UPM Inaugural Lecture Series

THE WONDER OF OUR NEUROMOTOR SYSTEM AND THE TECHNOLOGICAL CHALLENGES THEY POSE

Abdul Hamid Abdul Rashid

UPM
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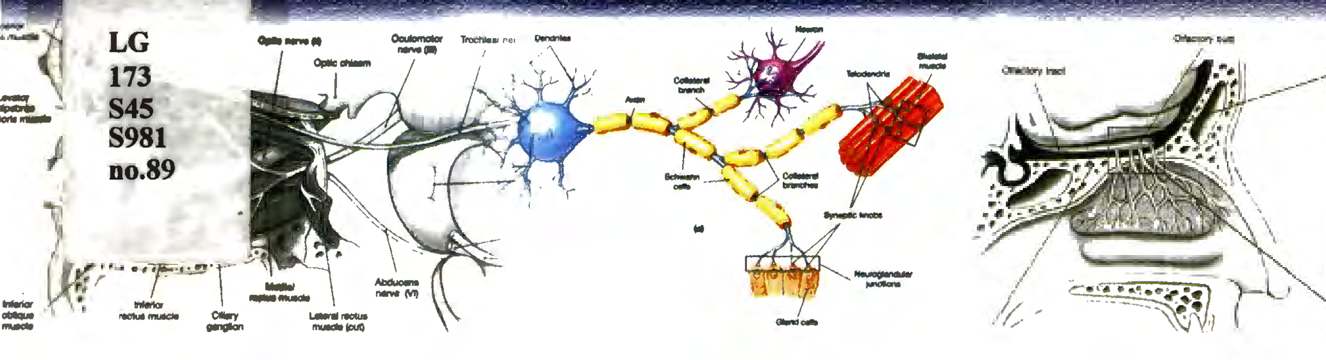

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PROF. DR. ABDUL HAMID ABDUL RASHID

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ABDUL HAMID ABDUL RASHID

Abdul Hamid Bin Abdul Rashid originated from Myanmar (Burma). His early education began at various schools as his father was a civil servant. After he lost his mother, he stayed with his paternal grandmother in a small coastal town called *Than-dwe*, where he completed his primary education. After his grandmother's death, he was sent to St. Albert's Residential Boys' School in a town called *May Myo*, a hill-station in northern part of Myanmar where he completed his secondary education. He was fortunate to be among the top hundred positions out of over one hundred thousand candidates who sat for the National Matriculation. He was awarded a full government scholarship to pursue his tertiary education. He graduated with his Bachelor of Medicine and Bachelor of Surgery in 1968 from the University of Rangoon.

After graduation, he served as a houseman at the General Hospital, Rangoon before he began his career as an Assistant Lecturer at the Department of Anatomy, Faculty of Medicine, University of Rangoon. In 1971, he married Khatiza Haida Ali, a fellow classmate in Standard One, whom he met again at the medical school after many years of separation.

Abdul Hamid joined as a Lecturer in the Department of Anatomy, Faculty of Medicine, *Universiti Kebangsaan Malaysia (UKM)* in March 1976. He started teaching the third batch of UKM medical students. A year later, he registered at the National University of Singapore (NUS) as an external postgraduate candidate for a Master degree in Anatomy. His Master thesis was later converted to a doctoral thesis and he succeeded in obtaining his Doctor of Medicine (Anatomy) in 1981. He was the first external doctoral candidate since University of Malaya in Singapore became NUS.

Later the same year, Abdul Hamid was promoted to Associate Professor and finally to Professor in 1992. He was not only involved in teaching medical students, but also the dental, nursing and paramedical students. He was one of the pioneers in setting the Basic Medical Sciences courses for postgraduate clinical sub-specialities programmes and later, was appointed as the person in-charge of the course until he left UKM in September, 2004. He is fortunate enough to have been involved in teaching around 4000 medical doctors, over 500 clinical specialists and many hundreds of paramedical graduates in Malaysia. He has always extended his voluntary service in the development of new medical faculties in Malaysia and also helped teach in the early stages of development to alleviate the problem of staff shortage. This included voluntary teaching of Anatomy to the first and second batches of medical students, UPM. His dedication as a lecturer consequently led to his being awarded "Best Lecturer" numerous times, and he received the *Anugerah Khas* (1993) and *Sijil Penghargaan Anugerah Pengajar* (1999) at UKM.

Abdul Hamid was also involved in administration, was a member of many committees and the UKM Senate as well as appointed as Head of Anatomy Department, UKM twice, a total of over 12 years. His initiative and efforts resulted in the setting up of the High-tech research Laboratory, Human Anatomy museum, Plastination Laboratory and the Semen Analysis Laboratory in the Anatomy department, UKM.

Abdul Hamid is also actively involved in research, publications and presentations and was awarded grants from UKM and IRPA. He was also fortunate to have supervised numerous Masters and PhD research theses. Most of all, he is very much grateful to *Allah s.w.t.* for allowing him to produce three text books of Anatomy, which were written in *Bahasa Melayu*, published by *Dewan Bahasa dan Pustaka* in 1991, 1992 and 1994 where all the diagrams in the books were drawn by him.

Abdul Hamid was also privileged to have been invited as a speaker and an external examiner by various universities locally and overseas. He is also a member of the Anatomical Society of Great Britain and Ireland, American Association of Clinical Anatomists (AACA), Electron Microscopic Association of Malaysia and Malaysian Medical Association. He is very much interested in drawing and is currently involved in preparing a 3-D computer aided teaching of Anatomy.

Abdul Hamid and his wife, Khatiza, also a lecturer in UPM have two daughters, Fatima and Zabeda; whom like their parents are both in academia, attached to the International Islamic University Malaysia (IIUM).

THE WONDER OF OUR NEUROMOTOR SYSTEM AND THE TECHNOLOGICAL CHALLENGES THEY POSE

ABSTRACT

As we go along in life, we perceive many types of sensation both from inside our body and from the environment. Perception leads to decision, including how to react. This leads to purpose or objective, and actual physical deed is done by movement of particular parts of our body. This is the action; which may be accomplished in accordance to our will or performed automatically, by reflex. Movements range from very fine and precise, such as those performed by fingers and eye rotating muscles, to the very powerful and deliberate such as those done by the leg muscles. The work of muscles has three main aspects: direction and range of movement; strength required; and speed at which movement is done. All these are controlled by the nervous system. Nervous system together with the muscular system is called neuromotor system. It is in fact the most complex and most intricate system in our body and made up of billions of nerve cells called neurons. In order to perform a specific task, a specific group of muscles and type of muscle fibres controlled by a specific component of the nervous system is needed. This has been confirmed by the author and his co-researchers from their studies on neuromotor system.

Any structure of our body can be damaged by any cause. Some damaged structures regenerate by themselves. However, the nervous tissue once formed will never regenerate when destroyed. Accordingly, as a therapeutic measure, Stem cells or olfactory mucosa from the nose are transplanted into the damaged area of the nervous system; so that they can grow and replace the damaged nervous tissue. Until the last few decades or so, this has been one of the most widely accepted facts of Medicine. Although there is some degree of regaining function in patients with injury or derangement of nervous system, complete restoration of functional status as normal has not been achieved. There can be many reasons for such outcome. One of the reasons is, as mentioned above, highly specific and complex neuromotor system is needed to perform a specific muscle function. Such a complex system is after all created by none other than the Almighty. With present day technology, are we ready to fully accomplish what our Creator created?

INTRODUCTION

As "Superman", Christopher Reeve can fly into outer space with supersonic speed and smash approaching meteorites into many tiny pieces. He can lift a derailed locomotive with one hand and run faster than a speeding bullet. But suddenly in real life, he fell into a condition where he could not even stand on his feet nor lift his little finger. What went wrong with Superman?

Stephen Hawking, the world-renowned theoretical cosmologist, one of the greatest surviving intellectuals and Professor of Mathematics at University of Cambridge, has humble ambitions to "unlock the beginning of time". Perhaps his most impressive feat was writing the international bestsellers *A Brief History of Time, Black Holes and Baby Universe, Universe in a Nutshell* and recently, *A Briefer History of Time.* Unfortunately, he cannot move parts of his body as he wishes to, and has to speak through a computerized voice box. What went wrong with Hawking?

The greatest sports personality of the 20th century, Muhammad Ali, with his physical prowess and powerful punches seizing the heavyweight boxing gold medal in the Olympic, had knocked out some of the greatest boxers of all time: Sonny Liston the bear, Joe Frazier in 'the thrilla in Manila' and George Foreman in 'the rumble in the jungle'. Ali who floats like a butterfly and stings like a bee today is suffering from extreme slowness in movement, and is unable to control the fine tremors of his hands. What went wrong with "the greatest"?

As we go along in life, we perceive innumerable things such as sight, sound, smell, taste, touch, pain, temperature and vibration through the organs of sense. Perception leads to decisions, including how to react or what to do about the perceived object. This leads to purpose or objective. The actual physical deed is done by movement (motion) of particular parts of the body. This is the action. Action may be *voluntary* (i.e. accomplished in accordance to will) or *involuntary* (i.e. performed automatically, independent of the will). Enjoyment of pleasantness, avoidance of unpleasantness, or preservation of life are the usual objectives which lead to action. By these actions we can do what our mind dictates, and ensure our survival. But to achieve these actions require coordinated activities with participation of many parts and systems in our body. However, one is usually not aware of what it takes to carry out these normal bodily activities and functions, until it does not perform well anymore.

Any part or structure of our body can be damaged by trauma, disease, degeneration or even genetic determination. Some damaged parts regenerate by themselves or can be repaired; some can even be replaced. There are other parts which do not regenerate, cannot be repaired or replaced until lately. Bones can be set to heal, joints can be replaced, skin can be grafted, heart, liver, kidney, blood vessel and muscle tendon can be transplanted. But once nervous tissue is disrupted, it is considered to be as shattered as a broken crystal; and those unlucky victims of such injuries are hopelessly immobilized permanently. Until the last decade or so, this has been one of the most widely accepted facts of Medicine. New technologies have attempted to correct the abnormalities in neuromotor system, with variable degrees of success so far. This presentation will try and explain the possible reasons why this is so. Accordingly, it will consist of:

a) The activities and capabilities of particular structures, organs or parts of the body;
b) Their anatomical setup and control of activities;
c) Possible causes of abnormalities and their clinical consequences, and
d) Current methods of correction of the abnormalities, and discussions on their possible effectiveness.

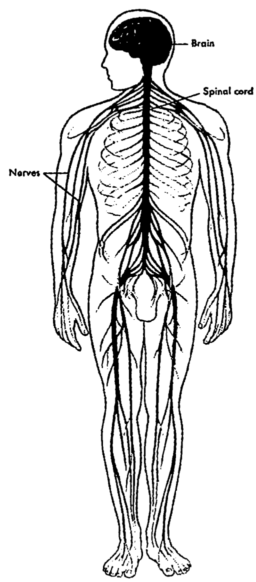

Figure 1.

Which system controls the movements of our body?

The movements of our body are effected by muscular activities, and the latter are controlled by the nervous system (NS) (Fig. 1). The nervous system is the body's control centre and communication network. Firstly, it senses changes within the body and in the outside environments; this is sensory function. Secondly, it interprets the changes; this is its integrative function. Thirdly, it responds to the interpretation by initiating action in the form of muscular contractions or glandular secretions; this is its motor function.

The nervous system consists of two main components; they are: central nervous system (CNS) and peripheral nervous system (PNS). The central nervous system comprises of brain and spinal cord, while the peripheral nervous system is composed of cranial nerves, spinal nerves and ganglia. Both systems are made up of nerve cells, *"neurons"* and the supporting cells, *"neuroglia"*. The human central nervous system contains about 100 billion neurons and it also contains 10-15 times this number of neuroglia. The neurons are specialized for the reception, integration and transmission of impulses. The activities of the NS may be voluntary or involuntary.

Neuron, Nerve Fibre and Nerve

Each neuron has a *cell body* and has one or more processes (Fig. 2). A single, longest process is the *axon*, which conducts impulses (electrical signals) away from the cell body. The short processes, if present, are *dendrites*; they convey incoming messages (electrical signals) towards the cell body. The neurons are linked to one another in a highly intricate manner. It is through these connections that the body is made aware of changes in the environment, or of those within itself; and appropriate responses to such changes are made and implemented.

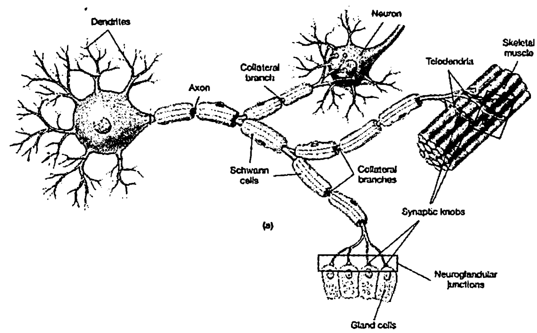

Figure 2. Neuron

Each axon is a *nerve fibre*. Most long nerve fibres are covered with a whitish, protein-lipid complex called *myelin*. Myelin protects and insulates the nerve fibre and increases the transmission rate of nerve impulses. Myelinated nerve fibres are found in both central and peripheral nervous systems. However, not all the nerve fibres are myelinated; some are unmyelinated. According to the diameter size, nerve fibres are classified into three main fibre types: **A, B** and **C**; type **A** fibres are subdivided into α, β, γ and δ. The larger the diameter of the nerve fibre, the faster the conduction velocity is. Fibre type **A** a is largest in diameter and thus it is fastest in conduction velocity. **A** and **B** fibres are myelinated; **C** fibres are unmyelinated (Table 1).

Table 1: Nerve fibres type

Fiber Type	Function	Fiber Diameter (mm)	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
A				0.4–0.5	0.4–1
α	Proprioception; somatic motor	12–20	70–120		
β	Touch, pressure, motor	5–12	30–70		
γ	Motor to muscle spindles	3–6	15–30		
δ	Pain, cold, touch	2–5	12–30		
B	Preganglionic autonomic	<3	3–15	1.2	1.2
C					
Dorsal root	Pain, temperature, some mechanoreception, reflex responses	0.4–1.2	0.5–2	2	2
Sympathetic	Postganglionic sympathetics	0.3–1.3	0.7–2.3	2	2

[1]A and B fibers are myelinated; C fibers are unmyelinated.

Some nerve fibres carry impulses from the spinal cord or brain to peripheral structures like muscles or glands; they are called *efferent* or *motor* fibres and their neurons are *motoneurons*. Other nerve fibres carry impulses from periphery to the brain or spinal cord; they are called *afferent* or *sensory* fibres and their neurons are *sensory neurons*.

Each nerve is made up of a bundle of parallel nerve fibres wrapped around with fibrous tissue. A nerve may therefore consist of many types of nerve fibres: motor, sensory and autonomic. The more the number of nerve fibres, the better the nerve-muscle ratio and more precise is the action.

The Lower and Upper Motoneurons

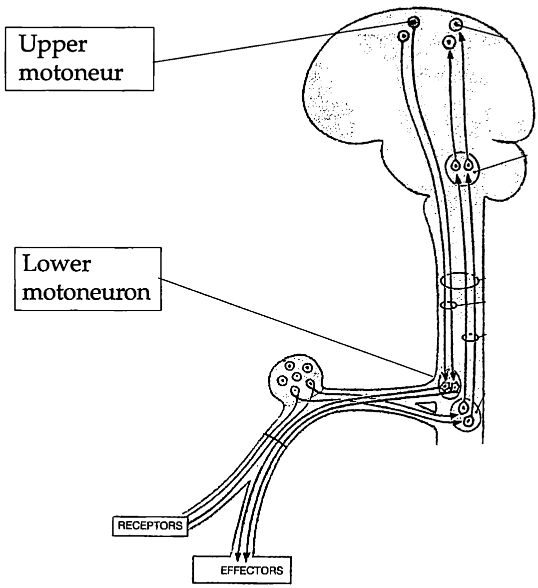

Figure 3. Upper and lower motoneurons

The motoneurons with the cell bodies in the spinal cord or brain stem are the *lower motoneurons (LMN)*. Their axons form the peripheral nerves and supply the muscles and glands. The LMNs are again controlled by another set of neurons whose cell bodies are located in the cortical layer of the brain; they are *upper motoneurons (UMN)* (Figure 3). The area of cerebral cortex concerned with a body region is related to the functional skill and innervation density rather than to the size of the body region. Thus, cortical areas representing the mouth, face, eye and hand, especially the thumb are disproportionately large (Figure 4). This indicates that the activities and complexity of these regions in our body are much more extensive indeed.

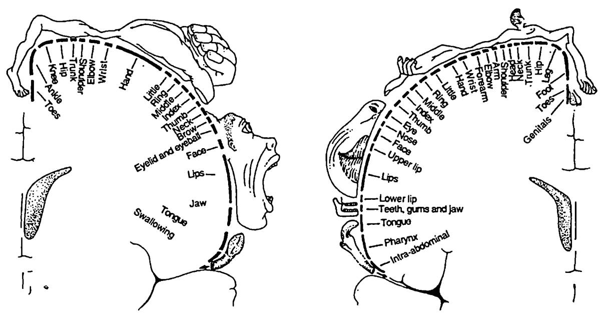

Fig. 4. Motor and sensory homunculi showing proportional somatotopic representation in the cortex of the brain.

Conduction of impulses along the nerve is *electrical*; however, at the junction between the neurons or between neurons and muscle fibres, it is *chemical* in nature by means of neurotransmitters; eg. acetylcholine.

EFFECTER ORGANS

The effecter organs for the *movements* in our body ultimately are muscles. There are three main types of muscles: *cardiac muscle* which forms the heart and some great blood vessels; *smooth muscle* which forms blood vessels, gastrointestinal tract, respiratory system and urinary system; and *skeletal muscle* which are attached to the skeleton for movements of the body. The first two are involuntary and the last is voluntary.

Skeletal Muscle

Skeletal muscles consist of bundles of muscle fibres. Each muscle fibre is a muscle cell and multinucleated. Under light microscope skeletal muscle fibres reveal striations and thus they are also known as striated muscles. They range from 5 to 100μ m in diameter and vary greatly in length, from 1 or 2 mm up to several centimetres, often spanning the entire length of the muscle.

Skeletal Muscle Fibres

Mammalian skeletal muscle fibres are composed of a succession of sacromeric units containing thick and thin filaments of myosin and actin respectively. Excitation of the myosin ATPase enzyme which is responsible for contraction is possible only with the presence of Mg-ATP and Ca^{2+}.

Although skeletal muscle fibres resemble one another in a general way, skeletal muscle is a very heterogenous tissue made up of fibres that vary in myosin ATPase activity, contractile speed, and other properties. The fibres fall roughly into two types, type I and type II, although each of these types is itself a spectrum. The properties of type I and type II fibres are summarized in Table 2.

Table 2: Properties of muscle fibrea

	Type I	Type II
Other names	Slow; oxidative; red	Fast; glycolytic; white
Myosin isoenzyme ATPase rate	Slow	Fast
Ca^{2+}-pumping capacity of sarcoplasmic reticulum	Moderate	High
Diameter	Moderate	Large
Glycolytic capacity	Moderate	High
Oxidative capacity (correlates with content of mitochondria, capillary density, myoglobin content)	High	Low

[1]Modified from Murphy RA: Muscle. In: *Physiology*, 2nd ed. Berne RM, Levy MN (editors). Mosby, 1988.

Motor Unit

Sherrington (1894) established that one motor unit is one -motoneuron attached to a group of skeletal muscle fibres. Therefore, a motor unit consists of one -motoneuron, its axon and a group of muscle fibres innervated by it. Each -motoneuron connects a group of muscle fibres to the central nervous system, and the motor unit acts as a functional unit in programmed movement and motor control. Motor units vary in size in two aspects: total number of muscle fibres and cross-sectional diameter of the individual muscle fibres.

The Characteristics of Motor Unit

They include:

- The number of muscle fibres in the unit;
- The size of the muscle fibres in the unit;
- The motor unit territory (the area and position the motor unit occupies relative to the total muscle);
- The force produced by motor unit contraction; and
- The speed of shortening of the motor fibres of the motor unit.

Muscles that require fine, precise motor control usually have many motor units with small number of muscle fibres in each unit. On the other hand, muscle that require coarse motor control have lesser number of motor units with large number of muscle fibres in each unit. The motor unit is subject to age-dependent, degenerative changes during the lifespan of an individual (Luff, 1998).

What are the Causes of Derangements in the Nervous System?

Common causes of derangements in the nervous system include: trauma, cerebrovascular diseases, motoneuron diseases, Parkinson's and Alzheimer diseases and infections.

Trauma. The most common cause of nervous system injury in the world today is motor vehicle accidents in which the vertebral column is damaged; the spinal cord is likely to be crushed, partially cut or totally transacted. This results in partial to complete paralysis of the body below the lesion.

In the case of Christopher Reeve, as the result of trauma from a riding accident a 20 millimetre separation occurred in the nerves that ran up his spine, and which command his movements entirely, as he dictates. It was like a broken electric cable with signals buzzing on one side and motors on the other side not able to receive those control signals. The gap at the break was less than an inch, but like the telephone cable that has been cut by a shovel, even a hair's width breakage means silence when there should be communication. Other than the spinal cord injury, individual nerves in our body can be damaged due to trauma. Example: lesion of common peroneal nerve, the commonest nerve to sustain injury in the lower limb, leads to *footdrop.*

Cerebrovascular diseases include cerebral haemorrhage and cerebral infarct; the layman's term for it is stroke. Stroke is the third leading cause of death and the most common cause of adult disability. About 30% die and 20-30% become severely and permanently disabled. The total cost for caring of all aspects of stroke is $41.9 billion annually in the United States.

Motoneuron diseases (MND) is the name given to a group of related diseases affecting the motoneuron in the brain and spinal cord. The prevalence of the disease is about 5 in 100,000. MND does not affect sensory function or sexual function; and in a majority, the intellect remains unaffected.

In the case of Professor Stephen Hawking, he has motoneuron disease (MND) also known as *amyotrophic lateral sclerosis (ALS)*. It is a progressive and degenerating nerve disease; that is, the nerves of his body are deteriorating due to an unknown cause and cannot relay the commands given by his brain. Thus, it primarily affects the motor function and has today rendered him incapable of much independent movement. His sensory and sexual functions are intact and thus he remarried his nurse who takes care of him.

Parkinson's disease refers to a group of degenerative diseases affecting the basal ganglia in the brain which co-ordinate the actions of muscles for smooth physical movements. There are degenerative changes and in particular, depletion of the pigmented dopaminergic neurons in the basal ganglia with reduction in dopamine output. This disease presents with slowness of movement, increased muscle tone, tremor and loss of postural reflexes. Muhammad Ali is an example of one who suffers from Parkinson's disease.

Alzheimer's disease is the most common cause of mental disorder involving impairment of memory. Macroscopically, the brain is small (atrophic). Histology reveals the presence of senile plaques and neurofibrillary tangles in the cerebral cortex.

Is there a cure for neuronal disorders?

In short, the answer is "Yes" eventually!
Christopher Reeve had contributed millions of dollars to the International Spinal Cord Regeneration Centre (ISCRC) and many more research centres around the world to develop treatments for neuronal disorders, especially for the spinal cord injury which he suffered. However, there are many factors involved in the achievement of successful recovery. Unfortunately, Christopher's unshakable confidence had not materialized and he succumbed to his injury before the discovery of the right treatment.

What are the main issues of the treatment?

There are three main issues to facilitate functional restoration in neuronal damage; they include: replacement of damaged neurons; remyelination of demyelinated axons and inducing severed axons to regenerate.

Being nerve cells, which have lost the ability to undergo cell division, neurons do not regenerate once it is formed. The latest effort made in the treatment for neuronal damage is therefore, replacement of damaged neurons, which requires transplantation of exogenous neurons. Re-myelination can also be achieved by transplantation of precursors of supporting cells. This leads to a new frontier in medical research today, hunting for the most suitable and effective replacement for damaged neurons.

What replacement for damaged neuron?

Many researches and proposals have been made on the replacement of damaged neurons in the last few decades. Scientists have been able to produce nerve cells in the laboratory by using Stem cells drawn from bone marrow, umbilical cord blood, or from teratoma, a reproductive tumor. This forms a breakthrough that could help people with neurological disorders. Foetal cells before 15 weeks of intrauterine life lack sufficient antigenic expression and provide excellent material for transplantation of foetal neuronal cells/tissues/organs. Even so, embryonic cells rather than foetal cells are utilized because they are not rejected by the host. The blue shark embryo is also chosen because it has a compatible immune system and its gestation period is nine months, similar to humans.

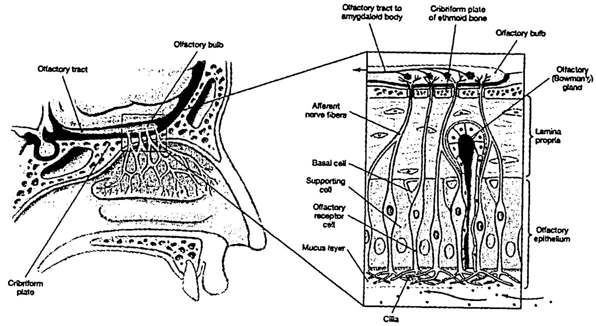

Fig. 5. Olfactory tissue's base from the upper part of the nasal cavity.

Lately, the source of these neurons constitutes a pool of progenitor stem cells that reside at the olfactory tissue's base, from the upper part of the nasal cavity (Fig. 5). They are found to have unique characteristics and possess extraordinary regenerative potential, which many scientists believe can be exploited to restore function after neuronal injury. Moreover, if the patient himself is the source of transplantation material (i.e., autologus grafting), immunosuppressive drugs would not be needed to minimize tissue rejection. Patient's tissue can be obtained by a simple biopsy through the nostril.

Is neuronal transplant effective?

A wide variety of reports have been made on neuronal transplants. Transplantation procedures and techniques vary from patient to patient, between types and degrees of diseases and injuries, and from treatment centre to centre.

The Neurosurgery Department of University of Pittsburgh reported that their stroke patients were able to walk and use their hands after an injection of between 2 million and 6 million nerve cells into the affected area in the brain. They claimed that an injection of six million cells showed even much more improvement. It was also noted by other researchers that the speed of recovery also depends on the spinal level of the injury (i.e., injury at the higher level of the spinal cord has a longer period of recovery than that at the lower level), and how frequently the patient comes in for cell injection therapy.

However, some argued that though there is some degree of success in patients with Parkinson's disease after neuronal transplant, there is no reported improvements in patients' "functional status" after cell transplant. Many are also in doubt that the injected cells will function normally. Another possible danger is that these injected cells may divide further and multiply producing new tissue and tumor; this eventuality could be difficult to control.

Nevertheless, neurologists around the world feel that the results are exciting, and provide some light at the end of the tunnel for patients with neurological disorders. But they also realize that there is so much that is still unknown. They do not yet know who would be the most suitable patient, how many neurons should be used for transplant, what types and size of neurons and their proportion should be injected, and exactly where these neurons should be put, or even what outcome to expect.

Actually, in our body, different groups of muscles undertake different types of functions and they are controlled by nerves made up of various fibre types and their motoneurons which act accordingly. In replacing a neuronal system for each group of muscle, only the neurons which posses very specific activity would function precisely. The author's research works with co-researchers on various aspects of motoneurons acting on various groups of muscles in our body clearly show their wide variations in morphology, activity, sensivity and functional aspects. How could we expect paralysed muscles of one specialized group to recover completely by transplanting just any type of motoneurons?

As an illustration, we are presenting the motoneurons and characteristic features of six specialized groups of muscles in our body. These include: the muscles of the lower limb, muscles of the hand and the thumb, muscles of the perineal region, muscles of the face, chewing (masticating) muscles and muscles which move the eyeballs. The results of our studies serve as further evidence of the need for transplanting with specific motoneurons to achieve complete recovery.

MUSCLES OF THE LEG

An upright posture and bipedal mode of locomotion are the unique features that distinguish human beings from other primates. While the erect posture allows the upper limb to be devoted to manipulative functions, it has left the lower limbs to serve for support, balance and locomotor functions.

The weight of the body is transmitted to the lower limbs through the pelvis. This has brought about several specializations in the architecture of the bones, joints and muscles of the spine, pelvis and the lower limbs. Skeletal frameworks and the muscles of the thigh are big and strong and their functions are more towards support rather than for locomotion. On the other hand, the skeletal framework and muscles of the leg and foot are specialized for locomotion in addition to their supporting functions.

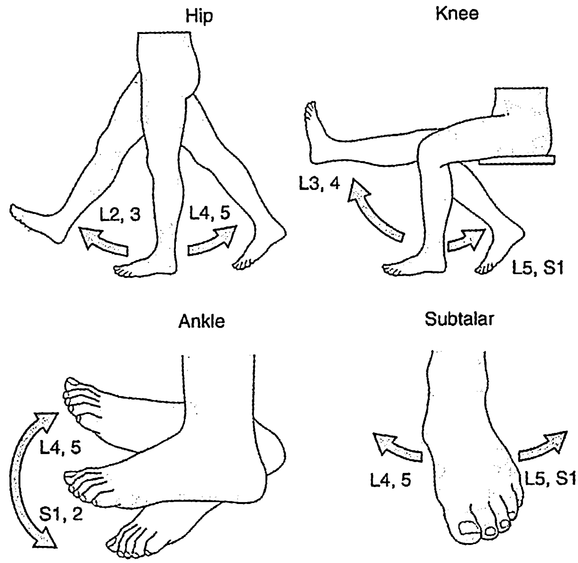

Fig. 6. Movements of the leg

Dorsiflexion and plantar flexion of the foot at the ankle joints, inversion and eversion of the foot (Fig. 6) at subtalar joints and flexion and extention of the toes at the metatarsophalangeal and interphalangeal joints allow the foot to accommodate to irregularities in terrain, gripping on slippery surfaces and efficiency in walking, running and jumping; in addition to even weight distribution and balance. The leg muscles are grouped into three: anterior (front), lateral (outside) and posterior (behind). The muscles of the anterior group are for dorsiflexion, of lateral group are for eversion and those of posterior group are for plantar flexion of the foot. Leg muscles perform not only power movements but also, to some extent, precision movements such as kicking the ball towards required distance and direction.

Innervation of the Leg Muscles

The muscles of the leg are supplied by two nerves, the tibial nerve and the common peroneal nerve, both of which are terminal branches of the sciatic nerve. The tibial nerve supplies the muscles of the posterior group of the leg while the common peroneal nerve supplies the muscles of the remaining two groups, anterior and lateral. Due to peculiar anatomical characteristic features, the common peroneal nerve is most vulnerable to injury among all the nerves of the lower limb because of its location and configuration.

Anatomy of the Common Peroneal Nerve

The common peroneal nerve is lateral of the two terminal branches of the sciatic nerve and it arises approximately at the middle to distal third of the back of the thigh. It curves around the neck of the fibular (Fig. 7) and is divided into two terminal branches, superficial peroneal and deep peroneal nerves. The former supplies the lateral group of muscles of the leg for eversion and the latter supplies the anterior group of muscles of the leg for dorsiflexion of the foot.

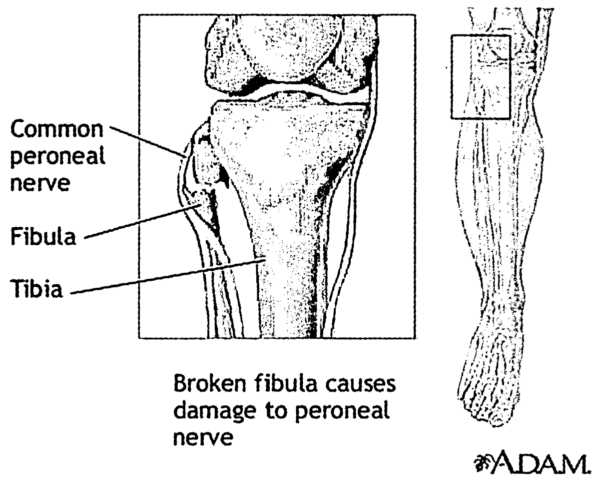

Fig. 7. Common peroneal nerve injury.

Motoneurons of the Common Peroneal Nerve

The author in collaborative work with Subramaniam and Hew (1985) has reported that the motoneurons of the common peroneal nerve were found in the ventro-lateral aspect of the anterior horn in the lumbar region of the spinal cord. Mean total number of motoneurons forming the common peroneal nerve was 1260.76, that for superficial peroneal nerve was 335.33, and deep peroneal nerve was 635.33. The motoneurons of the deep peroneal were much more in number than those of the superficial peroneal nerve because the former nerve supplies more muscles. The size of the motoneuroen cell bodies of the superficial peroneal nerve was smaller than that of the deep peroneal nerve; which suggests that the lateral group of muscles are more active and precise for eversion and external rotation of the foot, than the muscles of the anterior group of the leg which served for dorsiflexion and supplied by the deep peroneal nerve which is made up of neuronal cell of bigger sized.

Clinical Anatomy of the Common Peroneal Nerve

Where the common peroneal nerve curves around the neck of the fibular, it is not only securely fixed at this site but it is also angulated. In fact, at this site, the nerve is flattened and its constituent nerve bundles are separated so that the nutrient vessels are exposed and left unprotected. These anatomical features render the common peroneal nerve and its nutrient vessels particularly vulnerable to damage in injuries around the knee.

Causeses of Common Peroneal Nerve Lesion in Man

Lesions seen in other nerves such as those due to penetrating and lacerating injuries, pressure from tumours, neurilemmoma, and haematoma in nerve sheath are reported as also affecting the common peroneal nerve in man.

From the studies in 1980 and 1981, the author has listed several causes of damage to this nerve. These include motor vehicle accidents, sports injuries, dog bites, fracture of femur or tibia, condylar displacements, dislocations of the fibular head, bullet wounds, habitual crossing of leg and prolonged squatting, compression against the bed rail and obstetric table, pressure caused by tight bandages and plaster cast, vascular abnormalities and nerve entrapment by abnormal muscle.

Common peroneal nerve injury can affect gait in a condition often referred to as foot-drop. In foot drop, there is lagged swing to dorsiflex the foot, inability to evert the foot and rotate externally. Due to these defects, the patient has to make an excessively high step to clear the foot from the ground, and reach the dropped foot further forward to touch the ground with its heel as in normal gait; in what is called "high step and flop gait".

Daniel et. al. (2004) stated that surgical exploration and repair of peroneal nerve lesions achieved good results with timely operations and thorough intraoperative evaluations. The shorter the gap between the two ends of the sectioned nerve, the better the result. End -to-end suture repair has an 84% good recovery by 24 months. In graft repair, 75% achieved reasonably good success rate if graft is less than 6cm long but only 38% if the graft is 6-12 cm long. Longer grafts usually correlated with more severe injuries and thus poorer outcomes. However, it is impossible to achieve the precise movements back to normal level.

THE NIMBLE FINGERS OF THE HAND

Apart from the brain and neuromotor system for the movements of the eyes, perhaps no other control system in the human body has created as much interest as that of the hand. The hand is often seen as a symbol of power and precision, a reflection of emotions and extension of intellect, and an organ of sensory detection and discrimination. To function well, the hand needs the brain to guide and control it, but at the same time, the brain needs the hand to carry out its wishes and instructions. Civilization might have been designed by the brain but it was implemented by the hand. This interdependent relationship between the brain and the hand, and also coordination with movements of the eyes is of supreme importance. In fact, the area allocated in the brain for motor control of, and sensory feedback from the hand, is much larger than that of the entire lower limb.

Architecture of the Hand

Each hand, including the wrist is made up of 27 short bones with more than 30 small, but movable joints. They are moved by about 40 muscles, half of which extend from the forearm called the *extrinsic muscles* and the rest are located within the hand, called the *intrinsic muscles* of the hand. Under the innervations of three main nerves of the upper limb, the hand thus performs the widest varieties of movements and sensory detection in the human body.

Movements of the Hand

John Napier, an English physician in 1956, viewing the hand as a whole, categorized its movements into two basic categories: *prehensile* and *non-prehensile* movements.

a) Prehensile movements are those in which an object, fixed or free, is held by a gripping or pinching action between the digits and the palm. The prehensile movements are again subdivided into 3 types of grip: *power grip*, *hook grip* and *precision grip* (Fig.8).
   i. The power grip is that used for holding a tool or a weapon, for example a hammer. The fingers are flexed around the object, with counter pressure from the thumb. Movements comprise those of the whole hand and both intrinsic and extrinsic muscles are involved.
   ii. The hook grip is used to suspend or pull objects, as in carrying a suitcase. Generally, the fingers are used together and the thumb is not involved. Most important muscles involved are extrinsic muscles.
   iii. The precision grip is that used for holding a pen, pencil or small instruments. The object is gripped between the tips of the fingers (usually the index finger) and the thumb and the intrinsic muscles are involved.

b) Non-prehensile movements, on the other hand, include pushing, lifting, tapping and punching movements of the fingers, such as typewriting or playing musical instruments.

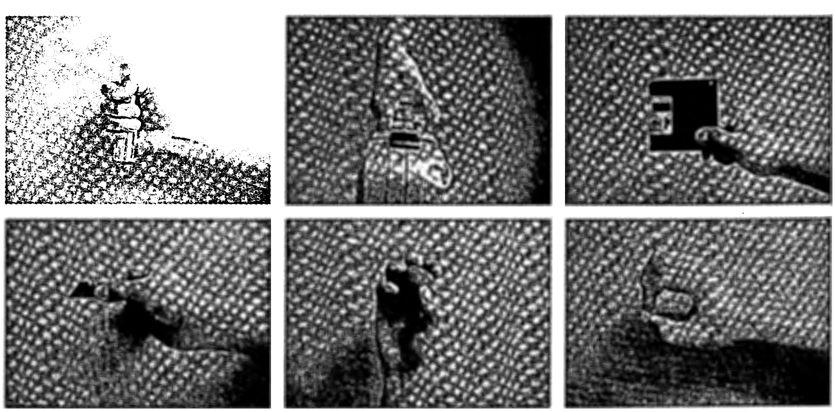

Fig. 8. Movements of the hand.

The Most Functional Movements and Important Digit of the Hand

The most functional and unique movement of the human hand is *opposition*. Opposition is movement by which the pulp surface of the thumb is placed squarely in contact with or diametrically opposite to the terminal pads of one or all of the remaining digits. The opposability of the thumb to the index finger is a particularly human trait and is, therefore, one of the 'hallmarks' of mankind. Without a thumb, the hand is put back sixty million years in evolution terms to a stage when the thumb had no independent movement and was just another digit.

In fact, it has been agreed that the evolution of human in the last century was based on the availability of the gadgets all around. True to it as one of the best examples is the invention of "remote control". Many functions, from locking and unlocking the car doors, switching on and off of TVs, videos, air conditioners and most commonly pressing the keys of the cellular phones can be done by just an opposition action of the thumb. Thus, in terms of a 'revolution in evolution' the human hand is second only to the human brain and the thumb becomes the most important digit in the hand.

The thumb consists of three bones: two phalanges and a metacarpal bone, with three movable joints. They are moved by a total of nine muscles, four extrinsic and five intrinsic muscles. The extrinsic muscles of the thumb are: flexor pollicis longus, abductor pollicis longus, extensor pollicis brevis and extensor pollicis longus. The intrinsic muscles of the thumb include: abductor pollicis brevis, flexor pollicis brevis, adductor pollicis, opponens pollicis and first palmar interosseous muscles.

Neuronal Control of Muscles of the Hand and the Thumb

The sensory and motor functions of the hand are controlled by three main nerves of the upper limb, namely: median nerve, ulnar nerve and radial nerve, which carry the nerve fibres from the lower cervical and upper thoracic region of the spinal cord.

All types of general sensations which include, pain, temperature, touch, pressure, vibration and two point discrimination of the hand are detected by various sensory receptors in the hand and carried through the nerves to the primary sensory area in postcentral gyrus of the contralateral side of the cerebral hemisphere. They are interpreted and conveyed to the primary motor area in precentral gyrus, which computes what type of movements should be undertaken and how much force is required, to instruct the motoneurones.

From the author's study in collaboration with a co-researcher, the lower motoneurons which innervate the intrinsic muscles of the thumb are found to be located in the retrodorsolateral nucleus in the anterior horn of the spinal cord extending from C7 to T1 segments. Some findings (Farihah & Hamid 1997) have revealed the various aspects of motoneurons of the intrinsic muscles of the thumb (Table 3).

It can be seen that the adductor policis muscle which is responsible for the adduction of the thumb is innervated by the highest number of motoneurons with the biggest size of the cell body, to produce slow but most powerful action of the thumb, the power grip. On the other hand, the opponens pollicis which is responsible for the opponent action, is innervated by motorneurons which have the smallest size of the cell body, and thus is active and precise in movements. These lower motoneurons are in turn controlled by the upper motoneurons.

Table 3. Number and diameter of the cell bodies of the motoneurons that innervate the intrinsic muscles of the thumb.

	Number of cells	**Diameter of Cell Body (mm)**
Abductor pollicis brevis	503.0 ± 121.4	34.7 ± 0.5
Flexor pollicis brevis	479.0 ± 64.9	34.9 ± 0.8
Opponens pollicis	340.0 ± 85.8	30.4 ± 1.0
Adductor pollicis	677.0 ± 132.9	37.0 ± 1.1

(Farihah & Hamid 1997)

Ehrsson et. al (2000) in their neuroimaging study of cerebral cortical activity in precision - versus power grip, found that the power grip was associated predominantely with contralateral sided activity, whereas the precision grip task involved extensive activities in both cerebral hemispheres. This indicates that in addition to primary motor cortex, premotor and parietal areas of the cerebral cortices are essential for the control of fingertip forces during precision grip. Moreover, the ipsilateral hemisphere also appears to be strongly engaged in the control of precision grip task.

How vulnerable is our hand to injury?

Report on injuries due to the industrial accidents in Malaysia, 2003, revealed that there were a total of 60,349 cases. The breakdown according to the localization of the injury is as follows:

Head	7,940	(3,791 of which were eye injuries)
Neck	165	
Trunk	5,250	
Upper limb	32,334	(18,495 of which were finger injuries)
Lower limb	14,660	(3,784 of which were hip injuries).

This indicates that finger injury is the highest among all the industrial injuries as the hand is involved in manual work.

Mechanically, the thumb is the only digit in the hand that has its freedom to rotate or swivel. It is also unique in that all of its movements can take place independent of those of any of the other fingers, as its plane of movements is at right angle to that of the others. Without the thumb, the most important movements of the hand, the power and precision grips are not possible. Hence, loss of the thumb or its functions would result in the greatest handicap, and the insurance compensation for it also is the highest compared to that for the other digits. The key to the thumb's uniqueness and utility lies in the metacarpal bone, carpometacarpal joint, its powerful but precisely acting intrinsic and extrinsic muscles, and its control by a large area of cerebral cortex.

Summary

Thus, it is evident that the hand is an amazing organ of versatility and dexterity. It detects various types of general sensations and also enable blind people to read brail; not only can it be used to grasp but it can also perform delicate maneuvers such as those performed by the skilled hands of a musician, surgeon or watchmaker. What will their lives be if their hands were functionless? Imagine how limited one's life would be without the use of one's hands. The thumb in particular has a wide variety of movements. The opposition of the thumb to the other fingers is one of the 'hallmarks' of mankind. Hands, especially the fingers are involved in daily work and thus exposed to the highest risk of injury.

Executing coarse and fine movements of the hand by synchronized contraction and relaxation of 40 long and short muscles, under the control of a complex higher neuronal centre from wide areas of both cerebral cortices for precise force and timing of the fingers and the thumb is complicated enough. Adding the functions of sensory detection and discrimination to it makes the neuromotor system of the hand much more complex, yet one is not aware what it takes for hands to function efficiently.

A robot of modern day can hold a crystal glass or an egg without slipping or crushing it. On the other hand, our human brain knows through vision, that the approaching object is an egg within a fraction of a second of seeing it thrown to us; decide what to do and instruct our body to swing towards it, and the muscles of our upper limb and hand to stretch out and catch it with precise pressure without dropping or crushing it. How can the human nervous system, muscular system and skeletal system coordinate to achieve this? Can this be done also by the most technologically advanced robot of the present day?

THE MECHANICS OF EJECULATION

Infertility and Sterility

What is infertility and sterility?
In medical studies and practice of human reproduction, infertility is usually defined as inability to conceive in a woman of reproductive age after one year of unprotected sexual relations. The term infertility is not the same as sterility, since many couples ultimately may conceive after one year. Sterility on the other hand is defined as: in female, inability to conceive and in male, failure to induce conception. It may be due to defect in either one or both partners.

It has been recorded that over 4.5 millions or roughly 15 – 20 % of couples in United States are infertile because they failed when attempting their first pregnancy in the first year. Though fertility is a major concern for every married couple, any sexual dysfunction can also cause considerable distress to men of all ages. Studies have estimated that over 50% of people with neuroendocrine disorders experienced some kind of sexual dysfunction, but approximately 25% expressed concern about their difficulty (Motofei & Rowland 2005). In a recent survey made by Ralph & Wylie (2005) on 12,815 men aged 50 - 80 years, 46% had an ejaculatory disturbance and 59% of them are highly concerned by it.

The sexual relationship usually culminates with two physiologically distinct events in male known as emission and ejaculation. Emission is the release of sperm and male accessory sex gland fluids into the urethra, while ejaculation is the forceful expulsion of the combined fluids (semen) from the urethra.

Mechanisms of Emission and Ejaculation

The mechanism of emission and ejaculation comprises two phases: the first is sympathetic nervous system-mediated emission of seminal fluid into the posterior urethra, followed by somatic nervous system mediated ejaculation with expulsion of the ejaculate. The reflex is initiated by stimulation of Krause-Finger sensory corpuscles in the glans penis, which is transmitted to the lumbosacral segments of the spinal cord. The impulses ascend along the spinal cord to the hypothalamus to the medial pre-optic area and paraventricular nuclei. Various neurotransmissions in the hypothalamus are responsible for seminal emission.

The efferent (outgoing) pathway of the reflex, responsible for emission, consists of sympathetic efferent fibres (T10 - L2) which cause sequential contraction of the epididymis, vas deferens, seminal vesicle and prostate, with closure of the bladder neck. Once semen arrives at the urethra of bulb of penis, true ejaculation, the second phase is then initiated from the sacral segments (S2 - S4) of the spinal cord via pudendal nerve, causing rhythmic contractions of the perineal muscles, especially bulbospongiosus muscle (Fig. 9). Strong contraction of the bulbospongiosus muscle takes place and compresses the bulbous urethra to expel its contents. Apart from neuronal control, the hormonal influence also plays an important role in it.

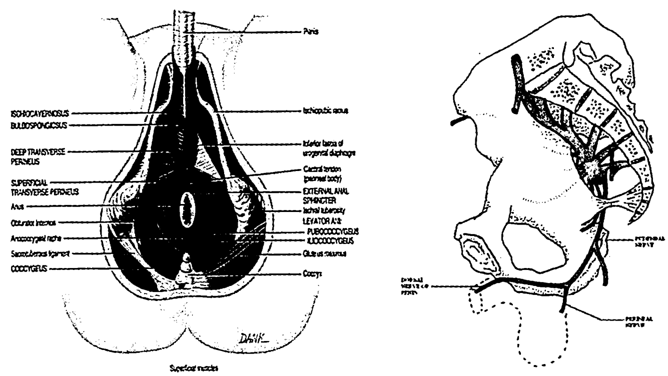

Fig. 9. Perineal muscles and pudendal nerve.

Sexual Dysfunctions in Male in Relation to Phases of Sexual Response Cycle

The sexual response cycle can be divided into three phases; they are: *desire, excitement* and *orgasm phases*. In men, the commonest dysfunction in the excitement phase is *erectile dysfunction* and in the orgasm phase is the *ejaculatory disorders*.

Erectile dysfunction (ED) is the consistent inability to attain and maintain an erection adequate for sexual intercourse. The term impotence implies penile failure or penile unreliability and thus the responsibility is not of the person. The ejaculatory disorders include premature ejaculation, deficient (delayed ejaculation and anejaculation / absence of ejaculation) and retrograde ejaculation (Ralph and Wylie, 2005).

It has been well documented that multiple sclerosis (partial demyelination of white matter of the central nervous system), diabetes neuropathy and derangements of gonadal hormones are among the main causes of sexual dysfunctions. Many ejaculatory disorders could be due to incoordinated action of the sympathetic and parasympathetic nervous activities on male reproductive organs. As a result, the contraction of the vas and accessory sex glands are not synchronized with the contraction of the perineal muscles, especially bulbospongiosus, which expels out the semen in the final phase of ejaculation. Therefore, an efficiency of timing and force in contraction of the bulbospongiosus muscle is essential and plays a key role in proper ejaculation.

What are the peculiarities of the perineal muscles especially the bulbospongiosus?

The perineal muscles including bulbospongiosus are skeletal muscles and they are supplied by the somatic nervous system. However, they, especially bulbospongiosus muscle differs from the other skeletal muscles in that it is mainly made up of fast acting type II muscle fibres. Moreover, the perineal muscles reduced in weight by 40 – 50% after castration and such change was prevented by administration of testosterone. If the perineal muscles are deprived from exposure to the male hormone during perinatal life (period between shortly before and after birth), their development and the functions are disrupted in adulthood. Because of this, the perineal muscles, including the bulbospongiosus muscle are considered as sexually dimorphic muscles.

Which neuroral system control the perineal muscles?

The perineal muscles are controlled by the somatic nervous system from a nucleus called Onuf's nucleus. This nucleus is located in the sacral segments of the spinal cord; its axons form the pudendal nerve which supplies the perineal muscles involved in copulation (Forger & Breedlove 1986). The following are findings on various aspects of motoneurons from the author's collaborative study with a co-researcher.

The Onuf's nucleus is cytoarchitectonically subdivided into subnuclei and each subnucleus is responsible for each perineal muscle. Table 4 shows various aspects of motoneurons of the pudendal nerve and the neurons of the Onuf's nucleus which supply two most important perineal muscles, the ischiocavanosus and bulbospongiosus muscles.

Motoneurons which supply the ischiocavernosus and bulbospongiosus are not significantly different in number. However, motoneurons of the bulbospongiosus are much smaller than those of ischiocavernosus; thus, the former group of motoneurons are more active, fast and precise in action. Both groups of motoneurons however, reduced in size after castration. It shows that they are sensitive to and dependent on the male hormone to achieve the effective function involved in copulation (Forger & Breedlove 1986).

Table: 4 Number and diameter of the cell bodies of the motoneurons of the pudendal nerve and those innervating the ischiocavernosus and bulbospongiosus muscles in normal and after castration.

	Number of cells	Diameter of Cell Body		%Reduced
		In normal	After castration	
Pudendal Nerve	457.75 ± 119.65	36.5 ± 6.75	-	-
Ischiocavernosus muscle	133.0 ± 52.69	37.05 ± 2.09	33.75 ± 0.43	8.8 %
Bulbospongiosus muscle	124.75 ± 58.94	31.53 ± 1.59	28.81 ± 0.41	8.62%

(Zainal A.M. 1995)

Freeman & Breedlove (1995) have reported that the male hormone also influences the size of motoneuronal body (soma) which is larger in males. The latter decreases with castration which can be reversed by replacement of testosterone (Yang et.al. 2004). In fact, Fishman et. al (1990) reported earlier that for proper development of the perineal muscles in male which are responsible for effective ejaculation, they need to be exposed to androgen during perinatal life. Forger & Breedlove (1986) have also identified a sex difference in human Onuf's nucleus known to be involved in copulatory behavior.

Androgen levels in Relation to Age and other Parameters

The autonomic nervous system and gonadal hormones play the main role in reproductive activities. Normally, plasma androgen (male hormone) level did not change significantly between 20-56 year of age (Hamid et.al. 1998). However, in the later years some decline in male hormone level is seen.

In fact, the author, in association with other researchers, has made extensive studies on various aspects of androgen. These include: activity of androgen (male hormone, testosterone) on drug effects (Nwe et.al. 1998a, 1998b); in stress (Nwe et.al. 1998, 2000b); in adrenal insufficiency (Nwe et.al 1999); in functional disorders of testis and liver (Nwe et.al 2000a); and on enzyme activities (Norhazlina 2000, Nwe et.al. 2000c). Moreover, potent effects of natural herbal products on plasma testosterone levels have also been studied in collaberation with Damayanthi et.al (2000), Norhazlina et.al (2000) and Nuraliza et.al. (2001). Finally, testosterone in relation to male accessory sex organs, testicular enzyme activities and spermatogenesis have also been studied (Hamid et.al. 2003; Hassan et.al. 2003; 2004, and Hassan 2005).

Summary

Therefore, the above has revealed that, in male, erectile dysfunction and ejaculatory dysfunction are some of the causes of infertility and sterility. Both erectile and ejaculatory dysfunctions are also due to some derangement in perineal muscles, especially bulbospongiosus muscle and their neuronal control system from the Onuf's nucleus. In fact, Onuf's nucleus does not act as an ordinary somatic nervous system, supplying the ordinary skeletal muscles. This nucleus and the perineal muscles it supplies are of a very special type which requires exposure to androgen during perinatal life to develop and function properly in the adulthood.

Moreover, the process of emission and ejaculation is controlled by a complex, highly organized and sophisticated neuroendocrine system consisting of gonadal hormones and autonomic and somatic components of the nervous system working in coordinated sequence. In short, precise and effective function of the perineal muscles for proper ejaculation would not be achieved if male hormone-dependent neurons of Onuf's nucleus were injured and were be replaced with ordinary motoneurons.

THE FACIAL EXPRESSION

Have you ever noticed when you meet a friend, talk to a person, watch a speech being given, or listen to your lecturer in a classroom, most of the time you are looking at their faces? Or the way that you can always tell when two people are in love or in disagreement by the way they stare into each other's eyes and by the expressions shown on their faces. What does it mean?

Fig. 10. Facial expression.

Emotion

All of these are due to the incredible power of the face to express emotion, and the social rules that govern emotional expression. Facial expressions are universal to all humans. In fact, the face is an important means of communication. In addition to identifying a person by looking at his/her face, we can see something of each other's thoughts and feelings in eyes, brow, mouth, jaw and so forth. Also, posture, hand gestures, and certain styles of movements or stillness can convey something of a person's state of mind. A facial expression may even communicate a whole message without a word being spoken, and send most "rapid signal" immediately after the emotion is felt.

Although the facial expressions correspond to the same emotions in people all over the world, different things cause different emotions in each individual. These differences are especially significant across cultures, as the things that surprise, disgust and anger people vary. Display rules also play a role in altering how facial expressions are interpreted, across cultures. For these reasons, the facial expressions are of interest to psychiatrists who have made a lot of progress in understanding and interpreting how they are made, perceived, and controlled and the reasons why.

Actually, true emotion-induced facial expression is involuntary and natural. Although you can purposefully choose to act surprised, the look on your face when you are actually surprised is an automatic reflex to external stimulus. So to try modulating or falsifying expressions requires working against the body's natural tendencies while in essence, the truth wants to come out. In fact, the face is harder to control than other methods of expression, such as voice, because there is no feedback from it, unless by looking in a mirror.

Facial Muscles and Neuronal Control

The expressions on the face are brought about by contraction of the muscles of the face which in turn is controlled by a wide and complicated network of neuronal system. Hence, the muscles of the face are also known as muscles of facial expression.

The muscles of facial expression include about 18 pairs of thin sheets of skeletal muscles which lie in the superficial fascia, as the face has no distinct deep fascia. They originate from either bone or fascia and insert into the skin of the face. Main groups of muscles of facial expression surround the orifices of the mouth, eyes and nose. They act as sphincters and dilators, which close and open the orifices.

Which neuronal system controls the muscles of facial expression?
As the muscles of facial expression develop from the second pharyngeal arch, they are supplied by the nerve of that arch, facial (VII cranial) nerve. Motor nucleus of the facial nerve lies in the ventrolateral part of the tegmental area of the pons.

Extracranial Branches of the Facial Nerve

The facial nerve emerges from the skull through the stylomastoid foramen and gives off:

1. Posterior auricular nerve: which supplies the occipitalis muscle. Facial nerve then enters the parotid gland and divides into:
2. Temporo-zygomatico-orbital branch: which supplies the muscles that close the eyelids.
3. Superior labial branch: which supplies the upper lip of the mouth.
4. Interior labial branch: which supplies the lower lip of the mouth and
5. Cervical branch: which supplies the platisma muscle of the neck. (A Hamid *et.al.* 1992).

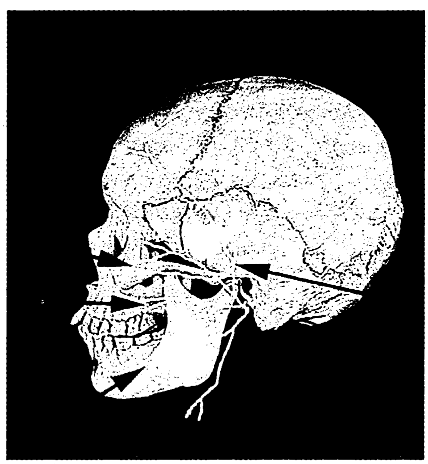

Fig. 11. Extracranial branches of facial nerve.

From my study in collaboration with co-reachers, we found that the motor nucleus of facial nerve is cytoarchitectonically subdivided into five subgroups: they are, ventral, dorsal, medial, lateral and intermediate. Each subgroup represents each branch of the facial nerve. The number, area and diameter of the motor neurons of each branch of the facial nerve are shown in Table 5.

Table: 5 Number, area and diameter of motor neuron cell bodies representing each extracranial branch of facial nerve

Facial nerve	Number of cells	Area of cell body µ_	Diameter of cell body (μm)
Trunk	2243.5	583.01 ± 259.9	26.61 ± 5.75
Auricular posterior Branch.	207	564.23 ± 239.3	26.17 ± 5.6
Tempro-Zygorratico- orbital Branch.	753.5	432.85 ± 162.7	23.01 ± 4.2
Superior labial Branch.	873	556.09 ± 236.4	26.01 ± 5.6
Inferior labial Branch.	149	854.5 ± 273.7	32.34 ± 5.7
Cervical Branch.	464	576.24 ± 262.33	27.05 ± 6.9

(Azian 1990)

The facial nerve controls the facial muscles, and each facial nerve nucleus is in turn controlled by the upper motor neuron from cerebral hemispheres. The latter is under the influence of the limbic system which is concerned with emotional state. Thus, it can be seen that, the neuronal system which controls the muscles of facial expression is influenced by various emotional conditions.

Facial Paralysis

Facial paralysis is psychologically and emotionally frustrating for many patients. It is a potentially devastating disorder. Few impairments have a more negative effect on the quality of an individual's life (Fig. 12).

Fig. 12. Facial paralysis

The paralysis, which results from injury to the facial nerve, can lead to a variety of troubling symptoms, including ocular problems, speech difficulties, drooling and nasal obstruction. Thus, this disorder can be quite debilitating for patients who suffer the emotional impact from the facial disfigurement as well as difficulties with communication, eating and drinking in social setting. A person with facial disfigurements may develop a habit of keeping their face averted so as to be less seen, speak as little as possible due to the defect in pronunciation, avoid the crowd and become unsociable, with loss of enthusiasm; impatient and easily irritated.

Why do the facial muscles paralyse?

The paralysis of facial muscles is commonly due to infection or injury to the facial nerve. The infection of the facial nerve, called Bell's palsy, is mainly because of viral infection. The average annual incidence per 100,000 population is 25-30 with predominance of females (66.7%). Diabetes and hypertention poses 4-5 times more risk of developing the Bell's palsy.

Trauma is the second most common cause of facial nerve paralysis (Hamid 1991), due to direct injury in accident; fracture of the skull bone; and surgical procedure of the parotid gland and face; because of a wide variations in branching pattern of the facial nerve (Hamid *at.el.*, 1992). At birth, using forceps for difficult delivery could injure the facial nerve at its exit from the skull as it is not protected by bony process at an early age.

Treating Facial Paralysis

In facial nerve injuries due to infection, medical treatment is the choice; however, if due to trauma, surgical procedures have been proposed. Two basic dynamic reanimation options currently available are:

1. Reconstruction of nerve continuity through direct microsuture, with interposition graft or nerve transpositions; and
2. Regional muscular transposition, most often using temporalis muscle.

The best results have been achieved in clean section of the facial nerve, with immediate direct end-to-end neural-epineural anastomosis repairs. The least favourable results were seen with myofascial transposition and long extratemporal rerouted autologous nerve grafts; where great auricular nerve, sural nerve or superficial peroneal nerve is used. Despite using advanced microsurgical approaches there is no total regain of motor function (Rawlands *et.al.*, 2002)

Summary

Therefore, though muscles of facial expression are skeletal muscle in type they differ from others in many aspects. First of all, one end of them are directly attached to the skin and act voluntarily as well as involuntarily in emotional situation under the influence of limbic system of the brain. Furthermore, the muscles in the upper half of the face on each side are controlled by a complex neuronal system from both cerebral hemispheres while those of the lower half of the face are controlled by the opposite cerebral hemisphere. The number, size and firing speed of the motoneurons also vary between different branches of the facial nerve nuclei acting with different force, extent and precision for respective muscle groups.

Facial paralysis is indeed psychologically and emotionally frustrating for all the patients. Though minor injuries could recover by medical treatments, severe injuries require surgical intervention. However, to perfectly replicate such complex neuronal control system created by the Almighty could be another impossible task even for the best surgeons with present day technology.

CONTROL OF MASTICATION

How are sucking, chewing, biting, talking, laughing and crying different from one another? We have been doing these daily since we were born. Have you ever noticed how our jaws are involved in such activities? How do we know the size of the bolus we take, its texture and character without looking at it and apply the exact force to our jaws at the precise place where the food is located to break it down smoothly?

Do you realize that by moving your teeth and the tongue you can separate the bones of the fish from the flesh; with precise pressure you can crack the nut shell without smashing the nut inside. How do we do that?

When food enters the mouth, sensory feedback renders the motor system to be programmed to the characteristic of the food. However, the exact relationship between the physical properties of different food and the motor response is poorly understood and has remained as one of the most unexplored fields to be studied further.

Humans have a set of jaws, the upper and the lower. The upper jaw is formed by a pair of maxillary bones situated at the front and lower part of the skull. Thus, it is involved in very minimal movement in speaking and chewing. On the other hand, the lower jaw is formed by the mandible, which is involved in many types of movements.

Movements of the Jaws

The movements of the human jaws are precisely controlled by the force produced by the masticatory (chewing) muscles. As the jaws move to open the mouth to receive the food, these muscles change in length and their linear strength simultaneously. Koolstra and van Eijden (1997) stated that the changes in length and strength of the sarcomeres are determinants for the forces they are able to produce. Masticatory (chewing) performance is associated with the quantitative movement parameters of duration (rhythm), velocity, and displacement of the mandible and the bite force, in relation to the chewing cycle. These also include frequency and length of chewing, distribution of the bite force appropriate for the specific texture between the upper and lower teeth. In fact, the frequency, length and pattern of chewing including grinding and even opening the mouth vary from individual to individual. Variations in jaw geometry according to age, race and gender; shape and size of the teeth, and their location in the jaw and their number, all contribute to masticatory (chewing) process of extremely complex nature which we fail to notice (Xu et.al 2005).

Other than mastication (chewing), the jaw movements are also involved in speech. However, movement amplitudes, maximum velocities, duration and force of closing the jaws, are much greater in mastication than in speech though jaw-closing and opening movements are mostly similar between the two. During sneezing, yawning and coughing however, the amplitude and velocity of the closing and opening movements of the jaws are much stronger.

Because of all these factors, the human motor system for moving the jaws must perform a much larger variety of motor tasks than the average limb or trunk motor system. An important advantage of motor system for mastication (chewing) is that it optimizes the required function while minimizing energy use.

Muscles of Mastication

Which group of muscles moves the jaw?
The movements of the jaw and mastication (chewing) are brought about by contraction of a group of muscles called muscles of mastication. They develop from the first pharyngeal arch and are controlled by a wide and complicated network of neuronal system.

The muscles of mastication include four pairs of essential muscles and two pairs of accessory muscles. The four pairs of essential mastication muscles are: temporalis, masseter, medial pterygoid and lateral pterygoid. The two pairs of accessory mastication muscles are: mylohyoid and digastric. All these muscles are attached to the mandible at one end. The other end of the essential muscles are attached to the skull and those of accessory muscles are attached to the hyoid bone.

Muscles of Mastication Acting on Movements of the Mandible (Fig. 13).

Movements of the mandible include elevation, depression, protrusion, retraction and side to side movements of the lower jaw.

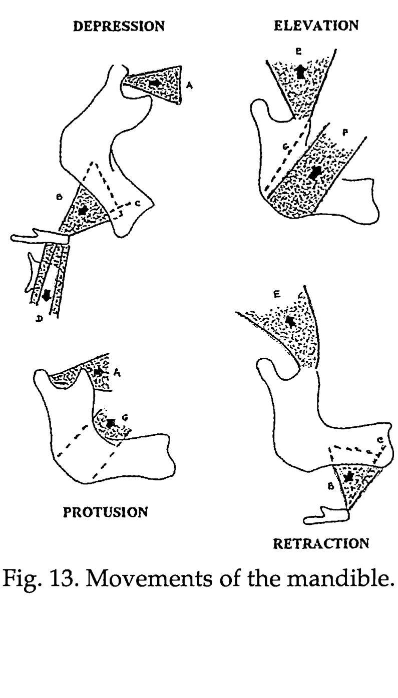

Fig. 13. Movements of the mandible.

a) Elevation is a very powerful movement generated by the temporalis, masseter, and medial pterigoid muscles.
b) Depression is generated by the digastric and mylohoid muscles.
c) Protrusion is mainly achieved by the lateral pterigoid muscle with some assistance from the medial pterigoid.
d) Retraction is carried out by the posterior and deeper fibres of the temporalis and masseter muscles respectively.
e) Side to side movement of the lower jaw is done by masseter of one side together with the medial pterygoid of the opposite side.

Fibre Type Composition of Masticatory Muscles

Fibre type composition of jaw closing muscles is different from that of jaw-opening muscles, as their functions, activities and power applied are not the same. Human jaw-closing muscles are composed of a relatively equal mixture of type I and II fibres, but the type II fibres are much smaller than the type I (Thornell et.al, 1984). The fibre types in the jaw-closing muscles are distinct from limb muscles with regards to fibre morphology and myosin isoform expression. On the other hand, in jaw-opening muscles, the majority of the muscle fibres are fast contracting type II A and/or II B, with relatively few slow contracting type I fibre.

Neuronal System that Controls the Masticatory Muscles

Which neuronal system controls the muscles of mastication?
As the muscles of mastication develop from the first pharyngeal arch, they are supplied by the nerve of that arch, mandibular (V_3 cranial) nerve. It is the third division of the trigeminal nerve and consists of motor, general sensory and propioceptive nerve fibres.

Motor Nucleus of the Mandibular Nerve

From the author's study in collaboration with other co-researchers, it has been found that the motor nucleus of the mandibular nerve is located at the posterior part of pons and medial to the main sensory nucleus of trigeminal nerve. In cross section, the motor nucleus is oval in shape and it is cytoarchitectonically subdivided into subnuclei for muscles of mastication. The subnucleus which controls the temporalis muscle is located dorsally, subnucleus for the medial pterygoid muscles is located ventrally, while subnucleus for the masseter muscle is in the middle between the two. However, subnucleus that controls the lateral pterygoid muscle is situated at the ventrolateral part of the mandibular nucleus and all the subnuclei are found partially overlapping each other (Mohd Aris 2001). The number, area and diameter of the motor neurons which supply each muscle of mastication are presented in Table 6.

Table: 6. Various aspects of motoneurons innervating the essential muscles of mastication.

Muscle of mastication	Number of cells	Area of cell body μ^2	Diameters of cell body (μm)
Temporalis	944.33 ± 151.6	1010.4 ± 23.54	42.46 ± 0.75
Masseter	802.67 ± 81.65	921.20 ± 31.43	40.24 ± 1.19
Lateral Pterygoid	543.33 ± 54.52	813.24 ± 36.2	39.42 ± 0.65
Medial Pterygoid	720.00 ± 128.26	748.40 ± 51.90	39.84 ± 0.63

(Mohd. Aris 2001)

Summary

The above is, therefore, a description of how once the food enters the mouth, various sensations of it provide feedback and programme the motor system to open the jaws just wide enough to adjust the food at the suitable place between the two jaws; to sense the character of the food and generate precise velocity and power to chew or to crush; and to recognize the bone and to separate it between the teeth if present. All are done by moving the jaws unmindfully. Despite variation in geometry of the mandible and difference in shape, size and number of teeth, the masticating muscles acting on the jaw adjust by themselves and provide the optimum velocity, force and pressure of bite required. All these are governed by highly complex sensory and motor systems.

EYE MOVEMENTS

For most of us who are fortunate enough to enjoy normal vision, perhaps give little thought to the wonder of what it takes to enable us to glance this way and that without conscious effort. In fact, with our two eyes, two images of an objective are formed. How is it then that we do not see two images, i.e. do not have double vision?

The answer to this question has to do with the way the visual pathway starting from the photoreceptive layer of the eye, *retina* to the *brain* is organized. Each point of the retina in one eye must correspond perfectly with a point of retina in the other eye, so that the two optical images can be superimposed exactly in the brain to produce a single image. A small specialized receptive area at the centre of the retina, called the *fovea*, has the highest visual resolutions because the photoreceptors are most numerous and tightly packed together at this place. To see an object in best resolution and clarity we need to turn our eyes toward it so that its image falls directly on the fovea (Fig.14).

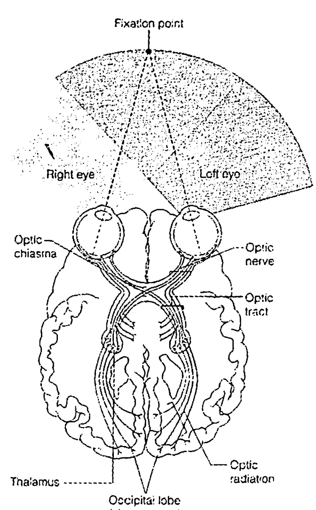

Fig. 14. Visual field and pathway

In which ways do our eyes move?
Our eyes move in many ways. They are:

1. *Sudden fast eye movements:* when an object of interest appears in the peripheral part of the visual field, the eyes rapidly turn towards it. It is called *saccades* and it is either voluntary or reflex movement.
2. *Slow, smooth eye movements:* tracking the slow moving object. It is either voluntary or reflex movement.
3. *The vestibulo-ocular reflex:* it is compensating each movement of the head with an equal and opposite movement of the eyes to maintain fixation of a stationary object. It is a reflex movement and the main sensor is in the inner ear.
4. *Vergence movements:* movements of the eyes that enable us to view very near objects by converging the eyes, and far objects by diverging the eyes.

Thus, in any type of movement, for the two optical images to be superimposed in the brain, there needs to be constant, accurate and coordinated orientation of the two visual axes towards the same object. The various movements of the eye are undertaken by a group of muscles called, *extraocular muscles* together with their nervous control system (Fig.15).

The extraocular muscles comprise six muscles for the *rotation* of each eyeball without shifting the position and one elevator of the upper eyelid.

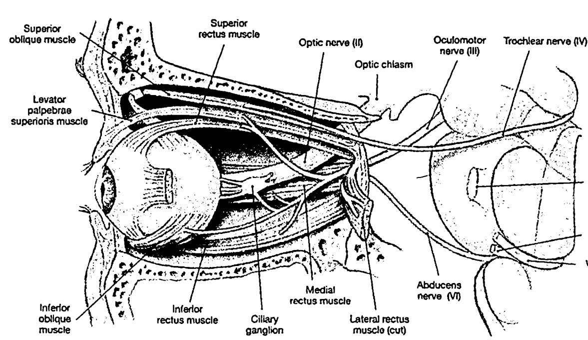

Fig. 15. Muscles of the eye and nerve supply.

Six rotater muscles are:

Four straight muscles (recti): *superior rectus muscle, inferior rectus muscle, medial rectus muscle* and *lateral rectus muscle.*

Two oblique muscles: *Superior oblique muscle* and *inferior oblique muscle.*

The elevator of the upper eyelid is *levator palpebrae superioris muscle*

Table 7. Differences between the extraocular muscles and other skeletal muscles.

Attributes	Extraocularmuscles	Other skeletal muscles
Motor unit (muscle fibres per neurons)	10 - 20	100 – 2000
Maximum motor neuron discharge rates		
Phasis (burst)	> 600 Hz	125 Hz
Tonic (sustained)	> 200 Hz	50 Hz
Time to peak contraction tension	4.5 msec	15 – 35 msec
Fibres type	6	3 - 4
Proprioceptors	Majority peculiar	Muscle spindle
Miosin	Special form	Ordinary form
Mitochondria	Large number	Normal
Blood supply	Greatest of all the skeletal muscles	Normal
Stretch reflex	Absent	Important feature
Mode of contraction	Twitch and tonic	Twitch
Fatigue resistance	High	Variable

The direction of each eyeball at any given moment is determined by a delicate and extremely precise balance of rotational tractions exerted by 6 extraocular muscles. Every muscular contraction has to be balanced by reciprocal relaxation of muscles opposing the action. When our two eyes rotate to a new direction of gaze, the action of each of our twelve extraocular rotating muscles changes. In fact, during any rotation of the eyeball these changes of action come into play as a seamless, highly coordinated continuous process.

How do the extraocular muscles differ from the ordinary skeletal muscles?
The tissue of the extraocular muscles are histologically classed as *striated muscle,* however these muscles display unique features and properties (Table: 7) consistent with activity characterized by speed, precision and finely graduated degrees of contraction and relaxation.

Which structure controls the functions of the exraocular muscles?
Six pairs of rotator muscles of the eyeball and a pair of elevator of the upper eyelid, a total of 14 extraocular muscles are controlled by 3 pairs of *cranial nerves.* They are : *abducent (VI cranial) nerve, trochlear (IV cranial) nerve* and *oculomotor (III cranial) nerve.*

The abducent (VI) nerve innervates the lateral rectus muscle and the trochlear (IV) nerve innervates the superior oblique muscle. All the remaining extraocular muscles including the levator palpebrae superioris are supplied by the oculomotor (III) nerve. They have 6,500, 2,400 and 15,000 neurons respectively (Jamilah *et.al* 1992).

The motoneurons of the extraocular muscles are sensitive to hormonal changes. In hypothyroidism, a condition with reduced production of thyroid hormone, there is atrophy of the neurons without any change in the total number (Jamilah *et.al* 1992). It is followed by disturbance in contraction of the extraocular muscles.

In fact, the extraocular muscles may be selectively or preferentially weakened, disturbed or spared in relation to other skeletal muscles. Examples include autoimmune disorders such as *myasthenia gravis* (affecting neuromuscular junctions), particularly or solely of the extraocular muscles. Conversely, however, in *Duchenne's muscular dystrophy,* a genetic disorder, there is progressive degeneration of skeletal muscle tissue throughout the body but the extraocular muscles are spared.

Summary

Thus, it is evident that the innervation of the extraocular muscles to orchestrate, modulate and coordinate them is a process of immense complexity in the nervous system. Add to this, the speed with which a human eye can rotate, its smoothness of movement and the accuracy of gaze redirection, all combine to make the ocular motility system one of truly phenomenal performance.

Having a second eye to complement and to be coordinated with the other eye multiplies the complexity. When the two eyes move in unison this requires equal innervation to the muscles producing the movement in both eyes (Hering's Law). Despite the intricacies of the computations required, from the conscious decision to look elsewhere or the reflex response to some stimuli, to synthesis of the command to the oculomotor nuclei in the brainstem, all is accomplished effortlessly in a fraction of a second. It hardly needs to be said therefore that the extraocular muscles, a very special type of skeletal muscle, would virtually be useless without such a highly organized, coherent and sophisticated neural control system.

CONCLUSION

Internal or environmental sensory perception leads to decision on how to respond about it and the actual physical deed is done by movement of particular part of the body. For this process, the neuromotor system of our body is responsible. This includes nervous system composing of location and size of the higher control area of the brain; number, size and location of the motoneurons; types, number and size of the nerve fibres; heterogeneity, number, types and directions of the muscle fibres and number and type of motor unit supplying each muscle in addition to the sensitivity of the neurons and muscle fibres to a particular hormone to produce optimum action.

In recent development, the treatment for deranged neuromotor system is by replacing its damaged component with a functional one. This includes replacing the damaged or degenerated neurons in the spinal cord or in the brain with embryonic cells, foetal cells or olfactory cells since nerve cells once damaged do not reproduce. The rational is that these cells are stem cells capable of developing into any type of cell; and the type of cell to develop depends on the environment. Presumably, by placing them at the site of injury they would develop into cells that are injured. It also includes reconnecting the injured segment of nerve with another normal nerve segment; and transplanting a normal muscle to take over the function of injured neighboring muscle. Though some surgeons and scientists achieved some degree of success after such treatment, unfortunately there is no report about total success in the functional status of the patient. It is due to the complexity of the neuromotor system and specificity of each of its components required for precise movement.

Latest researches on the repair of the nervous system have suggested that while there are factors which promote nervous tissues such as change in gene expression and trophic support, there are also factors which limit repair; the latter include chondroitin sulphate proteoglycans and myelin proteins. It is assumed that boosting the promoting factors and/or suppressing the limiting factors would enhance repair of damaged neurons system. Olfactory ensheathing cells provide continual renewal of olfactory system throughout life. The secret of this property is being sought. In the meantime, these cells are being transplanted into the central nervous system.

Findings show that combination of types of muscle fibres and heterogeneity in each muscle, and direction and location of muscle fibres in the muscle, create a very precise action, speed and force to perform an extremely specific function. Similarly, components of nerve fibres in a nerve; types, size and proportion of different nerve fibres in it, very much influenced the conduction rate and magnitude of the electrical impulses to stimulate the muscle for required optimal type of contraction. Variation in the number of motor units to a muscle; number and size of muscle fibres supplied by each motor unit; could also differentiate between the precision movement and coarse movement. Furthermore, position of the neurons in the spinal cord or in the brain, their number and size, the complexity of communication with other neurons and production of chemical substances by some neurons differentiate one group of neurons from another in accordance with their function and rate of regeneration. The higher control system of the brain, its area in relation to the region in the body they control compared to that of another; and involvement of one or both cerebral hemispheres also relate to the degree of functional essentiality.

Ten fingers of a pianist move effortlessly but precisely in coordinated manner and play the piano just by seeing the musical notes; and the typist's fingers will type automatically just by hearing what the boss has dictated. These are few more examples of automatic control-pathways of finger movements through vision and hearing. For these reasons, muscles of the fingers and the thumb, of facial expression and of eye movements are controlled by relatively large areas in the brain for extremely complex and precise movements in terms of speed, force, range and intricacy. The involuntary movements of facial muscles under the influence of emotional status, eye muscles in emergency states and jaw muscles in providing optimum force to bite each particular type of food are examples of awe-inspiring precision engineering work. Moreover, some neuromotor system in male involved in the process of ejaculation requires exposure to male hormone during perinatal period to perform a normal function in adult life long afterwards; which also indicates meticulous planning.

All these have revealed that the neuromotor system in our body is not only the most complex and complicated system, but also extremely well designed. Hence it can only be the work of one whose wisdom is beyond comprehension; in other words, the Almighty God. The wonders of this system pose technological challenges for His creatures, the human beings, to restore and replicate the Almighty's handiwork completely, when abnormalities or destruction occur due to any cause. With technology of the present day, are we ready to fully accomplish and achieve what our Creator created?

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