha yoga* [Section 1.7.3, Appendix C] as a means for generating and moving energy through the body as well as stabilising each of the nine major joint complexes [Section 1.5.3].
- The emphasis on *mudras* and *nadi-hatha yoga* [Section1.7.2] as a means of taking full advantage of nerve reflexes [Section 1.7.2.2.1], fascial connections between tissues [Section 1.3.2.1.3], as well as tensioning (stretching) nerves [Section 1.7.2.1], *nadis* (subtle channels) [Section 1.7.2] and acupuncture meridians [Figures 9.1 – 9.7].

1.0.4 A Working Model for Why and How *Hatha Yoga* Actually Works

Beneficial side effects of practising *hatha yoga* may include increases in strength, flexibility and the ability to relax [Section 1.0.2]. However, one of the main physiological purposes of *hatha yoga* is to improve the circulation of information, energy and matter throughout the body. Stimulation of body circulation is one of the main ways *hatha yoga* actually works [Section 8.4].

Hatha yoga stimulates circulation by creating regions of differential pressure throughout the body. Energy and matter always tend to move from regions of high pressure to regions of low pressure [Resnick & Halliday, 1977]. The word ***Hatha*** is Sanskrit for force [Kapp, 2001], and can also represent pressure. Pressure is defined as 'force per unit area' [Resnick & Halliday, 1977]. According to Woodroffe [1922], Iyengar [1966] and Devananda [1987], the sounds ***Ha*** and ***Tha*** are Sanskrit for sun and moon respectively. The sound ***Ha*** represents or implies heat, which is created by high pressure. The sound ***Tha*** represents or implies coolness or cold, which is created by low pressure [Borg-Olivier & Machliss, 1997] [Figure 1.5].

Therefore, ***hatha yoga***, which means literally **a force union or forced union**, works by setting up regions of relative high pressure and low pressure (forces) throughout the body, which help stimulate the circulation or flow of information, energy and matter, in a manner similar to the way that the heart works [Section 8.1.3.2]. As soon as a relative difference in pressure comes into existence within the body, there is a physiological tendency for **energy** (eg heat)**, matter** (eg blood and intracellular fluid), and **information** in the form of neurotransmitters, hormones, immunotransmitters and other more subtle agents, to **move from the region of higher pressure towards the region of lower pressure** [Borg-Olivier & Machliss, 1997] [Figure 1.5].

When the pressure in one part of the body is increased, this pushes energy and matter away from that region in a manner similar to squeezing the water out of a sponge. In other parts of the body the pressure is reduced and this pulls energy and matter towards that region, in a manner similar to putting a squashed sponge in water and letting it expand or stretch, drawing water into it.

Hatha yoga sets up differential pressures (relatively high and low pressures) within the body in six main ways using:

- Muscle activation (increasing local pressure) and muscle relaxation (decreasing local pressure) in certain *asanas* (static postures) and *vinyasas* (dynamic exercises and linking movements between *asanas*), which engage the musculoskeletal pump [Section 8.1.2.3.1]
- Specific *pranayamas* (breath-control exercises) which change the pressures in the thorax and abdomen, as well as the normal actions of the respiratory pump [Section 8.1.2.3.2], where a reduction in abdominal and thoracic pressure causes inhalation while an increase in pressure causes exhalation
- The effects of the force of gravity [Section 12.7.1.3.3.2], especially noticeable in the inverted and semi-inverted postures the *yoga* system offers
- The effects of the *asanas* (static postures), which physically compress some parts of the body (ie increasing local pressure), while stretching other parts of the body (ie decreasing local pressure)
- The effects of the *bandhas* [Section 1.7.3], which usually involve co-activation of opposing muscles across joints and can either increase (*ha-bandhas*) or decrease (*tha-bandhas*) local pressure [Section 1.7.3.4 & Appendix C]
- The effects of movement of the body and movement of the body parts to initiate centripetal, centrifugal and inertial forces around the body that can affect circulation. This is especially noticeable when the movements are fast and sharp in turning.

Figure 1.5: The Mechanism of *Hatha Yoga* [Borg-Olivier & Machliss, 1997]

HATHA = force YOGA = union

PRESSURE = Force / Area
(i.e. pressure is force per unit of area)

HA = Sun => Heat => High Pressure
THA = Moon => Cool => Low Pressure

HATHA = Force => Forces of high & low pressure

HATHA-YOGA => A union (YOGA) in the body resulting from movement (circulation) of energy from regions of

High Pressure (= HA force) to Low Pressure (= THA force)

The circulation of body substances, through blood vessels and intracellular spaces, between two different body parts, increases proportionally as the relative **difference** in pressure between the two body parts increases. Therefore, to achieve maximum stimulation of circulation with a minimum of effort, it is important that one part of the body is kept at a very low pressure. This is one reason why the face and neck are usually kept completely relaxed (ie at a low pressure) while doing *yoga*. If this is not ensured, then blood pressure [Section 8.4.2] and stress levels can increase significantly.

The movement of energy, matter and information in the body is promoted and pumped through the body by six (6) pumps other than the heart, which is the cardiovascular pump [Section 8.1.3.2]. These other pumps are referred to as the musculoskeletal pump [Section 8.1.2.3.1], the respiratory pump [Section 8.1.2.3.2], the gravitational pump, the postural pump, the muscle co-activation pump [Section 1.7.3] and the centripetal pump [Section 12.7.2.2.1].

Yoga utilises the musculoskeletal pump of circulation [Orsted et al., 2001] during *vinyasa* when one changes from one posture to the next. As muscles tense, they increase local pressure in the veins and push blood and intracellular fluid in the direction of the heart. One-way back-flow valves in the veins prevent movement of blood away from the heart in the veins. When a muscle relaxes, it decreases local venous pressure and pulls blood from regions more distal to the heart to that region.

Yoga utilises the respiratory pump of circulation [Hillman & Finucane, 1987] with *Pranayama*. Breath-control can affect the pre-load of the blood into the heart, which can alter heart rate depending on whether the inhalation is directed to the thorax, which increases heart rate, or the abdominal region, which decreases heart rate.

Yoga utilises a gravitational pump of circulation using *viparita-karani* [Section **12.7.1.3.3.2**]. *Viparita karani* represents all the inverted or semi-inverted postures. Simple postures such as lying supine and resting the legs vertically up a wall and more advanced poses like *sirsasana* (head stand), reverse the natural flow of gravity and can offer the same benefits as the technique referred to as postural drainage used in physiotherapy [Fink, 2002].

Yoga utilises a postural pump of circulation using *asanas. Asanas* are generally thought of as static postures. Relative to normal postures, such as anatomical position (*savasana*), *asanas* can physically compress (increase the pressure) at one region of the body while expanding or stretching (decreasing the pressure) in another region of the body.

Yoga utilises a muscle co-activation pump of circulation using *bandhas*. A *bandha* involves co-activation to create regions of high pressure (*ha bandhas*) or regions of low pressure (*tha bandhas*). Energy, in the form of blood and heat (among other things), will try to move from the regions of high pressure to the regions of low pressure. Intelligent control of the formation of these *bandha*s during a *yoga* practice can regulate the circulation in any part of the body.

Yoga utilises a centripetal pump (or inertial pump) of circulation during *vinyasa*. While the body, or parts of the body, moves through space, in its everyday activities and especially during a dynamic *yoga* practice, the blood and intracellular fluids move along with the body at a constant velocity. However, when the body, or a body part, changes its velocity by accelerating, or changing its direction of movement, the blood will initially keep moving with the same velocity and direction. Intelligent control of movement during a *yoga* practice allows the centripetal pump to significantly affect the flow of blood through the body, and allows energy to be gathered and moved through the body as required.

Circulation through the body is further discussed in terms of these six pumps and this model for how *hatha yoga* works in Section 8.4.

1.1 ANATOMICAL TERMINOLOGY

The following simple anatomical terms can greatly facilitate an understanding of the body and communication between health practitioners:

- **Anterior**: relatively closer to the front of the body
- **Posterior**: relatively closer to the back of the body
- **Medial**: relatively closer to midline of the body
- **Lateral**: relatively further from the midline of the body
- **Proximal**: relatively closer to the attachment of a limb, or the point of origin
- **Distal**: relatively further from the attachment of a limb, or the point of origin
- **Superior**: relatively closer to the head
- **Inferior**: relatively further from the head.

1.1.1 Anatomical Position:

Anatomical position is the standard position which most anatomical terminology relates to. It is standing erect with the arms placed by the side of the body and with the palms facing forward (like a standing version of *savasana,* the *yoga* relaxation posture) [Figure 1.3 Anterior View].

_No 1.2_ Observation of body symmetry and asymmetry in *yoga* postures can help identify problems

By understanding the symmetry inherent in the ideal, healthy body in the anatomical position

(*savasana*) one can compare and contrast the joint positions in various postures, which are also symmetrical and also those postures which are not symmetrical and look for regions of asymmetry, which may be the cause of musculoskeletal or physiological discomfort [Appendix B].

1.2 ORGANISATION OF THE BODY

For the purposes of study, the human body can be thought of as consisting of several levels of organisation:

- **Chemical level**: At the atomic level, atoms such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), calcium (Ca), potassium (K), phosphorous (P) and sodium (Na) are the most important for maintenance of life. At the

molecular level, atoms combine to make simple molecules such as water (H_2O), carbon dioxide (CO_2) and phosphate (PO_4), which then combine to form large complex molecules such as proteins, carbohydrates, fats, vitamins and DNA (deoxyribonucleic acid).

- **Cellular level**: Cells are made of complex molecules and generally consist of a central nucleus (containing the DNA or genetic material), surrounded by a peripheral cytoplasm. Cells are the basic structural and functional units of an organism.
- **Tissue level**: Tissues are groups of similar cells and the substances surrounding them, which work together to perform a particular function. The four basic tissue types are epithelial, connective, muscular and nervous tissue.
- **Organ level**: Organs are structures which are composed of two or more types of tissues and which have specific functions, eg heart, lungs, liver, kidney, brain.
- **Body system level**: A body system is loosely defined as a collection of related organs, tissues, and structures sharing a common function. The concept of a body system is a useful tool in the study of human biology. Important body systems include the:

    - **Skeletal system**, which consists of bones and the ligaments joining the bones.
    - **Articular system**, which consists of joints, joint capsules and articular discs.
    - **Muscular system**, which consists of muscles and tendons, which join muscles to bones.
    - **Nervous system**, which consists of the brain, nerves and neurotransmitters, which control the body and communicate via electrochemical signals.
    - **Respiratory system**, which consists of lungs, windpipe (trachea) and nasal cavity.
    - **Cardiovascular system**, which consists of the heart, blood vessels and the blood flowing through the system.
    - **Digestive system**, which consists of the digestive tract from the mouth to the anus and the associated digestive glands and organs that break down and assimilate food.
    - **Lymphatic system**, which consists of the lymph glands, lymph ducts and the lymph flowing through the system, and is concerned with the recovery of tissue fluid.
    - **Immune system**, which consists of immune system cells and body defence mechanisms.
    - **Endocrine system**, which consists of the endocrine glands and the hormones they secrete, and is concerned with control and communication throughout the body by chemical signals.
    - **Urinary system**, which consists of the kidneys and ureters, and is concerned with water and acid-alkali balance, and the elimination of wastes from the body.
    - **Reproductive system**, which consists of the sexual organs and their associated glands.

It must be understood however that these commonly used divisions are quite arbitrary and all have overlapping functions and locations. Often it is more useful to talk about combined systems such as the musculoskeletal system (muscular system and skeletal systems), and the cardiopulmonary system (cardiovascular system and respiratory system).

No 1.3 Yoga aimed at one body system can also affect other systems

Yoga is a holistic system and so is the human body. By working on one body system such as the musculoskeletal system, all the other body systems are also significantly affected. The *yoga* practitioner and *yoga* teacher must be aware that simple *hatha yoga* , while at first glance are only working on the muscles and joints, can actually have a profound effect on the cardiopulmonary system and the nervous system and can be shown to affect the other body systems.

1.3 BODY TISSUE TYPES [Table 1.1]

The four main tissue types of the body are described in Table 1.1. These tissues are:

1. Epithelial tissue [Section 1.3.1]
2. Connective tissue [Section 1.3.2]
3. Muscle tissue [Section 1.6 & Chapters 2-7]
4. Nervous tissue [Section 1.3.4 & Chapter 9]

Table 1.1 Four main tissues of the body [Section 1.3]

1. EPITHELIAL TISSUE [Section 1.3.1]	2. CONNECTIVE TISSUE [Section 1.3.2]	3. MUSCLE TISSUE [Section 1.3.3]	4. NERVOUS TISSUE [Sections 1.3.4, Chapter 9]
1. Skin Epithelium **2. Visceral (Organ) Epithelium** **3. Blood vessel Epithelium** **4. Glandular Epithelium**	**1. FIBROUS CT** • Loose CT • Dense regular CT (tendons and ligaments) • Dense irregular CT (Joint capsules) **2. CARTILAGE** • Hyaline • Elastic • Fibrocartilaginous **3. BONE** • Compact bone • Spongy bone **4. BLOOD** • Red blood cells • White blood cells • Platelets • Plasma	**1. VOLUNTARY MUSCLE** • Skeletal muscle **2. INVOLUNTARY MUSCLE** • Cardiac (heart) muscle • Smooth muscle	**1. Central nervous system (CNS)** • Brain • Spinal cord **2. Peripheral nervous system (PNS)**: • Cranial nerves • Spinal nerves PNS DIVISIONS: **a) Somatic nervous system** (voluntary) **b) Autonomic nervous system** (involuntary) • Sympathetic **nervous system** • **Parasympathetic nervous system**

1.3.1 Epithelial Tissues

1.3.1.1 Functions of epithelial tissues

The many various epithelial tissues have roles in:

- Lining every surface of the body
- Protection
- Absorption
- Synthesis and secretion
- Temperature regulation
- Fluid regulation
- Excretion

1.3.2 Connective tissues (CT)

Connective tissue (CT) contains a very wide variety of specialised cells. Many different types of cells perform the functions of binding, general support, connection, protection, storage, transportation, defence and repair. The state of a persons connective tissue plays a significant role in determining that persons range of joint motion (ROM).

No 1.4 **Condition of one's connective tissue affects one's flexibility**

To a large extent the degree of flexibility a person has is dependent on the condition of the connective tissues [Alter, 1996].

Types of connective tissues (CT)
1. Fibrous Connective tissue [Section 1.3.2.1]
2. Cartilage [Section 1.3.2.2]
3. Bone [Section 1.3.2.3]
4. Blood [Chapter 8]

Functions of connective tissues (CT)
1. Support
2. Packing
3. Storage
4. Transport
5. Defence
6. Repair

1.3.2.3 Structure of connective tissues (CT)

Connective tissue consists of connective tissue cells in an intracellular matrix.

> Connective tissue (CT) = CT Cells + Intracellular Matrix

- **Connective tissue cells** specialised for fibrous CT, cartilage and bone are described below [Sections 1.3.2.1, 1.3.2.2 & 1.3.2.3]; and later [Section 8.1.1] for blood.
- **The intracellular matrix** that CT cells are in varies immensely for each of the four types of CT. The intracellular matrix of fibrous CT has varying levels of flexibility and strength, while that of cartilage and especially bone are quite rigid. Conversely, the intracellular matrix of blood is like a soupy liquid.
- The intracellular matrix consists of a number of different types of fibres of different relative amounts for each of the four CT tissue types, and a ground substance, which is the binding agent that holds the matrix and cells together.
    - **Intracellular Matrix = CT Fibres + Ground Substance**
    - ***CT* Fibres** include:
        - **Collagen fibres**, which are strong and relatively non-elastic fibres making up about one third of all body protein
        - **Elastin fibres**, which have physiological and biochemical elastic properties
        - **Reticulin fibres**.
    - **Ground substance** mainly consists of:
        - **Water**, at different relative amounts for each of the four CT types, and
        - **Glycosaminoglycans (GAGs)** which are hydrating agents – molecules that can absorb and bind water to a high degree.

1.3.2.1 Fibrous connective tissue

There are four main types of connective tissue:
1. **Loose Areolar CT** is found deep in the skin and other epithelial tissues
2. **Dense Regular CT** is found in ligaments and tendons
3. **Dense Irregular CT** is found in the fascia, joint capsules and in the dermis of the skin. Dense irregular CT is omni-directional
4. **Fat cells** are specialised loose CT designed for the storage of fat.

The human body contains many structures that are composed of connective tissue. The most important to understand for *yoga* are ligaments, tendons and fascia.

1.3.2.1.1 Ligaments

> Ligaments are dense regular connective tissue structures that **join bone to bone**.

Ligaments function as mechanical restraints, keeping bones joined together. They:

- Contain proprioceptive sensory organs
- Cannot stretch much
- Do not regenerate or repair easily
- Only function to restrain a joint at the end of the range of movement (ROM) of the joint.

No 1.5 Protect ligaments from overstretching

Ligaments should not be overstretched. Therefore, at the extremes of joint movement the muscles crossing that joint may be kept gently tensed to avoid an over-stretch of the ligaments.

1.3.2.1.2 Tendons

Tendons are dense regular connective tissue structures that **join muscle to bone.**

Tendons have characteristics similar to that of ligaments, with the exception that:

- Tendons are slightly less elastic than ligaments, in order to transfer energy directly from the muscle to the bone
- Tendons have better healing power than ligaments.

No 1.6 Increase tendon stretching with muscle tension

The stretch on a tendon may be significantly increased if the attached muscle is gently and carefully tensed. For example, in *supta virasana* the stretch on the quadriceps tendon and the patella tendon [Section 5.2.2] may be increased by pressing the feet into the floor in order to activate the knee extensors.

1.3.2.1.3 Fascia

Fascia is the thin, strong and extensible connective tissue that **surrounds and separates individual muscle fibres, bundles of fibres and entire muscles** [St George, 1999].

Fascia surrounds and is contiguous (merges) with the tendons of the muscles. Fascia helps muscles move more easily and helps muscles keep their shape and form. Fascia is therefore sometimes referred to as the glad wrap of the muscles [St George, 1999].

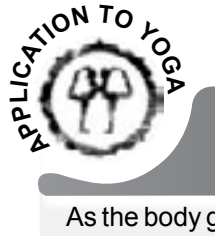
Fascia also exists around nerves, and certain organs. The outer layer of fascia provides muscles with their shape and form.

Fascial connections join one muscle to another and essentially connect the entire body. It is through fascial connections that movement of the toes can be felt in the scalp [Alter, 1986].

No 1.7 Use fascial connections between muscles and the stretch reflex to enhance muscle activations

It is because of fascial connections throughout the musculoskeletal system and by virtue of the myotatic (stretch) reflex [Section 1.7.2.2] that activation (or stretch) of one muscle can trigger the activation of another muscle at a distant part of the body that is not directly joined to the first muscle. For example, it is much easier to tighten the abdominal muscle transversus abdominis [Section 7.2.3] if the shoulders are pulled towards the hips by activating the underarm muscle latissimus dorsi [Section 2.3]. This is because these two muscles are joined by fascial connections. Hence activation (or stretch) of latissimus dorsi tensions (stretches and pulls on) transversus abdominis [Section 7.2.3] which then responds with myotatic (stretch) reflex activation.

There is a thin layer of fluid that lies between the fascia and the muscle or tissue it covers. This fluid, which helps the tissues glide and move more easily around and over each other, is thixotropic, like the synovial fluid in joints [Section 1.5.2.3]. Therefore, this fluid will become less viscous (more runny) in an environment that is relatively warmer and/or more alkaline.



No 1.8 Enhance muscle stretching and nerve tensioning with movement and muscle activation to increase body heat

As the body gets warmer, through the movements from one *yoga* posture to the next, and through the application of the nine major joint *bandhas* or muscle co-activations [Section 1.7.3], the fluid layer between the fascia and the tissues that the fascia covers (eg muscles and nerves) becomes more lubricated and the muscles and nerves can move more freely.

1.3.2.1.4 Joint flexibility

The range of motion (ROM) of a joint and its ability to move is restricted 47% by the ligaments and joint capsule, 41% by the fascia, 10% by the tendons and 2% by the skin [Alter, 1996].

No 1.9 Aim to stretch the fascia not the ligaments or joint capsule

A joint flexibility program should be targeted at stretching the fascia. One should not aim to stretch the ligaments and joint capsule as this may lead to instability of the joint complex. One way of doing this in exercises that may risk over-stretching ligaments or joint capsule is to keep the muscles around a joint gently activated (tensed) while they are being stretched. Since muscles are directly joined to fascia but are not directly joined to ligaments or joint capsules muscle tension during stretching exercises will target the fascia over the ligaments or joint capsule.

1.3.2.2 Cartilage

Cartilage is a tough, rubbery tissue that covers and cushions the ends of the bones and absorbs shock. It is also one of the materials out of which the ears, the nose and the trachea are made.

1.3.2.2.1 Functions of cartilage

The main function of cartilage is to strengthen and support areas requiring varying degrees of flexibility.
Cartilage also assists in movement over articular (joint) surfaces and allows the joint to move easily without pain.

No 1.10 Protect cartilage with some muscle tension while stretching

While stretching take care to protect the cartilage that lines all the major joints, the cartilaginous discs that rest between each spinal vertebra (intervertebral discs), and the cartilaginous discs that reside inside the knee joints (menisci). This is done by applying the *bandha* principle [Section 1.7.3] of creating and maintaining a gentle muscular firmness around a joint before trying to bend or stretch a joint. Bending or stretching a joint may result in the joint space being compressed to the point that the cartilage becomes damaged.

1.3.2.2.2 Types of cartilage

1.3.2.2.2.1 Hyaline cartilage (*Hylos* = glass)

- Most common type of cartilage
- Found over articular surfaces, respiratory rings in windpipe
- Aids joint movement.
- Frictionless (100 times as slippery as ice skates on ice).

1.3.2.2.2.2 Elastic cartilage

- Hyaline cartilage + elastic fibres
- Flexible supportive cartilage
- Found in external ear, epiglottis.

1.3.2.2.2.3 Fibrocartilage

- Contains large amounts of collagen.
- Found in intervertebral discs, articular discs (eg the menisci of the knee joint), and pubic symphysis.
- Resists tension and absorbs shock.

1.3.2.2.3 Characteristics of cartilage

There is an absence of blood vessels in cartilage. Therefore, this tissue relies heavily on diffusion for access to nutrients. Consequently, cartilage has a poor ability to heal or regenerate.

Cartilage has no nerve supply and therefore one cannot actually feel pain from cartilage damage. Hence, injures in cartilage will not immediately be felt. Usually one only feels the effect of the injury to cartilage, which may be a loss of function in a joint, at some later time when the damage to the cartilage has gone too far to be repaired.

With age and/or excessively acidic diet, insoluble mineral salts deposit in cartilage [Section 10.3] leading to stiffness, brittleness and osteochondritis (inflammation or defective growth of part of a bone or cartilage).

No 1.11 Regulate and reduce the amount of air you breathe and modify your diet to improve joint flexibility

Pranayama practice (breath-control) both during and separate to *Asana* practice (physical *yoga*) can help to protect the health of your cartilage. and improve joint flexibility by reducing the amount of insoluble mineral salts in your body. If you practise *pranayama* that eventually leads to a reduction in minute ventilation (the amount of air breathed each minute) then this causes a build-up of carbon dioxide in the blood and a mild respiratory acidosis due to carbonic acid is created [Section 8.4]. This may be altered by a diet high in fresh vegetables, salad and fruit thus allowing a metabolic alkalosis which leaves low levels of insoluble mineral salts in the body and reduces the tendency to deplete mineral from the bones [Section 10.3].

1.3.2.3 Bone

Bone tissue is rigid living connective tissue that makes up bones. There are 206 bones in the skeleton of the human body

1.3.2.3.1 Functions of bone

- Protects and supports the body and its internal structures
- Withstands and recovers from mechanical forces (Wolffs Law)
- Provides the body with efficient mechanical performance in terms of being lightweight with ease and freedom of movement
- Responds to external stimuli
- Produces blood cells
- Stores minerals, including Calcium (Ca+) Phosphorous (P) in the form of hydroxyapatite crystals ($Ca_{10}(PO_4)_6(OH)_2$).

1.3.2.3.2 Characteristics of bone:

- Bone tissue consists of widely separated cells surrounded by large amounts of matrix
- The matrix of compact bone contains by weight approximately:
  - 70% mineral salts (mostly hydroxyapatite)
  - Fibres (mostly collagen fibres)
  - Ground substance (extracellular fluid + proteoglycans),
- Bone is more rigid and stronger than cartilage and can thus withstand compression,
- Bone is metabolically active
- Bone is highly structured to achieve maximum support.

1.3.2.3.3 Types of bone

1.3.2.3.3.1. Compact bone tissue

- Compact bone consists of osteons (Haversian systems), which are dense concentric-ringed units that are well supplied with blood and nerves.
- Compact bone lies over spongy bone and composes most of the diaphysis (shaft of a long bone).

1.3.2.3.3.2. Spongy bone tissue

- Spongy bone consists of a thin latticework of plates called trabeculae that are arranged according to mechanical stresses applied to bone.
- Spongy bone forms most of the structure of short, flat and irregular bones, and the epiphyses (ends) of long bones.

1.3.2.3.4 Bone re-modelling

Living bones are plastic tissues [Moore 1992]. They are very responsive to the forces in their external environment.

> *Wolffs Law*
>
> *"The form of a bone being given, bone elements will place or displace themselves in the direction of the functional stress, and will increase or decrease their mass to reflect the amount of the functional stress."*

First stated in 1892 by Wolff, this very profound and important law describes the nature of the effect of the external environment and therefore the choice and will of an individual to affect the growth and development of a bone. Evidence that is more recent suggests that other tissues may also be subject to this law.

_No 1.12_ Bone density and shape can change with regular _yoga_

Wolffs Law implies that if one has a mal-aligned or mal-formed bony structure, then with repeated correcting exercises or *yoga* postures that put specific forces on that bone region, there is the possibility of re-aligning the bones.

Similarly, Wolffs Law implies that if one works incorrectly or with mal-alignment during repetitive daily activities or exercise, or while performing *hatha yoga* postures, then bone growth may be adversely affected.

1.3.3 Muscle Tissue

Muscle is a tissue type composed mainly of contractile cells that effects movement in the body. The human body has over 650 individual muscles [Sections 1.6, 2.3. 3.3, 3.6, 4.4, 5.3, 6.3 & 7.2].

1.3.3.1 Types of muscle tissue

There are three (3) types of muscle tissue:

1.3.3.1.1 Skeletal muscle

- Skeletal muscle is voluntary in its control,
- Skeletal muscle attaches to, and exerts a force on, the bones.

1.3.3.1.2 Smooth muscle

- Smooth muscle is autonomous (involuntary in its control)
- Smooth muscle is located in walls of hollow structures eg blood vessels, walls of the gastrointestinal tract and most abdominal organs, and in skin attached to hair follicles.

1.3.3.1.3 Cardiac muscle

- Cardiac muscle is the autonomous muscle of the heart.

1.3.3.2 Characteristics of muscle tissue

Muscle tissue:

- Joins body parts, via tendons, to attachments (places where muscle tendons attach)
- Conducts electrical signals from the nervous system (action potentials)
- Contains contractile proteins (muscle filaments)
- Generates tension
- When stimulated by nervous impulses attempts to pull the proximal & distal attachments of a muscle towards each other
- Requires calcium and ATP (major energy carrying molecule of all living cells) to start the contractile process

1.3.3.3 Functions of muscle tissue

Through sustained activation (generation of tension) or by alternating between activation and relaxation, muscle tissue is able to function in four ways:

1. **The production of body motion,** or motion of parts of the body.
2. **Stabilisation** of joints, body positions and regulation of organ volume.
3. **The generation of heat (thermogenesis).** Approximately 85% of all body heat is generated by muscle activations.
4. **The generation of pressure gradients** (high pressure when a muscle shortens as a result of tension, and low pressure when a muscle stretches), which result in the movement of energy (in the form of heat, and bio-electrical energy), blood, intracellular fluid, energy carrying molecules such as ATP and glucose; and information-carrying molecules such as DNA, RNA, neurotransmitters and hormones.

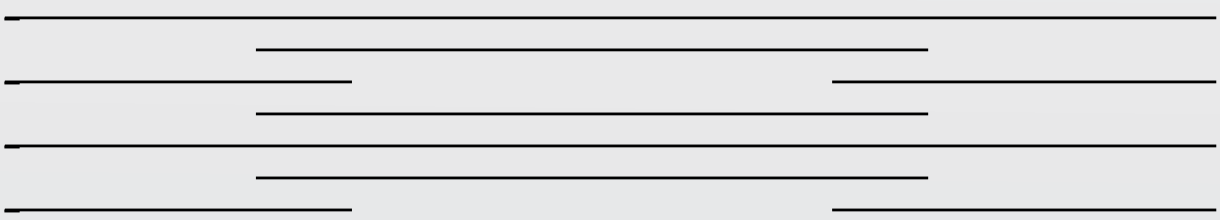
1.3.3.4 How muscles generate tension – sliding filament mechanism

Muscle tension or activation is stimulated by an electrochemical signal propagated through the nervous tissue of a nerve [Section 1.3.4 & 9.1]. The mechanism by which muscles are activated is believed to be by an (ATP driven) inter digitation (overlapping) of small muscle filaments (actin & myosin), which leads to a decrease in length of each basic muscle unit (sarcomere) [Figure 1.6].

Figure 1.6 How muscles are activated at the molecular level:

Contractile protein muscle filaments (horizontal lines) pulled together after the application of an electrical nerve signal and energy in the form of ATP overlapping in the process of muscle activation

Proximal Attachment **Distal Attachment**



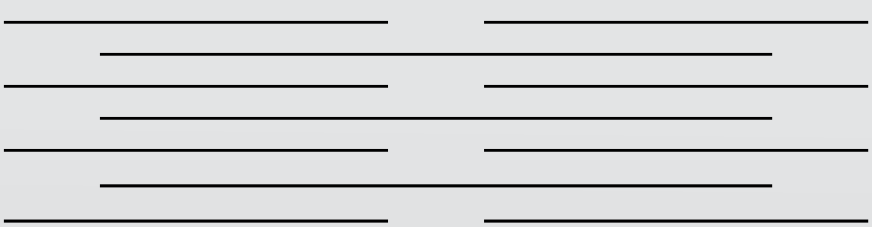
Contractile protein muscle filaments with slight overlap before muscle activation

⇓

- **Nerve impulse (electrical signal)**
- **ATP (energy source) + calcium**

⇓

Proximal Attachment ⇓ ⇓ ***Distal Attachment***



1.3.4 Nervous Tissue

Neurons or nerve cells, the main cells of the nervous system [Section 1.8.1 & Chapter 9], are able to conduct electrochemical impulses. They have a cell body (which contains the nucleus) and an axon (long-branched processes), which are usually enveloped in an insulating phospholipid called the myelin sheath.

1.3.5 Tissue Injury and Inflammation

When there is an injury in the body, tissues initially become inflamed. Inflammation [Sections 1.8.1 & 10.2] is a localised, protective response to tissue injury designed to destroy, dilute, or wall off the infecting agent or injured tissue. Inflammation is characterised by five cardinal signs:

(i) Redness
(ii) Pain
(iii) Heat
(iv) Swelling
(v) Loss of function (sometimes).

1.4 THE SKELETAL SYSTEM

A general overview of the skeletal system can be seen at the start of this chapter [Figure 1.1]. More detailed information about specific joints is also available for the shoulder [Figures 2.1-2.4], the elbow [Figures 3.1–3.5], the wrist [Figures 3.1 & 3.7], the pelvis and hip [Figures 4.1–4.3], the knee [Figures 5.1–5.6], the ankle and foot [Figures 6.1–6.4], and the spine [Figures 7.2–7.7].

1.4.1 Classification of Bones

Bones are classified as long, short, flat, irregular, or sesamoid.

Bone markings provide landmarks for study, and are used to further classify and characterise bones. They include:

- Projections in bones: spine, crest, line, trochanter, tubercle, tuberosity, head, condyle, epicondyle, ramus.
- Depressions in bones: facet, fossa, fovea, groove/sulcus, foramen, canal/meatus, fissure, sinus, notch.

Functions of Bone Markings

- Strengthen bone
- Provide passages for nerves and blood vessels
- Promote bone to bone articulation
- Provide attachment sites for muscles

1.4.2 Axial Skeleton [Figures 1.1, 7.2–7.7]

The axial skeleton consists of 80 bones that lie around the central axis of the body: the skull bones (22), auditory ossicles (6), hyoid bone (1), ribs (24), sternum (breastbone) (1), and the spinal vertebrae (26).

1.4.3 Appendicular Skeleton [Figures 1.1, 2.1–2.4, 3.1–3.5, 4.1–4.3, 5.1–5.6, 6.1–6.4, 7.2–7.7]

The appendicular skeleton consists of the 126 bones contained in the upper (60) *and* lower (60) limbs and the pectoral (shoulder) girdle (4) and pelvic (hip) girdle (2).

1.5 THE ARTICULAR (JOINT) SYSTEM

A joint (= articulation) is defined as the point of contact between bones, between cartilage and bones, or between teeth and bones [Figure 1.7].

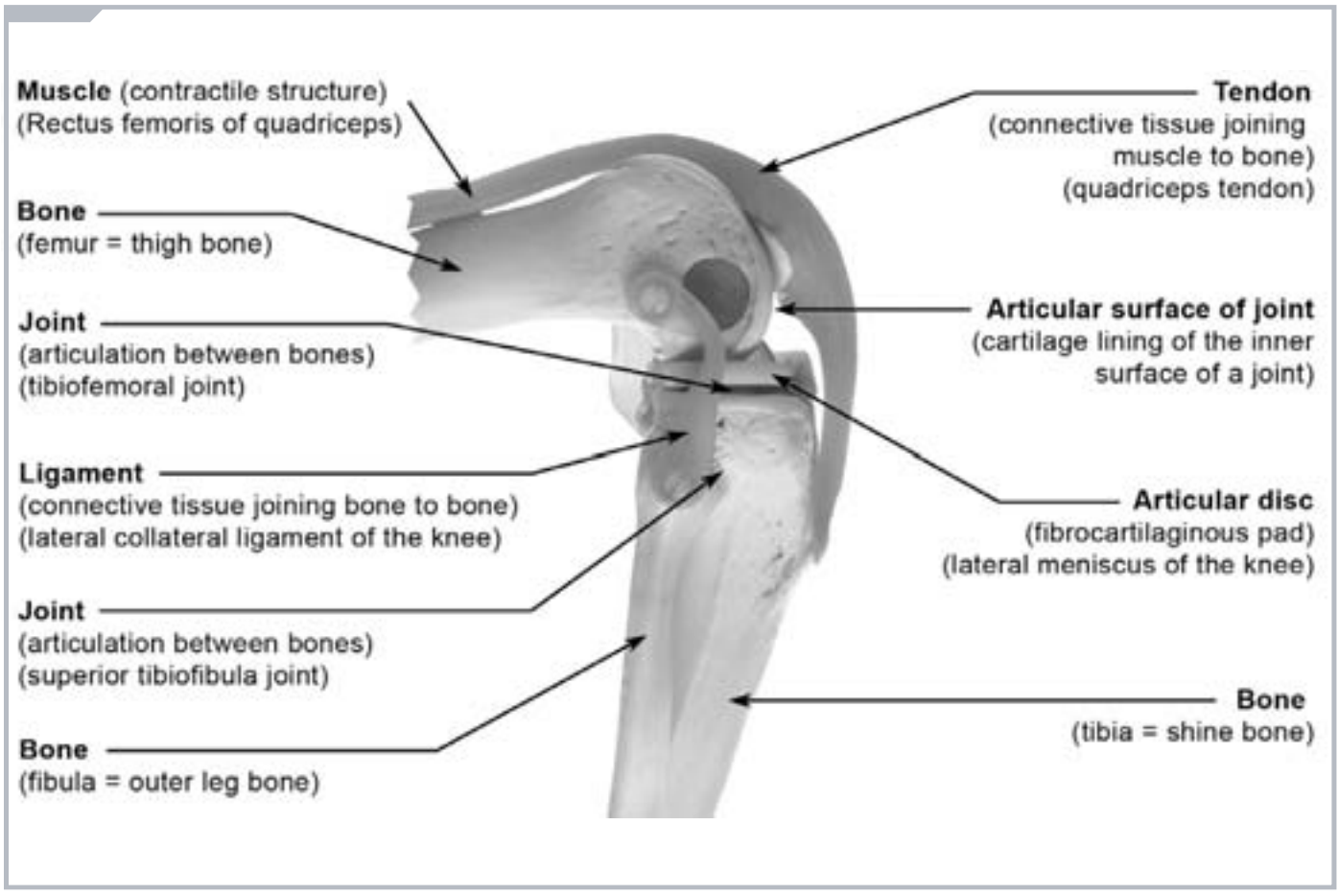


Table 1.2 Types of joints and their features [Section 1.5]

FIBROUS JOINTS [Section 1.5.1]	CARTILAGINOUS JOINTS [Section 1.5.1]	SYNOVIAL JOINTS [Section 1.5.2]
Characteristics: • No joint cavity • Joint **held together by fibrous connective tissue** **Types of Fibrous Joints:** **1. Sutures** • **No significant movement** • Strong connective tissues binding • **Found only in the skull** **2. Syndesmosis** • **Small amount of movement** proportional to distance between bones & flexibility of fibrous tissue • Consisting of a ligament or fibrous membrane • **eg Interosseus membrane between radius & ulna; Distal ends of tibia & fibula** **3. Gomphosis** • **No significant movement normally** • **Joints between the teeth & jaw sockets**	**Characteristics:** • No joint cavity • **Joint held together by cartilage** **Types of Cartilaginous Joints:** **1. Synchondrosis** • **Slightly movable joints** • Hyaline cartilaginous joints. • Union between bone & cartilage. • **eg Costochondral (rib to cartilage) joint**. **2. Symphysis:** • **Slightly movable joints** • Fibrocartilaginous in structure. • Bones covered with hyaline articular cartilage & joined by strong fibrous tissue. • **eg Intervertebral discs, & pubic symphysis**	**Characteristics:** **Easily moveable joints** Synovial joints always have: • Joint cavity • Articular cartilage • Articular capsule • Fibrous capsule • Synovial membrane • Synovial fluid. Synovial joints usually have: • Accessory Ligaments Synovial joints sometimes have: • Articular discs • Labrum • Bursae **Types of Synovial Joints:** **1. Ball & socket joint** **2. Hinge joint** **3. Saddle joint** **4. Ellipsoid / condylar joint** **5. Pivot joint** **6. Plane/gliding joint**

1.5.1 Classification of Joints

There are three (3) main types of joints. Fibrous joints and cartilaginous joints are classified as immovable under normal conditions, while synovial joints are classified as freely moveable. Table 1.2 outlines the main features of each type of joint. Synovial joints are described in detail in the next section, as they are arguably the most important

1.5.2 Synovial Joints

Synovial joints [Figure 1.7] are the most common and functionally important types of joints in the body. joints in the body, especially to do with movement, exercise and *yoga*.

1.5.2.1 Function of synovial joints

- Permit mobility of one bone against another
- Provide stability of the articulation between bones.

1.5.2.2 Important features of synovial joints

- Synovial joints always have:
  - A joint cavity between the articulating surfaces that is filled with synovial fluid [Section 1.5.2.3]
  - Articular cartilage, which covers and protects the surface of the articulating bones. Articular cartilage:
    - Is usually hyaline cartilage
    - Is deformable
    - Is permeable for nutrient diffusion
    - Allows for frictionless movement of joint
  - An articular capsule that consists of a
    - Fibrous joint capsule which is lined with a
    - Synovial membrane which secretes new synovial fluid, absorbs old synovial fluid, and is susceptible to inflammation

- Synovial joints usually have:
  - Accessory ligaments, which function in strengthening the articular capsules. They are either separate to the fibrous joint capsule (extrinsic ligaments) or part of the fibrous joint capsule (intrinsic ligaments).
- Synovial joints sometimes have:
  - Articular discs, which are usually fibrocartilaginous pads that protect and hold the bones together where joints are incongruous, eg the menisci of the knee.
  - **Labrum**: a fibrocartilaginous ring, which deepens the articular surface of one of the bones, eg the glenoid labrum of the shoulder joint complex.

1.5.2.3 Synovial fluid

The synovial fluid fills the joint or synovial cavity.

- Synovial fluid provides lubricant for joint motion
- Synovial fluid is a nutritive source for the articular cartilage
- Synovial fluid aids in removal of metabolic waste products from articular cartilage
- Synovial fluid is susceptible to inflammation [Section 1.3.3 & 10.2]
- The viscosity or thickness of the synovial fluid varies with environmental conditions (ie synovial fluid is thixotropic):
  - In conditions of heat or alkaline pH the synovial fluid becomes less viscous (more thin and runny), while in colder or more acidic conditions the synovial fluid becomes more viscous (thicker and less runny).

_No 1.13_ Joints are more flexible when they are warm and/or in an alkaline state

Synovial fluid is thixotropic (responds to the external environment). Therefore, joints will be more flexible, and better prepared for either a *yoga* practice or any exercise when they are warm and/or in an alkaline state.
Warming the body can either be achieved by placing the body in a warm environment (eg a hot room) or by engaging in muscular activity (ie either isotonic or isometric muscle activations). Most substances in the bloodstream easily enter the joint cavity [Moore, 1985].Therefore, if the blood becomes more alkaline then so will the synovial fluid. Alkalising the blood can either be done temporarily with increased breathing (hyperventilation) [Section 8.2.9.4.1], or more permanently by adopting a more alkaline diet [Section 10.3].

Synovial fluid is also present in several other structures in the body, including bursae and synovial sheaths, which may be extensions of the joint capsule as in the shoulder joint [Moore, 1985], or may be seen independently of joint capsules. Bursae are closed flattened sacs filled with synovial fluid.

- Bursae:
  - Are found between the skin and the bone, or between muscle and bone
  - Are lined with a synovial-like membrane
  - Contain a capillary thin layer of synovial fluid
  - Are usually located in areas that are subject to friction eg, the ischial tuberosity (sitting bone) of the buttock
  - Function in reducing friction
- Synovial sheaths are tubular sheaths filled with synovial fluid surrounding tendons, acting as lubricating devices and permitting smooth gliding of the tendons.
- Bursae and synovial sheaths are filled with synovial fluid and so, like joint capsules, they are susceptible to swelling and inflammation.
- Synovial fluid is also present between muscles and the fascia encasing and surrounding muscles.
- A synovial-like fluid is also present between nerves and the connective tissue sheaths surrounding the nerves.

No 1.14 Muscles, tendons and ligaments are more flexible when they are warm and/or in an alkaline state

Synovial-like fluid is present around tendons, muscles and nerves, inside bursae and joints. Since this fluid is thixotropic (responds to the external environment) all these structures will be more flexible, and better prepared for either a *yoga* practice or any exercise when they are warm and/or in an alkaline state.

1.5.2.4 Classification of synovial joints

- **Number of axes of movement**:
  - Uni-axial joints cross and directly act on one joint only eg. hinge joints such as in the elbow
  - Bi-axial joints, eg. bi-condylar such as the knee
  - Multi-axial eg ball and socket joints such as the shoulder or hip
- **Shape of articular surface**: eg ovoid, sellar, concave, convex
- **Number of mating pairs**:
  - **Simple joint**: only one mating pair of bone surfaces eg glenohumeral (GH) joint of the shoulder [Section 2.2]
  - **Compound joint**: more than one pair of bone surfaces eg where the radius, ulna and humerus meet at the elbow joint [Section 3.2]
- **Complex joint**: contains an articular disc eg the tibiofemoral joint of the knee [Section 5.2]

1.5.2.5 Movements about a synovial joint

Following are definitions of the major actions or movements of synovial joints in the body. All movements are described from the anatomical position (which is like a standing version of *savasana* or the corpse posture). Movements about a synovial joint occur in pairs. Each movement has an opposing movement. For example, in a typical ball and socket joint like the glenohumeral (GH) joint of the shoulder [Section 2.2], or the coxafemoral joint of the hip [Section 4.2]:

- Flexion is the opposite of extension
- Abduction is the opposite of adduction
- External rotation is the opposite of internal rotation.

These six (6) primary movements (three (3) opposing pairs of movement), which can occur at a ball and socket-type synovial joint can be described as follows:

Flexion and Extension:

- Flexion involves bending or reducing the angle between the bones of a joint.
- Extension involves straightening or increasing the angle between the bones of a joint.

  One exception to this general rule is the shoulder. When taking the upper arm towards the head (not the body), it is flexion. When taking the arm towards the body from above the head while also moving it behind the body, it is called extension.

Abduction and Adduction:

- Adduction involves movement towards the midline of the body.
- Abduction involves movement away from the midline of the body.

External Rotation and Internal Rotation:

- External rotation (also called lateral rotation) involves rotation away from the midline of the body.
- Internal rotation (also called medial rotation) involves rotation toward the midline of the body.

Additional specialised movement pairs for the scapula (shoulder blade) are:

Elevation and depression: [Chapter 2]

- Elevation involves movement of scapula superiorly (ie movement of the shoulder blade towards the head).
- Depression involves movement of the scapula inferiorly (ie movement of the shoulder blade away from the head).

Protraction and retraction [Chapter 2]

- Protraction involves movement of the scapula anteriorly (ie movement of the shoulder blade away from the spine).
- Retraction involves movement of the scapula posteriorly (ie movement of the shoulder blade towards the spine).

Additional specialised movement pairs for the ankle and foot are:
Plantarflexion and dorsiflexion [Chapter 6]

- Plantarflexion: moving the foot away from the body. Plantarflexion at the ankle joint is analogous to flexion at the wrist.
- Dorsiflexion: moving the foot towards the body. Dorsiflexion at the ankle joint is analogous to extension at the wrist.

Additional specialised movement pairs for the elbow are:
Supination and pronation [Chapter 3]

- Supination involves turning the palm of the hand upwards (like external rotation of the forearm).
- Pronation involves turning the palm of the hand downwards (like internal rotation of the forearm).

Additional specialised movement pairs for the ankle and foot are:
Inversion and eversion [Chapter 6]

- Inversion involves turning the sole of the foot to face inwards (medial movement).
- Eversion involves turning the sole of the foot to face outwards (lateral movement).

Additional specialised movement pairs for the hip and pelvis are:
Anterior pelvic tilt and posterior pelvic tilt [Chapter 4]

- Anterior pelvic tilt is anterior movement of the superior pelvis (ie forward movement of the top of the hips, or pushing the coccyx or tailbone backwards).
- Posterior pelvic tilt is a posterior movement of the superior pelvis (backward movement of the top of the hips, equivalent to tucking the coccyx or tailbone anteriorly, ie forwards or under).

1.5.2.6 Closed-packed and loose-packed positions of a joint

The close-packed position of a joint is position of a joint in which the joint surfaces fit perfectly. Close-packed positions:

- have maximal joint surface contact area
- often occur at extreme of range of the most habitual movement
- have joint capsules and ligaments at maximal tension
- have their joint surfaces compressed
- have no further movement possible
- are susceptible to damage at the joint surfaces.

All other positions of a joint are referred to as loose-packed positions. Loose-packed positions:

- have articular surfaces that are not congruent
- have their joint capsule partly lax, allowing combinations of spin, roll and glide and permitting maximal joint range of motion (ROM)
- have reduced frictional and erosive effects
- maintain efficient joint lubrication and nutrition of articular cartilage.

1.5.3 Joint complexes

A joint complex is a group of joints that function essentially as a single unit. There are nine (9) important joint complexes in the body. These are the:

- Ankle joint complex [Section 6.2]
- Knee joint complex [Section 5.2]
- Hip joint complex [Section 4.2]
- Lumbar spine joint complex [Section 7.1]
- Thoracic spine joint complex [Section 7.1]
- Cervical spine joint complex [Section 7.1]
- Shoulder joint complex [Section 2.2]
- Elbow joint complex [Section 3.2]
- Wrist joint complex [Section 3.5].

Joint complexes are at the core of *hatha yoga bandhas* [Section 1.7.3]. Many of the muscles that act in joint complexes to assist in the formation of the *bandhas* are multi-articular muscles (ie they cross more than one joint) [Section 1.6.5.7].

1.5.4 Joint Diseases

1.5.4.1 Inflammatory joint diseases

Inflammatory joint diseases are conditions of the synovial membrane due to systemic diseases, infections, and or unknown causes.

Rheumatoid arthritis (RA) is a common inflammatory joint disease

- In RA the synovial membrane becomes more vascular, more permeable and accumulates inflammatory cells and debris.
- In RA, synovial fluid becomes thinner and increases in amount, causing the joint to swell and become painful with a loss of range of movement (ROM) and stability.
- In RA the articular cartilage may get completely eroded which is usually followed by fibrous connective tissues joining the bony ends together. The joint may then ossify and become immovable.

Causes of rheumatoid arthritis:

- Some authors have suggested that RA may be an autoimmune disease in which the body attacks itself.
- However, much evidence has now been accumulated that suggests that diet has an important role in the regulation of RA activity [Peltonen *et al.,* 1997].
- It is well known that most substances in the bloodstream, whether normal or pathological, easily enter the joint cavity [Moore, 1985].
- Therefore it is suggested that inflammation of the joints resulting from an unknown substance that enters the joint cavity may in part result either directly from a dietary intake or indirectly from the substances produced by microbial degradation of dietary food (fermentation and putrefaction) in the gastrointestinal tract, which is then passed into the bloodstream and later into the joint cavities.

1.5.4.2 Degenerative joint diseases

Degenerative joint diseases involve localised wearing or deterioration of articular cartilage.

- **Osteoarthritis (OA)** is a common example of a degenerative joint disease.
  - OA results from a combination of aging, irritation of the joints, and wear and abrasion – commonly called wear and tear arthritis.
  - OA is a non-inflammatory progressive disorder of moveable joints especially those bearing weight.
  - OA is characterised by a slow degeneration of the cartilage, but rarely any change in the synovial membrane as in rheumatoid arthritis.
  - The bone ends gradually become exposed in OA and small bony bumps or spurs of new bony tissue are deposited on them, which reduces the size of the joint cavity and thus limits pain-free movement.

1.6 THE MUSCULAR SYSTEM

Muscles are contractile structures made up of muscle tissue [Section 1.3.3] and connective tissue [Section 1.3.2] that join different parts of the body together. When muscles are activating or generating tension, they appear to be trying to pull the body parts they are attached to closer towards each other. When muscles succeed in pulling their attachments closer together, this is called a concentric activation. When the attempt of a muscle to pull its attachments further apart is unsuccessful, if the attachments don't actually move at all then this is termed an isometric activation, or if the attachments are moved apart then this is termed an eccentric activation.

1.6.1 Skeletal Muscle Structure

The contractile elements of a muscle are formed from muscle tissue [Section 1.3.3]. Muscle tissue is arranged in bundles then wrapped in a thin strong, layer of connective tissue called fascia [Section 1.3.2.1.3]. The fascia wrapped muscle is attached to bones via tendons [Section 1.3.2.1.2] at their attachments.

- There are various types of skeletal muscle shape including parallel, fusiform, pennate, and circular.
- **Attachments** of muscles to bones by tendons are named the:
  - **Origin** (= the proximal attachment in muscle charts) of a muscle, which by definition remains stable and does not move during concentric muscle activation.
  - **Insertion** (= the distal attachment in muscle charts) of a muscle, which by definition moves during a concentric muscle activation.

Bones act as levers and the joints act as the fulcrums of these levers to produce movement in the body.

1.6.2 Mechanics of Movement

- A lever can be defined as a rigid rod that moves about some fixed point called a fulcrum.
- A fulcrum (F) is acted on at two different points on the lever called the effort (E) and the resistance (R).

First-class lever

- A first-class lever is the most efficient type of lever
- A first-class lever has the fulcrum (F) between the effort (E) and the resistance (R) (ie order is E-F-R)
- A mechanical example of a first-class lever is a seesaw
- A human example of a first-class lever is the head resting on the spine. When the head is raised the facial portion of the skull is the resistance (R), the atlanto-occipital joint between the spine and skull is the fixed point of the fulcrum (F) and the activation of the back muscles is the effort (E).

Second-class lever

- A second-class lever is the second most efficient type of lever
- F is at one end and R is between F and E (ie order is F-R-E)
- A mechanical example of a second-class lever is a wheelbarrow
- A human example of a second-class lever is the raising the heel off the ground so the body weight (R) is raised onto the ball of the foot (F) by activation of the calf muscles (E).

Third-class lever

- A third-class lever has the lowest efficiency
- F is at one end and E is between F and R (ie order is F-E-R)
- A mechanical example of a third-class lever is a crane
- Human examples of third-class levers are many and include the adduction of the thigh, and the flexing of the forearm at the elbow.

Leverage

- Mechanical advantage gained by a lever is largely responsible for a muscles strength, speed and joint range of motion (ROM)
- Consider two muscles of the same strength crossing and acting on the same joint. If one attaches close to the joint, and the second attaches far away from the joint, then the close attaching muscle will have a greater speed and ROM than the muscle attaching further away. The second further away muscle will have the greater strength and be able to produce the more powerful movement.

1.6.3 Types of Skeletal Muscle Activations

There are three (3) main types of skeletal muscle activations. These are isotonic, isometric and isokinetic.

1.6.3.1 Isotonic muscle activations

Isotonic muscle activations involve body movement and a change in muscle length. The muscle is said to be generating tension (activating) against a movable resistance. There are two types of isotonic activations – concentric and eccentric.

1.6.3.1.1 Concentric muscle activations

Concentric muscle activations are where the muscle shortens while working or generating an active tension eg the quadriceps when straightening the knee from a squat position.

1.6.3.1.2 Eccentric muscle activations

Eccentric muscle activations are where the muscle lengthens while working or generating an active tension eg the quadriceps when bending the knee to a squat position.

_No 1.15_ Use of isometric and isotonic muscle strengthening in _yoga_

Basic practice of *hatha yoga asanas* (static postures) uses isometric activations when the body is kept still in postures and no movement about a particular joint is occurring. Basic practice of *hatha yoga vinyasas* (dynamic exercises) uses isotonic activations when the body is moving from one posture to the next and there is movement about a particular joint.

1.6.3.2 Isometric muscle activations

Isometric muscle activations involve no body movements and have no change in muscle length. Most static *yoga* postures have isometric muscle activations. The muscle is said to be generating tension against an immovable resistance.

1.6.3.3 Isokinetic muscle activation

Isokinetic muscle activations involve body movement and a change in muscle length. The muscle is said to be generating tension against a maximal resistance throughout full joint range of movement (ROM). Isometric and isotonic activations require no specialised equipment, but generally isokinetic exercises can only be performed with large and very expensive computer-backed machines.

APPLICATION TO YOGA

No 1.16 Use of isokinetic muscle strengthening in *yoga*

Intelligent use of *hatha yoga asanas* (static postures) and *vinyasas* (dynamic exercises) enables one to work one limb or body part against another in such a way that a muscle can be made to generate tension against maximal resistance through its full joint range of motion (ROM), giving many of the same benefits that can be obtained from the large expensive computer-backed isokinetic exercise machines.

For example, *utthita pavanmuktasana* (a one-legged standing pose with the non-weight-bearing knee flexed and hugged to the chest) becomes isokinetic in nature if one pulls the leg towards oneself with the arms (using elbow flexors, shoulder extensors and shoulder adductors) and resists this effort by pushing away the thigh (using the hip extensors), while moving back and forth between elbow extension and partial hip extension to elbow flexion and hip flexion.

The three main types of skeletal muscle activation are summarised in Table 1.3.

Table 1.3 Types of skeletal muscle activations and their characteristics [Section 1.6.3 & 1.6.5.5]

Isotonic	Isometric	Isokinetic
• Dynamic • Change in muscle length • Involves movement • Muscle generating tension against a moveable resistance **Two types of isotonic activations:** **(a) Concentric** • Muscle shortens while working/tensing **(b) Eccentric** • Muscle lengthens while working/tensing • Can be done in *yoga vinyasas*	• Static • **No** change in muscle length • **No** movement • Muscle generating tension against an immovable resistance • Can be done in *yoga asanas*	• Dynamic • Change in muscle length • Involves movement • Muscle generating tension against a maximal resistance throughout full range of movement (ROM) • Isokinetic activations require expensive computer rehabilitation equipment such as the CYBEX machine • Can be done in *yoga vinyasas*

1.6.4 Muscle Actions and Roles

Muscle actions and roles are often confused. Most tables of muscles only show muscle action. The muscles in these books also describe some muscle roles. For the study of applied anatomy, understanding the role of a muscle at any one time is very important.

1.6.4.1 Muscle action

Muscle action is the movement produced (eg flexion, extension) when a muscle activates concentrically (ie shortens due to its tension) in isolation. It is also defined as when a muscle pulls its insertion closer to its origin. The insertion of a muscle is defined to be the moving attachment. In applied anatomy, either or both ends of a muscle may actually move, but in anatomy tables, which were originally deduced from examining cadavers in the anatomical position or *Savasana* (corpse posture) the insertion is always the distal attachment. By definition, a muscle action will always be the same for any given muscle.

1.6.4.2 Muscle role

The role of any muscle may vary with every movement that is made. The same muscle under different conditions may be working as an:

- **Agonist** if it is the principle muscle producing a movement,
- **Antagonist** if it must relax to allow the desired movement to occur, the antagonist opposes the agonist
- **Neutraliser** when it cancels out unwanted movements that would otherwise be produced by the agonist
- **Synergist** when it works with other muscles to produce a desired effect
- **Fixator** or **stabiliser** when it supports a body part so that another muscle may have a firm base to act on to produce the desired movement.

The balancing of the agonist muscle against its opposing antagonist is integral to the generation of *bandhas* [Section 1.7.3].

1.6.5 Factors Affecting Muscle Function

There are several factors that will alter a muscles function and its ability to perform certain tasks. Some of these factors are fixed for a particular muscle in every situation such as the type of joint [Section 1.6.5.1] or joints the muscle crosses, location of the muscle attachments [Section 1.6.5.2] and the type of muscle attachment [Section 1.6.5.3]. Other factors such as angle of muscle attachment [Section 1.6.5.4], type of muscle activation [Section 1.6.5.5], muscle role [Section 1.6.5.6], exercise type [Section 1.6.5.9] and muscle sufficiency [Section 1.6.5.8] will vary from one situation to the next and even vary through a joint range of movement (ROM).

1.6.5.1 Type of joint

Muscles will behave in different ways depending on what type of joint they are crossing (eg hinge, ball and socket, etc).

1.6.5.2 Location of the muscle attachments

The location of a muscle attachment relative to the joint will affect the lever-like quality of the muscle.
If the attachment is close to the joint then the muscle can act very quickly but it needs to be quite powerful to do so. Such a muscle is referred to as a spurt muscle. If a muscle is relatively distant from a joint then it will be able to move the joint with much greater ease because of the longer lever arm, but it will be slower in doing so. Such a muscle is referred to as a shunt muscle.

1.6.5.3 Type of muscle attachment

A muscle can be attached in many different ways. For example, there may only be one distal attachment or perhaps there are several attachments spread over a wide area.

1.6.5.4 Angle of muscle attachment

The angle of attachment of a muscle is the angle between body of the muscle or the main line of force from which the muscle generates its contractile (pulling) force, and the central axis of the bone that the muscle is attached to. A change in the angle of attachment can significantly affect how effective the pulling power of that muscle is. If the angle of attachment (angle of pull) is close to 90^0, the pulling power of the muscle will be at its strongest. Conversely, if the angle of attachment (angle of pull) is close to 180^0 the pulling power of the muscle will be at its weakest.

1.6.5.5 Type of muscle activation [Section 1.6.3 & Table 1.3]

The type of muscle activation can either be:

- Isometric (static tension)
- Isotonic concentric (dynamically tensing or pulling while shortening)
- Isotonic eccentric (dynamically tensing or pulling while lengthening)
- Isokinetic (offering maximal resistance or pulling throughout the range of movement (ROM) whether the muscle is shortening, lengthening or staying the same length).

1.6.5.6 Role of a muscle [Section 1.6.4]

Each muscle always has a defined action, which does not change. However, at any one time a muscle will have a role for a particular situation (eg stabiliser, neutraliser, agonist, antagonist) which can vary from one situation to the next.

1.6.5.7 Number of joints crossed by the muscle

When a muscle is said to cross a joint it implies that it can exert a contractile force across that joint or move that joint.

- **Single joint (uni-articular) muscles** are muscles that cross only one joint, eg the elbow flexor biceps brachii.
- **Two joint (bi-articular) muscles** are muscles that cross two joints. For example, biceps femoris (the lateral hamstring muscle) crosses the knee joint and can flex the knee, but it also crosses the hip joint and can extend the hip. Another example is rectus femoris (the main quadriceps muscle), which crosses the knee joint and can extend the knee, but it also crosses the hip joint and can flex the hip.
- **Multi-joint (multi-articular) muscles** are muscles that cross more than one joint. They are economical since they are able to produce motion at more than one joint. Examples of multi-joint muscles are the extensors and flexors of the wrist, hand and fingers, and many of the spinal muscles.

1.6.5.8 Muscle sufficiency

The amount a muscle is lengthened (stretched) or shortened (not stretched) at the time it is activated (generates tension) is referred to as the muscle sufficiency. A muscle cannot adequately perform its role if it is actively insufficient, or if its antagonist is passively insufficient.

- **Active insufficiency** occurs when a muscle is in either a too shortened or too lengthened position to actively generate tension.
- **Passive insufficiency** occurs when a muscle (the antagonist) is to short (stiff) to allow the opposing muscle (the agonist) to act through its full range of movement.

For example, in a hamstring curl such as *niralamba natarajasana* movement may be restricted due to an inability for the shortened hip extensors and knee flexors (eg hamstrings) to generate sufficient tension (active insufficiency) while stiffness in hip flexors and knee extensors at the front of the thigh may prevent the hip extensors and knee flexors from taking the leg very far backwards into the air (passive insufficiency).

Similarly, in *niralamba padangusthasana* movement may be restricted due to passive insufficiency of hip extensors and knee flexors (eg hamstrings) and active insufficiency of hip flexors and knee extensors.

1.6.5.9 Type of joint movement or exercise

1.6.5.9.1 Open-chain (OC) movement or exercises

Open-chain (OC) movement or exercises are where the distal end of a limb is not fixed (ie free to move). Here the origin of a muscle (the part that does not move) is the proximal attachment and the insertion of a muscle (the part that moves) is the distal attachment. The limb is said to be acting in an open kinetic chain. Muscle actions in the tables in these notes (and in most anatomical texts) are described in terms of open-chain movements.

1.6.5.9.2 Closed-chain (CC) movement or exercises

Closed-chain (CC) movement or exercises are where the distal end of a limb or limb segment is fixed (ie attached to the floor or wall etc.). Here the origin of a muscle (the part that does not move) is the distal attachment and the insertion of a muscle (the part that moves) is the proximal attachment. The limb is said to be acting in a closed kinetic chain. Many of the movements in everyday life and during exercise are closed-chain movements or exercises.

1.6.5.9.3 Weight-bearing (WB) exercises

Weight-bearing (WB) exercises are static or dynamic exercises in which a particular limb or body part is taking part or all of the weight of the body and is said to be loaded.
Many but not all weight-bearing exercises are closed-chain exercises.

1.6.5.9.4 Non weight-bearing (NWB) exercises

Non weight-bearing (NWB) exercises are static or dynamic exercises in which a particular limb or body part is taking little or no body weight and is said to be unloaded.
Many but not all non-weight-bearing exercises are open-chain exercises.

1.6.6 Muscle Training

It has been shown that muscle training is quite specific [Carr & Shepherd, 1987]. In other words, a muscle will get good at doing precisely what it practises most. Table 1.4 describes three (3) main factors to consider in muscle training – muscle length, muscle activation type, and exercise type.

Table 1.4 Three different factors that lead to 16 possible states for each muscle [Section 1.6.6]

Muscle Length [Section 1.6.5.8]	Muscle activation type [Section 1.6.3 & 1.6.5.5]	Exercise type [Section 1.6.5.9]
	Relaxed (No muscle activation)	
Shortened (not stretched)	**Isometric** (Static muscle activation)	Open-chain exercise
	Isotonic concentric (Dynamic muscle activation)	
Lengthened (stretched)	**Isotonic eccentric** (Dynamic muscle activation)	Closed-chain exercise

Table 1.5 describes 16 different states of exercise and rest that any muscle may be in.
The most effective exercise includes muscle training in all these different states.

Table 1.5 Sixteen (16) different possible states for each muscle [Section 1.6.6]

	Muscle length	Muscle activation type	Exercise type
1.	Shortened (not stretched)	Relaxed	Closed-chain
2.	Shortened (not stretched)	Relaxed	Open-chain
3.	Shortened (not stretched)	Isometric	Closed-chain
4.	Shortened (not stretched)	Isometric	Open-chain
5.	Shortened (not stretched)	Concentric	Closed-chain
6.	Shortened (not stretched)	Concentric	Open-chain
7.	Shortened (not stretched)	Eccentric	Closed-chain
8.	Shortened (not stretched)	Eccentric	Open-chain
9.	Lengthened (stretched)	Relaxed	Closed-chain
10.	Lengthened (stretched)	Relaxed	Open-chain
11.	Lengthened (stretched)	Isometric	Closed-chain
12.	Lengthened (stretched)	Isometric	Open-chain
13.	Lengthened (stretched)	Concentric	Closed-chain
14.	Lengthened (stretched)	Concentric	Open-chain
15.	Lengthened (stretched)	Eccentric	Closed-chain
16.	Lengthened (stretched)	Eccentric	Open-chain

Additional notes for Tables 1.4 & 1.5

1. **Muscle length**: [Section 1.6.5.8] ie how lengthened (stretched) or shortened (not stretched) the muscle is. If the muscle is too long or too short, it becomes actively insufficient and not able to actively generate tension. For this table, it is assumed that the active muscle activation can only be performed before the muscle becomes actively insufficient. Only two lengths of the muscle (lengthened or shortened) are considered in these tables, but the number of possible lengths is obviously infinite.
2. **Muscle activation type**: [Section 1.6.3 & 1.6.5.5] Is the muscle relaxed (not activated and not generating tension) or activated? If activated, is the muscle tension isometric (static) or isotonic (dynamic/moving)? If isotonic, is the muscle activation concentric (associated with muscle shortening) or eccentric (associated with muscle lengthening)?
3. **Exercise type**:[Section 1.6.5.9], whether open or closed-chain. Hence, the total number of possible states of a muscle in this scenario is 16. (2 lengths states X 4 muscle activation types X 2 (OC or CC) exercise types = 16). Note that weight-bearing and non-weight-bearing [Section 1.6.5.9] are two more factors that could also be taken into account but have not been included here for simplicity.

Special Note: Muscle training is specific therefore yoga practice should be varied, ie muscles have been shown to get good at what they practice. Therefore, to be best trained one's *yoga* practice should include a variety of types of exercises for each muscle or muscle group.

Control over one's body in *hatha yoga* includes being able to bring each of the body's muscles into any of these states at will, as all these states are required to master the vast spectrum of *hatha yoga* postures and exercises.

A complete anatomical understanding of the body helps one to know when and why to exert such muscular control in order to prevent and treat injuries and give maximum benefit to the body.

A useful exercise is to pick a muscle or muscle group eg gluteus maximus (main buttocks muscle and hip extensor), then try and invent or describe and perhaps practice 16 different exercises which would represent the 16 different muscle states.

1.6.7 Working with Muscle Groups in *Hatha Yoga* Postures

IMPORTANT INFORMATION ON HOW TO SIMPLIFY THE APPLIED ANATOMY OF YOGA

Working with muscle groups rather than individual muscles simplifies the study of muscles and allows anatomical theory to be practically applied without having to learn hundreds of muscle names.

When working with musculoskeletal anatomy, it is ideal to know the exact locations and names of the muscles crossing a particular joint. This, however, takes most people hundreds of hours of regular study, over many years, to learn. Nevertheless, Figures 1.2 and 1.3, at the start of this chapter, as well as the tables of muscle attachments throughout Chapters 2–7 of this book may serve as a reference to begin to learn where each muscle specifically attaches.

However, a simpler approach to learning about muscles considers all the muscles crossing a particular joint that have the same function at that joint to be one group. For example, all of the muscles that cross over the hip joint, and which cause hip flexion when they are activated, are called hip flexors. Similarly, all of the muscles which cross over the hip joint, and which cause hip extension when they are activated, are called hip extensors. Figure 1.4 at the start of this chapter shows the approximate regions of each of the bodys main muscle groups.

Since flexion and extension are antagonistic movements, it can therefore be seen that concentric muscle activation of a flexor muscle group, which takes a joint into flexion, will lengthen or stretch the antagonistic extensor muscle group. Similarly, concentric muscle activation of an extensor muscle group leading to joint extension will lengthen or stretch the antagonistic flexor muscle group.

Table A1 in Appendix A shows which muscle groups are actively tensing and which muscle groups are being lengthened or stretched in various *yoga* postures.

1.7 APPLIED ANATOMY & PHYSIOLOGY OF *HATHA YOGA*

Hatha yoga is commonly thought of as a series of static, passive, stretching and relaxation exercises that lead to meditation. It is not often realised that the flexibility *yoga* practitioners often obtain is balanced with musculoskeletal strength.

In *hatha yoga*, the attributes of strength, flexibility and relaxation are developed concurrently through a practically-applied understanding of the principles of musculoskeletal anatomy and neurophysiology.

In other words, it is not sufficient to merely know how to passively stretch a muscle in a static posture, but one must have a practical understanding of how to activate or tense each muscle throughout its full range of joint motion, whether the muscle is stretched (ie in a lengthened state) or not stretched (ie in a shortened state). Furthermore, one must be able to control the tension of each muscle while its length is actually changing from short to long, and vice versa, at various speeds [Section 1.7.1].

In addition, the *yoga* practitioner should have a working knowledge of basic neurophysiology. One should have a practical understanding of nerve reflexes in order to be able to use this knowledge to help develop flexibility, strength and relaxation at the same time. Also, one should practically understand the concept of nerve tensioning and be able to safely tension (stretch) the nerves in order to further facilitate improvements in flexibility, strength and relaxation [Section 1.7.2].

When *hatha yoga* postures and exercises are correctly performed, the inherent balance between musculoskeletal strength and flexibility significantly affects the practitioner's neurophysiology. The balance between musculoskeletal strength and flexibility affects nerve reflexes and nerve tensioning (stretching) in a Synergistic fashion to produce *bandhas* [Section 1.7.3].

On a physical level, *hatha yoga bandhas* [Section 1.7.3] reflect the phenomenon of co-activation (simultaneous tensing) of antagonistic (opposing) muscle groups around a joint complex [Section 1.5.3].

1.7.1 *Hatha Yoga*: A Balance Between Strength, Flexibility and Relaxation

The union that is *hatha yoga* is partly in the balance between musculoskeletal strength and flexibility. A very flexible muscle or joint that has little strength may not be able to function properly in everyday life. Similarly, a very strong muscle or joint that is very stiff or immobile may also be unable to function properly in everyday life. If a joint or joint complex is forcibly stretched into an *asana* (*yoga* posture) while the muscles around the joint are passive there is a risk that the joint may be damaged due to overstretch of the ligaments or joint capsule. If an inexperienced *yoga* practitioner tries to apply muscular tension around a joint after the joint has been placed in a stretched position, then they may have trouble activating either the agonist due to active insufficiency or the antagonist muscle due to passive insufficiency. If a stretched muscle is activated or tensed then this may lead to an increase in the stretch of the muscle via nerve reflexes [Section 1.7.2]. However, there is a chance that tensing a stretched muscle may strain or tear muscle fibres which are trying to shorten while they are already under great tension.

The safest way to apply the principle of strength with flexibility is to commence a stretching posture with the muscles around the joint to be stretched already toned (ie in an active state). Although, a stretch initiated with muscular strength may not be as intense as a relaxed muscle stretch, the balance between strength and flexibility will be maintained, and the risk of over-stretching other structures such as ligaments [Section 1.3.2.1.1] and nerves [Section 1.7.2] will be avoided.

No 1.18 Use your own muscles to enter a posture

A general safety principle of *hatha yoga* is that one should only do the versions of postures that activation of your own muscles can achieve and maintain.

1.7.2 *Nadi Hatha yoga*: Nerve Tensioning and Stimulation of Nerve reflexes

When the practice of *hatha yoga* creates differential regions of pressure within the body [Section 1.0.4], *prana* (the vital force) is made to move along the *nadis*. A *nadi* is a subtle channel of energy found within the body along which moves *prana* and *citta* (consciousness) [Goswami, 1980]. When the body is stretched in a *yoga* practice, it is *nadis* as well as muscles that are stretched. Blood vessels and nerves are examples of gross manifestations of the *nadis* but are not actually the *nadis* themselves.

More subtle *nadis* include the so-called acupuncture meridians of eastern medicine [Motoyama 1993]. Western medicine acknowledges the existence of acupuncture or trigger points which are found along nerve pathways but is reticent to acknowledge the existence of the acellular flows of energy that the meridians are supposed to represent.

The practice of *hatha yoga* must take into account the presence of *nadis* and in particular, on a gross level the presence of the nerves for two main reasons:

- Nerves have a profound effect on the body if they are impinged and also if they are tensioned (stretched).
- Nerve reflexes can affect the activation or inhibition of muscle groups.

1.7.2.1 Nerve-tensioning

When the *nadis* are stretched a significant proportion of the physical sensation that may be experienced results from nerves being tensioned (stretched). An increased sense of well-being can result if nerves are carefully tensioned. Tensioning (stretching) nerves mobilises and allows them to function more effectively as instigators of muscle activation. However, excessive tensioning or over-stretching may result in nerve damage, pain, or loss of muscle strength or control [Section 9.7.3].

APPLICATION TO YOGA

No 1.19 Be aware and apply caution when tensioning (stretching) nerves

Care must be taken when doing the following postures or stretches in order to take into account the possibility of nerves being over-tensioned or (over-stretched):

- *Halasana* (plough pose) may over-stretch and perhaps cause irritation to the nerves roots of the spinal cord.
- *Pascimottanasana* *uttanasana* and all straight-legged forward bends may cause an over-stretch of the sciatic nerve and possibly the spinal cord if the head and neck are in flexed position (ie chin brought to the chest) [Section 9.7.3].
- *Supta virasana* , *san calanasana* , *kulpha hanumanasana* and all stretches of the front of the groin (hip flexors) may cause an over-stretch and perhaps damage to the femoral nerve [Section 9.7.3].
- All postures in which the arms are outstretched and the neck is being moved may cause an over-stretch and perhaps damage to the brachial plexus, the median nerve, radial nerve and ulnar nerve [Sections 3.8 & 9.7.3] [Figures 9.1-9.5].

  These include all postures that tension (stretch) nerves of the brachial plexus [Figures 9.1-9.5]. The radial nerve of the brachial plexus is tensioned in *atanu puritat mudra* [Figure 9.1] which also tensions the large intestine meridian. The median nerve of the brachial plexus is tensioned in *kloman mudra* [Figure 9.2] which also tensions the lung meridian. The median nerve is tensioned in *bukka puritat mudra* [Figure 9.3] which also tensions the pericardium meridian. The ulnar nerve of the brachial plexus is tensioned in *buddhizuddhi mudra* [Figure 9.4] which also tensions the heart meridian. The ulnar nerve also tensions *anumukha puritat mudra* [Figure 9.5] which also tensions the small intestine meridian. The names of these *mudras* [Appendix F: Glossary of Sanskrit Terms] relate to the acupuncture meridians which are being tensioned (stretched).

1.7.2.2 Stimulation of nerve reflexes

1.7.2.2.1 Nerve reflexes

A reflex is an automatic response to some types of stimulus. Three (3) reflexes or automatic responses of the nervous system are important to understand in *hatha yoga*.

1.7.2.2.1.1 The myotatic (stretch) reflex

Whenever a muscle is tensioned or stretched, the myotatic (stretch) reflex mechanism is initiated [Alter, 1996]. The myotatic (stretch) reflex can be thought of as a protective mechanism to maintain the homeostasis (the unchanging nature) of the body and prevent any sudden potentially damaging change that an extreme stretch could possibly incur. Stretching a muscle will result in the deformation of receptors called muscle spindles, which send a nerve impulse to the spinal cord. If the nerve impulse is strong enough it will trigger the nerve roots of the spinal cord to transmit an impulse to the stretched muscle that results in reflex muscle activation.

_No 1.20_ Inhibit the myotatic (stretch) reflex when stretching

The myotatic (stretch) reflex can be inhibited by:

- Moving slowly into a stretch
- Exhaling while moving into a stretch
- Concentrating on the muscle that is being stretched while it is being stretched
- Activating an antagonistic (opposing) muscle or muscle group (reciprocal innervation).

The myotatic (stretch) reflex can be taken advantage of by virtue of its ability to cause the recruitment of adjoining and distant muscles and muscle groups by virtue of the fascial (connective tissue) connections between muscles [Section 1.3.2.1.3].

1.7.2.2.1.2 Reciprocal innervation or reciprocal relaxation

Muscles usually operate as opposing pairs. Generally, when agonist muscles are activating, their opposing muscles, the antagonists, are relaxing. This organisation of co-ordinated and opposing agonist and antagonist muscles is called reciprocal innervation [Alter, 1996] or reciprocal relaxation. At the same time that a muscle receives excitatory impulses that cause it to be activated or tensed, the opposing muscles receive inhibitory impulses that cause it to relax. Reciprocal innervation also takes place when a muscle is stretched and the antagonistic (opposing) muscle is signalled to relax to allow the stretch to take place.

_No 1.21_ Use the reciprocal reflex to relax muscles being stretched

In order to assist in the relaxation of the knee flexors (such as the hamstrings at the rear of the thigh) while trying to stretch the hamstrings, it is useful to activate the knee extensors, by tensing the quadriceps at the front of the thigh.
In order to assist in the relaxation of the shoulder elevators (muscles between the neck and the shoulders), it is useful to activate the shoulder depressors, by tensing the muscles under the armpits.

1.7.2.2.1.3 Autogenic inhibition (inverse myotatic reflex)

When a muscle is stretched, it is initially subject to the myotatic (stretch) reflex [Section 1.7.2.2.1.1]. This will cause that muscle to become activated (ie it will generate tension in order to try and shorten as if trying to prevent the stretch). After a certain period of time (about 12-15 seconds) the muscle relaxes, usually before there is a risk of the muscle tearing if it were to remain active. Muscle activity is inhibited

by a nervous system reflex signal from the spine (autogenic inhibition), which causes that muscle to subsequently relax. This phenomenon, known as a lengthening reaction is believed to occur after 12–15 seconds if the stretched muscle is initially in a relaxed state. The lengthening reaction is more noticeable however if a muscle is actively tensed while it is being stretched. After the active tension is released the muscle is usually seen to have stretched further.

1.7.2.2.2 Co-activation of muscles and its relationship to *nadis*, *bandhas* and *cakras*

Co-activation is when two antagonistic (opposing) muscle groups are simultaneously tensing and in some way working against each other. If the opposing muscles are activated with equal force, then the joint will be immobile but quite stable. If one muscle is activated more than the antagonistic (opposing) muscle then the joint will be able to move, but there will be some resistance to movement. Recent studies have demonstrated that co-activation is happening in most of the major joints in everyday life, but closed-chain exercises yield a higher incidence of co-activations than open-chain exercises [Hubley-Kozey & Earl, 2000].

Co-activation has a variable effect on the nervous system depending on the individual. In some cases it may result in the activation of all three nerve reflexes mentioned above [Section 1.7.2.2.1]. However, since co-activation is sometimes under voluntary control, all the nerve reflexes may be inhibited. Research studies have shown that during co-activation there is a significant interaction with the nervous system [Proske *et al.*, 2000; Aagaard *et al.*, 2000; Barbeau *et al.* 2000]. However, further research is needed to establish exactly what is taking place in the nervous system both in the co-activations that are generated by everyday life, and also with the voluntary co-activations generated as *bandhas* [Section 1.7.3] by the experienced *yoga* practitioner.

It may be suggested that the co-activations of opposing muscles across joint complexes that form *bandhas* [Section 1.7.3] generates heat energy (*prana*), which is then pushed and pulled along the *nadis* (subtle energy channels) by differential pressure gradients formed by the *bandhas*, to *marmas* (key places) where *cakras* (whirling energy centres) can be activated. Many authors say that *cakras* are related in some way to the nervous system and endocrine system [Saraswati, 1985; Motoyama, 1993]. The relationships between *nadis*, *bandhas* and *cakras* and how they relate to conventional Western physiology are discussed in more detail in Section 12.7.

1.7.2.2.3 Stretching and its relation to the nervous system

Several methods of stretching have been described in the literature. Each may be used in a *yoga* practice and in other exercise but always with caution in mind.

- **Ballistic stretching** often involves dynamic bouncing in and out of stretches. It is considered to be dangerous by many authors as it is fast and this is generally not safe to teach in a *yoga* class as there is a risk of tearing muscles due to the myotatic (stretch) reflex activation. However, muscle training is very specific and it has been shown that ballistic stretching is important in the development of dynamic flexibility. An experienced *yoga* practitioner may have the skills to stretch safely with ballistic stretching but it is not recommended for most people.
- **Static stretching** is the opposite of ballistic stretching so the pros and cons of ballistic stretching are reversed here. In static stretches a stretch is moved into slowly and held for some time. Therefore the myotatic (stretch) reflex is inhibited and the inverse myotatic reflex comes into play. However, static stretching does not really prepare one for real life in which the activities tend to be ballistic in nature.
- **Passive stretching** is stretching where the individual makes no contribution to generating the stretching force beyond the weight of his or her own body. This type of stretching requires minimal effort but does not really have any training effect on the muscles, ie there is no motor learning effect.
- **Active stretching** [Figures 1.8-1.11] is accomplished by the voluntary use of one's muscles without external aid. Examples of comparisons between active and active-assisted stretches of the hips and spine can be seen in Figures 1.8-1.11.

Figure 1.8: Active stretching (AS) versus active assisted stretching (AAS):
Hip flexion and spinal forward flexion: *Utthita pavanmukta vinyasa*

a Active Stretch (AS) (a). *Niralamba pavanmuktasana* (AS)
b Active Assisted Stretch (AAS) (b) *Utthita pavanmuktasana* (AAS)
c Active Assisted Stretch (AAS) (c) *Utthita trivikramasana* (AAS)

Figure 1.9: Active stretching (AS) versus active assisted stretching (AAS):
Hip abduction and spinal lateral flexion: *Parsva utthita pavanmukta vinyasa*

a Active Stretch (AS) (a). *Parsva niralamba pavanmuktasana*;
b Active Assisted Stretch (AAS) (b) *Parsva utthita pavanmuktasana*;
c Active Assisted Stretch (AAS) (c) *Parsva utthita trivikramasana*;

- **Passive-active stretching** starts as a passive stretch, and is following by the individual trying to maintain the posture by activating the agonist muscles isometrically for a few seconds. This can strengthen the agonist as it works in a shortened range against a tight antagonist.

Figure 1.10: Active stretching (AS) versus active assisted stretching (AAS)
Hip flexion and spinal axial rotation: *parivrtta utthita pavanmukta vinyasa*

a Active Stretch (AS) (a). *Parivrtta niralamba pavanmuktasana*;
b Active Assisted Stretch (AAS) (b) *Parivrtta utthita pavanmuktasana*;
c Active Assisted Stretch (AAS) (c) *Parivrtta utthita padangusthasana*

- **Active assisted stretching** [Figures 1.8-1.11] is initiated by an individuals own muscle force then supplemented by an external force. This can help strengthen the agonist as it works in against a tight antagonist, and helps to establish a pattern for motor control (muscle control).

Figure 1.11 Active stretching (AS) versus active assisted stretching (AAS)
Hip flexion and spinal forward flexion: *Urdhva mukha pascima vinyasa*

a Active stretch (AS)
(a) & (b) *Niralamba urdhva mukha pascimottanasana* (AS)

b Active stretch (AS)

c Active assisted Stretch (ASS)
(c) *Urdhva mukha pascimottanasana* (ASS)

APPLICATION TO YOGA

***No 1.22* Active stretches are generally safer than passive stretches**

Active stretches are a good way of preparing for active-assisted stretches, which are one of the most effective ways to safely develop a balance between strength and flexibility.

1.7.2.2.4 Proprioceptive neuromuscular facilitation (PNF)

Proprioceptive neuromuscular facilitation (PNF) is a method developed in the middle of the 20th Century to increase muscular strength, flexibility and coordination. PNF has been described as a method for promoting the neuromuscular mechanism by the stimulation of proprioceptors (receptors given information about body position). PNF techniques mimic techniques that advanced *yoga* practitioners have always used to increase strength, flexibility and relaxation. It is nevertheless useful to understand the technique and learn how to adapt it and safely teach it to beginner *yoga* students.

1.7.2.2.4.1 Neurological basis of PNF

PNF uses a variety of techniques, which include:

(i) Facilitatory mechanisms to excite the motor neurons and cause a greater stimulation of muscle activity
(ii) Inhibitory techniques to reduce nervous excitability and muscle activation
(iii) Resistance techniques to get muscles to work effectively throughout their range of joint motion
(iv) Irradiation techniques which recruit Synergistic muscles to assist the main muscles to accomplish their task
(v) Nerve reflexes such as the myotatic (stretch) reflex, the reciprocal reflex and the inverse myotatic reflex [Sections 1.7.2.2.1.1-2]

The two most common techniques associated with the PNF system, and which are regularly used by the advanced *hatha yoga* practitioner (whether they know it or not) involve

(i) Activation of an agonist muscle during a stretch to elicit a reciprocal relaxation of the antagonist muscle, and increase the strength of the agonist in a shorted state [Section 1.7.2.2.1.2 Application to *yoga*].
(ii) Activation of an antagonist muscle during a stretch, which strengthens the antagonist in a lengthened state and which appears to increase the stretch of the antagonist muscle perhaps due to the effects of the inverse myotatic reflex [Section 1.7.2.2.1.3 Application to *yoga*] (although recent research makes the real cause as yet unclear).

1.7.3 *Bandha Hatha Yoga*: Co-activation of Opposing Muscle Groups Around Joint complexes

In traditional *hatha yoga*, a *bandha* (from the Sanskrit: meaning to bind or lock) is described as a subtle internal energy lock or grip. *Bandhas* are said to be used to control and guide the energy gathered and generated by the internal body pressures created during *hatha yoga* via the postures, the muscles and the breath [Sections 1.0.4 & 8.4.1].

On a more physical level a *bandha* is the co-activation of opposing muscles [Section 1.7.2.2] around a joint or joint complex [Section 1.5.3] that helps stabilise, strengthen and energise that joint or joint complex. Depending on the type of agonist antagonist synergy that takes place, a joint will either be compressed or expanded [Section 1.7.3.4] by co-activated opposing muscles that form a *bandha*. Since one of the effects of co-activation and *bandhas* is to help circulate blood and energy around the body, it then follows that one may refer to the *bandha* system as a kind of muscle co-activation pump of blood around the body that is analogous to the musculoskeletal pump.

The formation of *bandhas* throughout the body depends on several important features of musculoskeletal structure and function.

- *Bandhas* are more easily created around joint complexes [Section 1.5.3] rather than simple joints.
- Muscles involved in the physical aspect of *bandhas* can be co-activated around joint complexes because of their tendency to be multi-joint muscles (ie they cross and have an effect over several joints) [Section 1.6.5.7].
- Co-activation of opposing muscles across a joint complex may also be promoted by the fascial connections between muscles and by virtue of the myotatic (stretch) reflex that can elicit the activation of muscles adjacent to muscles that have been voluntarily activated [Section 1.3.2.1.3].

_No 1.23_ Use _bandhas_ (co-activations) to stiffen weak flexible parts of the body in order to access stiff parts of the body

If the *bandhas* are not activated, then when a joint complex such as the lumbar spine joint complex [Section 7.1.5.3] is flexed or extended the stiffest part will be unlikely to bend, while the most flexible part will bend easily and may perhaps become unstable.

Example 1: Backward-bending (spinal extension) postures such as *bhujangasana* (cobra pose) and *urdhva mukha svanasana* (upward-facing dog pose), tend to bend or stretch the weakest part of the lower back (lumbar spine) and often do not bend or stretch the upper back (thoracic spine). If the abdominal muscles and the deep muscles of the lower back (*mula bandha* [Section 1.7.3.1.1]) are tensed prior to coming into the pose, they can function to stabilise and protect the weakest parts of the lower back (which usually bend easily) and can prevent the lower back from over-stretching and risking possible injury. This allows the possibility for the stiffer parts of the spine to be mobilised (bent or stretched) instead.

Example 2: Postures that simultaneously bend or stretch the knee and hip, such as *padmasana* (lotus pose), often tend to over-stretch the knee (which is a relatively weak and flexible joint) while often tending to only minimally bend or stretch the hip (which is a relatively stiff and strong joint). If the muscles around the knee (*janu bandha* [Section 1.7.3.2.5]) are tensed prior to coming into the pose, they can function to stabilise and protect the knee (which usually bends easily) and it can prevent the knee from over-stretching and risking possible injury. This allows the possibility for the hip (which tends to be stiffer) to be opened or stretched instead.

1.7.3.1 Central *bandhas*: co-activations of opposing muscles in spinal joint complexes

There are three (3) main or central bandhas. These are essentially co-activations of the opposing muscles of the lumbar, thoracic and cervical spine joint complexes.

In most of the texts on *yoga* only three main *bandhas* are described. These *bandhas* are intimately connected with the strength and stability of the lumbosacrococcygeal spinal joint complex of the lower back (*mula bandha*), the thoracic spine joint complex of the upper back (*uddiyana bandha*), and the cervical spine joint complex of the neck (*jalandhara bandha*). The formation of these three *bandhas* is also integral to the muscular sequence involved with deep or complete breathing [Sections 1.7.3.7, 8.2.8, 8.4.2].

1.7.3.1.1 *Mula bandha*

On a muscular level, *mula bandha* [Sections 7.1.5.3 & 7.5.1.1] is formed when the lumbosacrococcygeal spinal joint complex (lower back) is supported and stabilised by co-activation of antagonistic (opposing) muscle groups around the lumbar spine, sacrum and coccyx. The muscles involved with *mula bandha* include transversus abdominis, obliquus externus abdominis, obliquus internus abdominis and lumbar extensors such as multifidus. Co-activation of antagonistic muscle groups help stabilise and strengthen the lumbar spine in the same manner as that described by the system known as core stabilisation [Richardson & Jull, 1995].

A recent study [Cholewicki *et al.*, 1997] demonstrated that antagonistic trunk flexor-extensor muscle co-activation was present around the neutral spine posture in healthy individuals. This co-activation increased with added mass to the torso. Using a biomechanical model, the co-activation was explained entirely on the basis of the need for the neuromuscular system to provide the mechanical stability to the lumbar spine.

No 1.24 A complete exhalation is only possible when *mula bandha* is firmly established

Mula bandha may be learnt by gently tensing the muscles of the perineum and lower abdomen and then making a complete exhalation.

1.7.3.1.2 *Jalandhara bandha*

In a similar manner, *Jalandhara bandha* [Section 7.1.5.1 & 7.5.1.2] is formed when the cervical spine joint complex (neck) is supported and stabilised by co-activation of opposing muscles around these joints. *Jalandhara bandha* is generally formed by bringing the chin down towards the sternum (head flexion), while simultaneously moving the chin inwards towards the throat and the back of the neck (neck extension / retraction).

1.7.3.1.3 *Uddiyana bandha*

Uddiyana bandha [Sections 7.1.5.2 & 7.5.1.3] is formed when the thoracic spine joint complex (upper back) is supported and stabilised by co-activation of opposing muscles around these joints. *Uddiyana bandha* is essentially an expansion of the chest and rib cage due to the combined actions of the external and internal intercostal muscles. This leads to the creation of an expansive force or relatively low pressure that draws air into the lungs and blood up to the heart during an inhalation. *Uddiyana bandha* also can cause the abdominal region to appear to suck inwards when a false inspiration is made in which no air is allowed to enter the nose or mouth but the chest cavity nevertheless is made to expand via the intercostal muscles and also some of the accessory muscles of inspiration.

_No 1.25_ A complete inhalation is only possible when *uddiyana bandha* is firmly established

Uddiyana bandha may be initially learnt by expanding the chest and making a complete inhalation. Later the same muscles can be used to make the same expansion of the chest but without breathing. This generates the classical *uddiyana bandha* as shown above and in Figure 7.9.

1.7.3.2 Peripheral *bandhas*: co-activations of opposing muscles in upper and lower limb joint complexes

There are six (6) peripheral *bandhas*. These are co-activations of the opposing muscles of the main joint complexes of the upper and lower limbs

The concept that *bandhas* are co-activations of opposing muscles can be extended to the major joints of the upper and lower limbs. Co-activation of opposing muscles around joint complexes (*bandha*) provides the strength and stability to safely perform advanced *yoga* postures, and to assist in the flow of energy throughout the body.

Groups of people who practise extreme stretching exercises for a significant period of time without injury, all exhibit co-activation of opposing muscles around each of the major joints while they are stretching. Practitioners of the martial arts [Zehr *et al.*, 1995], gymnastics and even classical ballet are all instructed to, and observed to, maintain muscle tone in their limbs (co-activation) when they perform extreme movements and stretches. This muscular tone is often also clearly visible in advanced *yoga* practitioners who can safely perform the more difficult *asanas*.

Studies on the stability of spinal joint complexes, such as the lumbar spine joint complex [Section 7.1.5.3], have demonstrated that a joint-stabilising effect from the co-activation of opposing muscles of the lower back and abdomen [Richardson & Jull, 1995] can reduce the risk of lumbar spinal injury and help minimise lower back pain. This concept of co-activation of opposing muscles can be expanded to other joint complexes. If a weak region of an upper or lower limb joint complex is not supported by some muscular activation or strength, then when that joint is moved to an extreme position (stretching), the weakest part of the joint will probably be the first part to move and may be the only part of the joint to be stretched at all. Hence, many stretching exercises which are extreme in nature, and which are not supported by some muscular activation or strength, are at risk of damaging joints.

There are numerous research studies available on the phenomenon of co-activation of opposing muscles. Co-activation of opposing muscles has been demonstrated in the ankle joint complex [Hubley-Kozey & Earl, 2000],

knee joint complex [Aagaard *et al.*, 2000], shoulder joint complex [Gribble & Ostry, 1998], elbow joint complex [Yamazaki *et al.*, 1995], and wrist joint complex [Smith, 1981]. These studies support the basic concept that joint stabilisation is a result of co-activation of opposing muscles around these joint complexes.

Therefore, the concept or definition of a *bandha* as co-activation of opposing muscles around a joint complex can be extended to all major joint complexes in the body. In the various *yoga* postures and exercises joint *bandhas* are generated around the nine (9) major joint complexes.

There are nine (9) major *bandhas* within the body. These are co-activations of antagonistic (opposing) muscles of the spine (3) and of the main joint complexes of the upper limb (3) and lower limb (3).

On one level, one can consider *bandhas* to be muscular stabilisers of the nine major joint complexes throughout the body. These nine *bandhas* in their various states and forms are the instigators of pressure gradients that assist in the flow of energy through the body.

The nine (9) types of major joint *bandhas* in the body considered in this book are:

- **Three (3) central or spinal *bandhas*** are related to the neck (cervical spine), upper back (thoracic spine) and lower back (lumbosacrococcygeal spine) regions of the spine respectively [Section 1.7.3.1].
  - ***Jalandhara bandha*** is formed when the neck joint complex [Section 7.1.5.1] is supported and stabilised by co-activation of opposing muscles around this joint complex.
  - ***Uddiyana bandha*** is formed when the upper back joint complex [Section 7.1.5.2] is supported and stabilised by co-activation of opposing muscles around this joint complex.
  - ***Mula bandha*** is formed when the lower back joint complex [Section 7.1.5.3] is supported and stabilised by co-activation of opposing muscles around this joint complex. (Note that here the lower back joint complex includes all the joints from the start of the lumbar spine (T12-L1) to the end of the coccyx including the sacrum and sacroiliac joints. The term lower back joint complex is used in these notes as an abbreviation for the lumbosacrococcygeal spinal joint complex).

- **Three (3) pairs of upper limb peripheral *bandhas*** related to the joint complexes of the shoulders, elbows and wrists respectively.

  1.7.3.2.1 *Amsa bandha*

  Amsa bandha is formed when the shoulder joint complex is supported and stabilised by co-activation of opposing muscles around this joint complex [Section 2.5.1, Figures 2.5, Table C1].

  1.7.3.2.2 *Kurpara bandha*

  Kurpara bandha is formed when the elbow joint complex is supported and stabilised by co-activation of opposing muscles around this joint complex [Section 3.9.1, Figure 3.8, Table C1].

  1.7.3.2.3 *Mani bandha*

  Mani bandha is formed when the wrist joint complex is supported and stabilised by co-activation of opposing muscles around this joint complex [Section 3.9.1, Figure 3.8, Table C1].

- **Three (3) pairs of lower limb peripheral *bandhas*** related to the joint complexes of the hips, knees and ankles respectively.

  1.7.3.2.4 *Kati bandha*

  Kati bandha is formed when the hip joint complex is supported and stabilised by co-activation of opposing muscles around this joint complex [Section 4.5.1, Figure 4.4, Table C1]

  1.7.3.2.5 *Janu bandha*

  Janu bandha is formed when the knee joint complex is supported and stabilised by co-activation of opposing muscles around this joint complex

  1.7.3.2.6 Kulpha bandha

  Kulpha bandha is formed when the ankle joint complex is supported and stabilised by co-activation of opposing muscles around this joint complex [Section 6.5.1, Figure 6.8, Table C1] .

The tonic (ongoing) co-activation of opposing muscles around nine major joint complexes can also be observed in the teaching and the advanced practice of other major physical disciplines involving movement and posture such as classical ballet and the martial arts [Alter, 1998]. Interestingly, co-activation has been observed more commonly in Type A personalities than in Type B personalities [Glasscock *et al,*. 1999].

In order to learn the *bandhas* for each joint, there are key *asanas* (*yoga* postures) *mudras* (yogic gestures), and *pranayamas* (*yoga* breathing techniques), which when performed correctly will cause *bandhas* to be automatically generated or formed around that particular joint or joint complex. The main instructions on how to safely perform the *asanas*, *mudras* and/or *pranayamas* required to create the *bandhas* are described and discussed in subsequent chapters. However, they are best learnt from an experienced teacher.

1.7.3.3 A Safe Approach to the use of *Bandhas* in *Yoga* Exercises:

sthira sukham asanam [Patanjali Yoga Sutra II.46; Iyengar, 1993]:
A prudent approach to *yoga asana* practice, with safety in mind, needs to be adopted when working with the *bandhas*. It is always important to practice *yoga* (or any similar exercise) keeping the face, neck and throat relaxed and shoulders generally moving away from the neck towards the hips. Before any major joint or joint complex is bent (flexed, extended etc) in any way, that joint needs to be protected by the stabilising grip of a *bandha*. In other words, do not bend more than just very gently unless you can have a firm muscular grip around the area you are about to bend. Only grip the *bandha* to the extent such that you can keep the face, neck and throat relaxed, and the internal physiology (such as nervous system and blood pressure) comfortable. If any muscle activation, including those related to the *bandhas,* is maintained too strongly or for too long it can lead to a significant increase in blood pressure or an over-stimulation of the nerves, which can be counter-productive and even dangerous.

This concept was clearly stated by the great yogic sage Patanjali [Patanjali Yoga Sutra II.46; Iyengar, 1993] in one of the few sutras mentioned regarding the asanas: *sthira sukham asanam*. Note the significance of the order of the words and their meanings. The sutra says first s*thira*, meaning be firm, or create a *bandha* around the region that is being bent. The sutra then says *sukham*, implying happy or comfortable, or relax the face neck throat and do not disturb the internal physiology. Finally, the sutra says *asanam*, or move into the next stage of the pose or exercise. In other words, one should not bend any further unless there is a firmness where it is being bent and yet an overall feeling of comfort. Alternatively, one should only bend a joint complex [Section 1.5.3] beyond one's everyday limits with the application of a *bandha* (co-activation of opposing muscles) around that joint.

1.7.3.4 *Bandha* States: *Ha bandhas* and *Tha bandhas*:

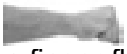
Co-activations of antagonistic (opposing) muscle groups around a joint complex (*bandhas*) are able to generate relatively high or relatively low pressures. Hence one can define two main *bandha* states, which may assist in the understanding of the principles that the *bandha* concept relates.

1.7.3.4.1 *Ha-bandhas* (hot or high pressure *bandhas*)

A *ha-bandha* or hot *bandha* state can be said to have been formed when the co-activation (simultaneous tensing) of antagonistic (opposing) muscle groups around a joint complex leads to the formation of uniform compressive forces (a relatively high pressure) around that joint complex.

Examples of stereotypical *ha-bandhas* include *mula bandha* as it is most typically practised by tightening the region of the perineum and lower abdomen, and *jalandhara bandha* as it is usually practised with the neck flexors bringing the head into flexion and the neck extensors co-activated to simultaneously bring the neck into extension. *Ha-mula bandha* is able to push energy and matter in the form of blood and air away from the region of the lower trunk. Similarly, *ha-jalandhara bandha* is able to push energy and matter in the form of blood and air away from the region of the head and in so doing can prevent unnecessary pressure reaching the head during certain *kumbhakas* (breath retentions) of *yogic pranayama* (breath-control exercises) .

Two other main *ha-bandhas* involve co-activations of the multi-joint muscles crossing the feet and hands that produce a compressive effect from the fingers and toes:

- *Ha-mani bandha*  involves the co-activation of the multi-joint muscles crossing the wrist and hand that activates finger flexors and wrist extensors [Section 3.9.1.2].
- *Ha-kulpha bandha* involves the co-activation of the multi-joint muscles crossing the ankle and foot that activates toe flexors and ankle extensors (dorsi flexors) [Section 6.7.1].

1.7.3.4.2 *Tha-bandhas* (cool or low pressure *bandhas*)

A *tha-bandha* or cool *bandha* state can be said to have been formed when the co-activation of antagonistic (opposing) muscle groups around a joint complex leads to the formation of uniform expansive forces (a relatively low pressure) around that joint complex. *Tha-bandhas* are usually formed when the joint complex involved is in a relatively neutral position or anatomical position.

An example of the stereotypical *tha-bandha* is *uddiyana bandha* as it is practised in its most usual form as an expansion of the chest that sucks the abdomen upwards usually after the breath is held out. *Tha-uddiyana bandha* is able to pull energy and matter in the form of blood and air towards the region of the chest and upper trunk.

Two other main *tha-bandhas* involve co-activations of the multi-joint muscles crossing the feet and hands that produce a stretching effect in fingers and toes:

- *Tha-mani bandha* involves the co-activation of the multi-joint muscles crossing the wrist and hand that activates finger extensors and wrist flexors [Section 3.9.1.2].
- *Tha-kulpha bandha* involves the co-activation of the multi-joint muscles crossing the ankle and foot that activates toe extensors and ankle flexors (plantarflexors) [Section 6.7.1].

1.7.3.5 *Bandha* inter-connectedness

Each *bandha* is in some way affected by the *bandhas* adjacent to it and even those more distant to it. Each *bandha* when formed can help stimulate the generation of *bandhas* adjacent to it, and subsequently onto more distant *bandhas*. Examples of *bandha* inter-connectedness are described below and in subsequent chapters.

Each *bandha* is generally enhanced if the *bandha* of the adjacent joint complexes are also activated. Due to the holistic nature of the body and, in particular, the connections between adjoining muscle groups by virtue of the fascia or connective tissues that cover the muscles and tendons, the activation of one muscle (say as part of one *bandha*) can cause a subtle pulling against an adjoining muscle, which may then be stimulated to undergo a muscle activation by virtue of the myotatic (stretch) reflex. Hence the activation of one *bandha* can enhance, stimulate and/or initiate the activation of an adjacent *bandha*.

1.7.3.6 Counter *bandhas*

When any of the *bandhas* are activated, the tension of the muscles involved needs to be isolated to the region of the *bandhas* only. There is a tendency for the untrained person to inadvertently and unnecessarily tense other muscles when they try and isolate *bandhas*. To counter this problem, one should consciously focus on the regions that inadvertently tense when a *bandha* is gripped and consciously relax those muscles. This conscious relaxation of regions during the process of creating a *bandha* may be termed a counter *bandha*. Counter *bandhas* and the regions they relate to will vary somewhat from person to person, but for most people the following regions tend to become tense when particular *bandhas* are activated.

- The counter-*bandha* for *mula bandha* generally relates to the need to relax the face neck and throat.
- The counter-*bandha* for *uddiyana bandha* generally relates to the need to relax the shoulders and pull them closer to the hips. Therefore, the counter *bandha* for *uddiyana bandha* is the shoulder *bandha*

(*amsa bandha*).

- The counter-*bandha* for *jalandhara bandha* generally relates to the need to relax the jaw as the chin moves down and in towards the throat.

1.7.3.7 Relationship between the *bandhas* and the respiratory system

The three central *bandhas* are intimately related with breathing.

Mula bandha, the root lock that is essentially a co-activation of lower abdominal muscles and lumbar extensor muscles, is naturally formed with a complete exhalation.

Uddiyana bandha, which is an expansion of the chest and rib cage via the intercostal muscles, is naturally formed during an inspiration, which causes an expansion of the chest. The expansion of the chest corresponding to *uddiyana bandha* is facilitated when an inhalation is begun with the abdominal muscles held in isometric muscle activation.

Jalandhara bandha in its *ha-* form (when the chin is brought down and into the throat) is important in *yogic* deep breathing to help stimulate the abdominal muscle activation (*mula bandha*) and also to help facilitate the thoracic expansion (*uddiyana bandha*) [Sections 8.2.8 & 8.4.2].

It is important to note that although formation of the three central *bandhas* is integral to the muscular sequence involved with breathing, they are not dependant on taking air into the lungs, ie *uddiyana bandha* and *mula bandha* can be made either while inhalation is taking place, after inhale retention or after exhale retention [Table A2], and even during the exhalation [Sections 8.2.8 & 8.4.2].

1.7.4 Increasing Strength, Flexibility and Relaxation with *Hatha Yoga*

Hatha yoga can be thought of as a balance between strength, flexibility and relaxation [Section 1.7.1]. When one has some understanding of nerve tensioning (stretching) and the principles of nerve reflex utilisation as practised in *nadi-hatha yoga* [Section 1.7.2], and when one understands how these concepts can be applied to create the co-activations of antagonistic (opposing) muscle groups used in *bandha-hatha yoga* [Section 1.7.3], then strength and flexibility can both be developed and increased while maintaining a controlled ability to relax.

In most conventional exercise, strength training and flexibility training are practised separately. In *hatha yoga,* however, strength and flexibility develop together in conjunction with joint stabilisation and general relaxation. By working holistically, *hatha yoga* exercises aim to improve performance of functional tasks, while decreasing the effort involved.

Synergistic muscle activations are used in *yoga* exercises to maximise the distance between proximal and distal attachments of the muscle to be stretched. Co-activations of muscles around a joint are engaged in order to help stabilise joints. Static *yoga* postures may utilise isometric muscle activations. Dynamic *yoga* exercises, with varied velocity of movements, help develop concentric and eccentric muscle activity.

Yoga includes many exercises that are weight-bearing or non-weight-bearing [Sections **1.6.5.9.3-4**]. on any combination of upper and lower limbs. Hence, *yoga* incorporates both open-chain and closed-chain exercises [Sections **1.6.5.9.1-2**]. *Yoga* exercises may require muscles to either generate tension or to relax completely in either a lengthened or shortened state [Section 1.6.6]. Hence, muscles are taught to function through a full joint range of motion (ROM).

Although strengthening, stretching and relaxation are usually inter-linked in *yoga* exercises, it is helpful to outline the main principles to consider for stretching, strengthening, and relaxation. These points will be discussed further in later chapters.

1.7.4.1 Principles of stretching in *yoga*

In order to safely and effectively stretch both muscles and tissues in *hatha yoga*, one must address four main areas. One must (1) establish correct positioning (*asana*), (2) understand nerves (as the physical manifestation of specialised *nadis*), (3) understand muscle co-activations (as the physical manifestation

of *bandhas*), and (4) create the proper physiological environment through a combination of breath-control (*Pranayama*) and diet.

1. Establish correct positioning for maximum stretch or tension

- **Stretching muscles**: Establish correct local joint positioning in order to maximise the distance between proximal and distal attachments of individual muscles and muscle groups.
- **Tensioning (Stretching) nerves**: Establish correct whole body positioning (eg curvature of the spine) in order to maximise neural tensioning (nerve stretching) [Section 1.7.2], especially of those nerves involved with the correct functioning of muscles that are being stretched, strengthened or relaxed [Figures 9.1-9.7].

2. Apply an understanding of nerve reflexes

- Inhibit the stretch or myotatic reflex in the muscles that are being stretched [Section 1.7.2.2.1.1]
- Take advantage of the fascial connections between muscles that can cause an activation of adjacent and distant synergistic muscles as a result of the myotatic (stretch) reflex [Section 1.3.2.1.3].
- Make use of reflex reciprocal inhibition [Section 1.7.2.2.1.2] by activating a muscle or muscle group that opposes the action of the muscle being stretched, in order to reciprocally relax the muscle being stretched (ie activate an agonist muscle in order to reciprocally relax the antagonist).
- Make use of inverse myotatic reflex [Section 1.7.2.2.1.3] by activating a muscle when it is already under tension to help stretch, strengthen and (later) relax it further.

3. Use joint *bandhas* to employ a stretch not squash principle

- Where possible create space rather than compression around joints, ie do not squash the side of the joint you are moving towards but instead stretch the side of the joint you are moving away from. This can be achieved with the coordinated use of the *bandhas*.
- For example, when raising the chin (ie head extension) maintain the length in the cervical spine and in the back of the neck by stretching the front of the neck and not by squashing the back of the neck.

This can be achieved with the *tha-jalandhara bandha* which involves lifting the chin using the head extensors while bringing the throat slightly forward (ie neck flexion) with the neck flexors.

4. Create an internal environment that facilitates greater fluidity in the synovial-like fluids around the joints and cartilage, between fascia and muscle, and within the sheaths of tendons and nerves:

- To increase the fluidity of thixotropic synovial-like fluids, use either heat from muscle activations, or use alkalinity generated either temporarily through hyperventilation (breathing more than the body actually needs) or more permanently through long-term change to a more alkaline diet [Section 10.3].
- Protect cartilage by creating heat and/or alkalinity around and within joint spaces in order to increase the fluidity of the synovial fluid and thus lubricate and increase the mobility of the joints [Section 1.3.2.2.3].

1.7.4.2 Principles of strengthening in *yoga*

In order to fully increase strength in the body, one must increase the strength of the bones and the muscles. **Strengthen bones** by applying Wolffs Law [Section 1.3.2.3.5], which states that increases in force through a bone will lead to increased deposition of bone in that area as a result of the force.

- Work towards weight-bearing on all parts of the body
- Generate muscle tension between bones
- Ensure correct alignment in the postures.

Strengthen muscles by applying the basic principles of a training schedule [Section 12.3] incorporated with many variations of basic *yoga asanas* (static postures) and *vinyasas* (dynamic exercises).

- Activate muscles (generate muscle tension) in three different ways
  - i. Work against gravity using partial or full body weight as resistance
  - ii. Work against other muscles or other body parts as resistance
  - iii. Work isometrically against no external resistance (this involves an innate use of joint *bandhas*

eg to make a bulging biceps brachii against no resistance, one must generate a co-activation of triceps brachii with the biceps brachii that is part of *kurpara bandha*) [Section 3.9.1.1].

- Improve neural activation of muscles [Section 12.3.3.]. Often when a muscle is untrained in a particular task it does not fully become activated and cannot generate its maximum tension and strength. Improving neural activation of muscles is essentially training the brain and nervous system to get better at activating all the muscle fibres in muscle so that a muscle is able to be fully active.
- Improve functional strength. Training is most effective if it is task specific [Carr & Shepherd, 1987], ie practice the muscle movement you wish to strengthen.
- Apply an optimal training load. *Asanas* (static postures) and *vinyasas* (dynamic exercises) can be modified where needed to be safer and more accessible or, conversely, more challenging for those who are ready for that.
- Use the appropriate number of repetitions for each *asana* or *vinyasa*, occasionally to the point of fatigue. Increases in muscle strength will not be provoked unless the muscle is exercised to a point where it cannot work as hard any more (fatigue) [Section 12.2.4].

- Utilise five types of muscle activations:
  i. Isometric muscle activations in static postures
  ii. Isotonic muscle activations in dynamic exercises (concentric and eccentric)
  iii. Synergistic muscle activations
  iv. Co-activation of opposing muscles around joints (*bandhas*).
  v. Postural muscle activations (including use of the muscular locks or *bandhas*).

1.7.4.3 Principles of relaxation in *yoga*

In order to fully relax one must address three (3) main areas. One must relax the muscles, the nerves and the brain.

Relax the muscles

- By bringing awareness to the muscles. One needs to feel and/or know where a muscle is before one can learn how to relax it. *Yoga* exercises bring an awareness or sensation to muscles through learning to activate or stretch these muscles in the different body parts.
- By first learning how to activate muscles it is then easier to relax them, ie you must be able to turn a muscle on before you are able to turn it off.
- By holding stretches for a reasonable length of time (at least 30 seconds) the myotatic (stretch) reflex can be overcome and the muscle is more able to relax.
- By applying a practical understanding of reflex reciprocal inhibition/relaxation, one is able to consciously relax a muscle, then relax even further by activation of the antagonist muscle.

Relax the nerves

- By knowing the paths of the main nerves and being aware of tensioning (stretching) them [Figures 9.1-9.7].
- By not over-tensioning (over-stretching) the nerves as this leads to their over-stimulation

Relax the brain

- Relaxing muscles reduces stress. The basic concepts that *yoga* uses to help relax muscles translate to a reduction of stress in the brain.
- By maintaining an awareness of the breath in postures. This gives the brain something to focus on which is quite tangible
- By keeping the face and neck relaxed throughout a *hatha yoga* practice. This can help to reduce the pressure and tension in the head.
- The supine *yoga* relaxation (*savasana*) for 5-15 minutes at the end of each *yoga* practice is important for many people. Recent studies [Bera *et al.*, 1998] have revealed that the effects of physical stress were reversed in significantly shorter time in *savasana*, compared to the resting

posture in a chair and a supine posture. In *savasana* the muscles can be fully relaxed if they have been stimulated by either stretch or activation during the practice. However, if the nervous system was over-stimulated during the practice then relaxation will still be difficult. The brain can relax if it has been engaged throughout the practice in the process of either focusing on a particular type of breathing, or feeling the sensations of intelligently organised stretching and activation. If the brain was not engaged in the functioning of the body in the *yoga* exercises then it will be less able to relax and more likely to become either restless or sleepy.

1.8 *YOGA CIKITSA*: *HATHA YOGA* AS A FORM OF THERAPY [Sections 2.5, 3.9, 4.5, 5.6, 6.7, 7.5, 8.4, 9.7, 10.3, 11.4, 12.7]

A very experienced practitioner may be able to use *hatha yoga vidya* (*yogic* science) and *hatha yoga cikitsa* (*yoga* therapy) for specific diagnosis and treatment of musculoskeletal problems and medical conditions. However, this should not be attempted by most people and is beyond the scope of this book. Nevertheless, it is important to have a general idea of what you can do and what you should not do if you or someone you are teaching gets injured while practising yoga (perhaps in your class) or has a musculoskeletal problem or medical condition which is not as a result of yoga.

We have outlined some general principles below that may be applied when there are physical problems. This is an overview of what not to do in certain situations and what may help the healing process in other situations.

In dealing with any injury or illness, the most important thing is to not make things worse. If there is any uncertainty as to the nature of the problem, it is safest to rest the injured part, and if necessary, rest the entire body, then refer the person to a health professional. Never assume that, as the teacher of a class, you have to know how to cure someone.

First, it is important to learn the general principles of injury and healing. When there is some understanding of what is happening in a particular persons body, it becomes relatively safe to work with the holistic principle of improving the health of the body as a whole without really interfering with an injured part. As the overall health improves then the injured part often improves also. Therefore, improving a bodys overall level of strength, flexibility, musculoskeletal control and cardiovascular fitness is the first step in the process of more specific *yoga* therapy.

Generally, when dealing with someone who has a musculoskeletal injury or problem one needs consider the following factors:

- Is the injury acute or chronic?
- Is the injury irritable or non-irritable?

Irritable conditions are easily stirred up and must be treated very carefully or else they can become very sore after exercise or after a treatment.

Non-irritable conditions, on the other hand can be treated or exercised quite firmly. While they may have a sense of discomfort while exercising or while being treated, the discomfort settles down quickly after the treatment.

1.8.1 Treating Acute Injuries with *Hatha Yoga* [Table 1.6]

An acute problem usually shows the cardinal signs of inflammation [Sections 1.3.3 & 10.2.2.1], and is often quite recent.

The cardinal signs of inflammation usually seen in acute conditions are:

(i) **Redness**
(ii) **Pain**

(iii) **Heat**
(iv) **Swelling** and sometimes
(v) **Loss of function**

Acute conditions are usually treated in medical circles with the **R.I.C.E. principle** (**Rest**, **Ice**, **Compression** and **Elevation**).

If a musculoskeletal problem is acute in nature, it is usually best to rest the injured part, or if necessary, rest the entire body.

Hatha yoga can be still be practised in this situation if the problem area can be suitably bypassed and allowed to rest. Postures need to be suitably modified and a greater emphasis made towards a gentle more relaxed practice that does not generate too much excess heat.

Table 1.6 Treatment of acute injuries: Medical treatment versus *hatha yoga* therapy [Section 1.8.1]

MEDICAL TREATMENT OF ACUTE INJURIES (R.I.C.E.)	TREATMENT OF ACUTE INJURIES WITH *HATHA YOGA* [Section 1.8.1]
Rest	Rest injured part & keep working with the rest of the body (Or rest the whole body if necessary)
Ice	Do not generate excess heat with practice (Do a gentle *hatha yoga asana* & *vinyasa* practice)
Compression	Gentle isometric co-activations (*bandhas*) around a joint (Activate joint *bandhas* if possible and if appropriate)
Elevation	Inverted or semi inverted postures (*Viparita Karani*)

1.8.2 Treating Chronic Injuries with *Hatha Yoga* [Table 1.7]

Chronic injuries are usually long-standing injuries where the inflammation has subsided.

- Chronic musculoskeletal injuries or conditions may be cautiously approached with the following general methodology [Table 1.7], when there are no signs of inflammation.
- When there are no contraindications, one can use *hatha yoga* postures and exercises, breathing exercises, and relaxation to give general and specific improvements in circulation, strength, flexibility, and musculoskeletal alignment.

To improve circulation [Section 8.4.1] use:
- **Breathing techniques** (*Pranayama*) to utilise the respiratory pump of circulation.
- **Dynamic exercises** (*Vinyasa*), activating and relaxing muscles during movement to utilise the musculoskeletal pump [Section 1.0.4] of circulation and varying the speed of movements to utilise the centripetal pump of circulation [Section 1.0.4].
- **Inverted and semi inverted postures** (*Viparita Karani*) to utilise the Gravitational pump of circulation [Section 1.0.4].
- **Static postures** (*Asanas*), creating regions of relative high pressure (compression and/or isometric muscle activation) and relative low pressure (stretching and/or muscle relaxation) to utilise the postural pump of circulation [Section 1.0.4].
- **Co-activation of opposing muscles around joints** (*Bandhas*) to utilise the muscle co-activation pump of circulation [Section 1.0.4].

To improve strength [Section 1.7.1.2] develop:

- **Muscle control**: develop the ability to fully relax or turn off a muscle and then smoothly activate or turn on a muscle to its maximum level of muscle activation in any of its states [Tables 1.4 & 1.5].
- **Muscle balance**: develop muscle symmetry and learn how to co-activate muscles for increased joint stability
  - **Symmetry**: restore and/or develop balance between:
    - Left side and right side of the body
    - Agonist and antagonist muscle groups
    - Anterior and posterior, medial and lateral, and superior and inferior musculature.
  - **Muscle co-activation**: develop the ability to co-activate (simultaneously tense) agonist and antagonist muscle groups for increased joint stability (*bandhas*) [Sections 1.7.3, 2.5.1, 3.9.1, 4.5.1, 5.6.1, 6.6.1, & 7.5].
- **Muscle specificity**: To develop functional task specificity:
  - Use isometric, isotonic and isokinetic exercises
  - Use varied velocities of joint movement
  - Move joints through their full range of motion (ROM)
  - Use weight-bearing (WB) exercises and non-weight-bearing (NWB) exercises
  - Use open-chain (OC) exercises and closed-chain (CC) exercises

To improve flexibility [Section 1.7.1.1, Chapters 1 – 7]

Develop:

- Joint mobility: ie develop ease of joint movement not just the ability to stretch further.
- Symmetry of flexibility: both inter-joint, ie between right and left sides of the body; and intra-joint (ie superior and inferior, medial and lateral, and anterior and posterior).

To improve musculoskeletal alignment [Chapters 1 – 7]

Work towards restoring and or developing normal:

- Joint structure
- Joint space
- Joint symmetry: both inter-joint, ie between right and left sides of the body; and intra-joint (ie superior and inferior, medial and lateral, and anterior and posterior).

Table 1.7 Treatment of chronic injuries with *hatha yoga* [Section 1.8.2]

FOR Chronic injuries	METHOD	
Improve Circulation	By using	
	1. Pranayama	= Breathing exercises [Section 1.0.4] ⇒ **Respiratory pump**
	2. Vinyasa	= Dynamic exercises ⇒ **Musculoskeletal pump** & **Centripetal pump** [Section 1.0.4]
	3. Viparita karani	= Inverted postures ⇒ **Gravitational pump** [Section 1.0.4]
	4. Asanas	= Static postures ⇒ **Postural pump** [Section 1.0.4]
	5. Bandhas	= co-activation of antagonistic (opposing) muscle groups around a joint complex ⇒ **Muscle co-activation pump** [Section 1.0.4]
Improve Strength	By focusing on	
	1. Control	to be able to voluntarily activate or relax any muscle to a desired amount
	2. Balance	symmetry & co-activation
	3. Specificity	functional task specificity
Improve Flexibility	By focusing on	
	1. Mobility	of joints, muscles, nerves etc.
	2. Symmetry	equal flexibility on both sides of the body
Improve Alignment	By focusing on	
	1. Structure	of each joint
	2. Space	within each joint
	3. Symmetry	between both sides of a joint & both sides of the body

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