BIOLOGICAL CONTROL SYSTEMS

PUPIL CONTROL SYSTEM:

Pupillary response is a physiological response that varies the size of the pupil, via the optic and oculomotor cranial nerve. A constriction response (miosis), is the narrowing the pupil, or which may be caused by scleral buckles or drugs such as opiates/opiods or anti hypertension medications. A dilation response (mydriasis), is the widening the pupil and may be caused by anticholinergic agents or drugs such as MDMA, cocaine and amphetamines. Dilation of the pupil occurs when the smooth cells of the radial muscle, controlled by the sympathetic nervous system (SNS), contract. Constriction of the pupil occurs when the circular muscle, controlled by the parasympathetic nervous system (PNS), contracts.

The responses can have a variety of causes, from an involuntary reflex reaction to exposure or inexposure to light — in low light conditions a dilated pupil lets more light into the eye — or it may indicate interest in the subject of attention, or sexual stimulationThe pupils contract immediately before REM sleep beginsA pupillary response can be intentionally conditioned as a Pavlovian response to some stimuli

The latency of pupillary response (the time in which it takes to occur) increases with ageUse of central nervous system stimulant drugs and some hallucinogenic drugs can cause dilation of the pupil

In ophthalmology, intensive studies of pupillary response are conducted via videopupillometry

SKELETAL MUSCLE SERVOMECHANISM:

It is difficult to define the term in a way that includes everything we call a reflex, yet says anything that allows one to decide if any particular event is a reflex. We will follow suit in a sense and define a reflex as "a relatively stereotyped movement or response elicited by a stimulus applied to the periphery, transmitted to the central nervous system and then transmitted back out to the periphery." Most reflexes involve activities that are nearly the same each time they are repeated, but no activity of an organism is fixed and independent of either the state or the history of the organism. Most reflexes involve the simplest of neural circuits, some only two or a few neurons; but many, like the scratch-reflex in a dog, are so complicated that their organization remains a mystery. Most reflexes are "involuntary" in the sense that they occur without the person willing them to do so, but all of them can be brought under "voluntary" control. Some reflexes serve protective functions, like the eyeblink reflex. Some reflexes act as control systems to maintain homeostasis in some bodily systems.

There are a number of ways of classifying reflexes. One is in terms of the systems that receive the stimulus and give the response. There are viscerovisceral reflexes, for example the decrease in heart rate that follows distention of the carotid sinus; viscerosomatic reflexes, like the abdominal cramping that accompanies rupture of the appendix; somatovisceral reflexes, such as the vasoconstriction that results from cooling the skin; and somatosomatic reflexes, like the knee jerk that follows tapping the patellar tendon. Reflexes can also be classified in terms of the number of neurons or synapses between the primary afferent neuron and the motor neuron. We distinguish two types, the monosynaptic reflex and the much more common multisynaptic or polysynaptic reflex. The term multisynaptic implies that more than one synapse is involved, whereas polysynaptic usually implies that the pathway is of variable length, some parts disynaptic, some trisynaptic, etc.

Tapping the tendon of the rectus femoris muscle of the quadriceps group produces a brief stretch of that muscle that acts as a powerful stimulus for the group Ia afferent fibers of the muscle, causing them to give a brief, synchronous discharge. Each discharge, after propagating down the group Ia axon to its termination, produces an EPSP in the rectus alpha-motoneurons. Because there are many EPSPs from many group Ia afferent fibers occurring nearly simultaneously in some alpha-motoneurons, the membrane potentials reach critical firing level (by spatial summation) with hypopolarization to spare, and the motoneurons discharge action potentials. The action potentials travel out by way of the ventral root to the muscle and, because the neuromuscular junction is an obligatory synapse, the muscle contracts. The contraction in turn causes the spindle to be unloaded or shortened passively, its equatorial region to relax, the group Ia afferent fiber to turn off, and the muscle to relax. This is the tendon jerk reflex.

Many of the homonymous alpha-motoneurons are not discharged by the Ia afferent fiber input, but have EPSPs evoked in them that do not achieve the critical firing level. The excitability of the motoneuron is therefore increased. This group of excited neurons is called the subliminal fringe. The presence of the subliminal fringe accounts for enhancement of the reflex response under certain circumstances, for example with the Jendrassik maneuver. In the Jendrassik maneuver, the fingers of the two hands are locked together and one hand pulls against the other

while the tendon tap reflex is evoked. The reflex evoked is stronger than in the absence of the maneuver. (Interestingly, mental arithmetic and a number of other activities will do the same thing!) During the Jendrassik maneuver activity, originating perhaps in the cervical enlargement of the spinal cord or some other rostral center, descends the spinal cord to excite alpha-motoneurons. This activity by itself does not cause the alpha-motoneurons to discharge or the muscle to contract, but when added to the subthreshold excitation of the subliminal fringe caused by the tap-induced muscle stretch, it causes the neurons in the subliminal fringe to discharge. The reflex contraction will therefore be larger than normal. There may also be some influence of increased gamma-motoneuron activity, increasing the sensitivity of the primary spindle endings, but this influence should be small because the stimulus for the reflex is very brief.

The value of the stretch reflex mechanism may not be clear at first, but some reflection may clarify its role in motor control. It is unlikely that muscles undergo such rapid stretches very often, with the possible exception of when a person jumps off a wall or jumps up and down on a pogo stick. However, in these instances, the rapid stretch of the rectus femoris that occurs when the feet or the pogo stick contract the ground causes a reflex contraction that helps prevent the gluteus from being overly bruised.

Usually, the postural muscles experience relatively slow, sustained stretches and the anti-gravity muscles, of which the quadriceps is an example, are pulled upon by gravitational forces. This steady force sets up a sustained discharge in each group Ia afferent fiber, but the discharges in different fibers are not synchronized as they are when the tendon is tapped. In addition, longer, larger stretches are able to excite secondary muscle spindle receptors which also have connections with homonymous alpha-motoneurons, di- and trisynaptic ones. These longer, larger stretches therefore activate the alpha-motoneurons by both monosynaptic and polysynaptic reflex pathways. The resulting reflex contraction of the muscle is called the stretch reflex. The polysynaptic effects are not seen in the tendon tap reflex for two reasons: (1) the brief stretch does not excite secondary spindle receptors and (2) the brief input over the polysynaptic pathways arrives after the monosynaptic input and finds the alpha-motoneurons in their refractory periods and therefore cannot cause them to discharge again.

In controlling posture, the asynchronous discharge in mono- and polysynaptic pathways induced by gravitational forces on muscles sums in the alpha-motoneuron with other activity from within the CNS to produce a contraction that just balances the gravitational force. If an additional force is applied, stretching the muscle, additional tension is developed by the stretch reflex to counteract that force. In this way, the stretch reflex serves as a mechanism for maintaining an upright body orientation under a variety of load conditions; the mechanism is automatic ("unconscious") and fast (19-24 msec for the quadriceps in man).

In addition to the monosynaptic connections of the group Ia afferent fibers with the homonymous alpha-motoneurons (e.g., rectus femorisIa with rectus alpha-motoneuron), there are also monosynaptic connections with synergistic alpha-motoneurons, those innervating muscles that act in the same way at the same joint, but the effects are not as strong in the synergists as they are in the homonymous alpha-motoneurons. Thus, the rectus group Ia afferent fibers also excite the vastus alpha-motoneurons, though not as strongly as they do the rectus alpha-motoneurons. Fewer of the synergistic alpha-motoneurons actually discharge, and the subliminal fringe is larger than for homonymous alpha-motoneurons.

Most skeletal muscles exhibit a tendon tap reflex, but the reflex is strongest in the antigravity or physiological extensor muscles. This makes some sense in light of the discussion of the last paragraph. Note that physiological extensors are not necessarily anatomical extensors. The biceps brachii are a case in point; they are anatomical flexors of the elbow but they are physiological extensors, moving the forearm against gravity.

It is clinically important to note that these reflexes involve only one or two segments of the spinal cord. In fact, the spinal cord can be cut above and below these segments, and the reflexes will still occur. For this reason, testing such reflexes cannot be used as an indicator of the condition of the brain or even other segments of the spinal cord.

Muscle Spindle: A Servo In Its Own Right

servo control mechanism of scanning tunneling microscopeYour refrigerator or air conditioner automatically switches off their compressors when their preset thermal set points are reached. They resume again on their own when the entropy (heat) rises inside. This is an example of servo mechanism: a sensor arm, processing unit and an actuator arm. The apparatus senses heat (more specifically temperature), uses the information and compares it with the preset value (error correction) and then sends signals to the motor (the actuator) to turn it on (or off). This error sensing feedback to optimize a mechanism is what servo is all about. The picture depicts how a scanning tunneling microscope uses this servo mechanism technique.

Such controls are abundant in our bodies. The muscles, for example, contain miniature 'sensors' called intrafusal fibers. They reside in the interior belly of the muscle bulk. These fibers run parallel to the rest of the muscle fibers, the extrafusal fibers. Intrafusal fibers are of two types: nuclear bag fibers (bag, sincethe middle of this fiber is swollen) and nuclear chain fibers (these fibers end on the previously mentioned nuclear bag fibers). The number of these intrafusal fibers in a muscle are scanty and there are few contractile elements in them, which are located at the ends. The center portions of these fibers are devoid of contractile elements.

If you stretched a muscle by pulling it or by tapping on the patellar tendon, the muscle spindle and reflex arc resemble servocontrollersquadriceps muscle would become elongated. The intrafusal fibers would lengthen too. The central portion of these fibers would stretch just as a balloon does when stretched. The central portions of Intrafusal fibers are supplied by sensory nerve fibers, called type 1a nerve fibers. Since the nerve fibers are wrapped intimately around (annulospiral or primary endings in both bag and chain type; and flower spray or secondary endings in case of chain fibers) these portions, the nerve endings stretch too along with the muscle fibers themselves. This opens up stretch sensitive ion channels, allowing cations (positively charged ions like sodium ions) to enter the cells interior. The cells depolarize and fire. The information is carried (as shown) to the spinal cord which springs into action by sending action potential via alpha motor neurones, through a monosynaptic pathway. These nerves innervate extrafusal fibers, fibers rich in contractile proteins, the muscle contracts as a result: stretch reflex.

Although the intrafusal muscles which constitute the muscle spindle (a sketch is shown alongside) are poorly endowed with contractile machinery, they do have some at their ends. sketch of muscle spindle showing intrafusal muscle fibers (nuclear bag and nuclear chain fibers) along with their efferent and afferent innervationThese elements are supplied with motor nerves called gamma efferent of Leksell. As the muscle contracts in the said example, we can visualize that the central portions are no longer stretched, rather they are relaxed. How will the muscle know how much work it has yet to do when its informing machinery is limp and no longer in a state to give its valuable feedback? This is achieved by the super intelligent computer, our body, which energizes the gamma efferents each time alpha motor neurons are activated: alpha gamma coactivation. Now as gamma motor neuron discharges, the contractile elements of the intrafusal fibers contract. Thus you can see that the central portion is stretched again. So each time the muscle contract, intrafusal fibers contract too, making sure that type 1a fibers were able to process and send information on muscle length and the rate of change of this length. The muscle is doing differential calculus by computing ds/dt (rate of change of length)!

(Our good old speedometer also does calculus using a magnet (mechanically coupled to the wheel) and a coil (or a metal foil) to compute rate of change of flux as a function of time. The magnet of a car also rotates (RPM= a function of time) as its wheel rotates. This rotating magnet induces current (change of flux) in a metal disk with a needle, which then indicate as a result of magnetic repulsion. Calculating distance is rather easy: 2*pi*r)

OCULO MOTOR SYSTEM:

The oculomotor nerve is the third cranial nerve. It enters the orbit via the superior orbital fissure and innervates muscles that enable most movements of the eye and that raise the eyelid. The nerve also contains fibers that innervate the muscles that enable pupillary constriction and accommodation (ability to focus on near objects as in reading). The oculomotor nerve is derived from the basal plate of the embryonic midbrain. Cranial nerves IV and VI also participate in control of eye movement. [1]

The oculomotor nerve originates from the third nerve nucleus at the level of the superior colliculus, in the midbrain. The third nerve nucleus is located ventral to the cerebral aqueduct, on the pre-aqueductal grey matter. The fibers from the two third nerve nuclei located laterally on

either side of the cerebral aqueduct then pass through the red nucleus. From the red nucleus fibers then pass via the substantia nigra exiting through the interpeduncular fossa.

On emerging from the brainstem, the nerve is invested with a sheath of pia mater, and enclosed in a prolongation from the arachnoid. It passes between the superior cerebellar (below) and posterior cerebral arteries (above), and then pierces the dura mater anterior and lateral to the posterior clinoid process, passing between the free and attached borders of the tentorium cerebelli.

It traverses the cavernous sinus, above the other orbital nerves receiving in its course one or two filaments from the cavernous plexus of the sympathetic nervous system, and a communicating branch from the ophthalmic division of the trigeminal nerve. As the oculomotor nerve enters the orbit it divides into a superior and an inferior branch, which enter the orbit through the superior orbital fissure

The inferior branch of the oculomotor nerve or the inferior division, the larger, divides into three branches.

One passes beneath the optic nerve to the medial rectus.

Another, to the inferior rectus.

The third and longest runs forward between the inferior recti and lateralis to the inferior oblique. From the last a short thick branch is given off to the lower part of the ciliary ganglion, and forms its short root.

All these branches enter the muscles on their ocular surfaces, with the exception of the nerve to the inferior oblique, which enters the muscle at its posterior boRDER.

Paralysis of the oculomotor nerve, i.e., oculomotor nerve palsy, can arise due to:

direct trauma,

demyelinating diseases (e.g., multiple sclerosis),

increased intracranial pressure (leading to uncal herniation)

due to a space-occupying lesion (e.g., brain cancer) or a

spontaneous subarachnoid haemorrhage (e.g., berry aneurysm), and

microvascular disease, e.g., diabetes.

In people with diabetes and older than 50 years of age, an oculomotor nerve palsy, in the classical sense, occurs with sparing (or preservation) of the pupillary reflex. This is thought to arise due the anatomical arrangement of the nerve fibers in the oculomotor nerve; fibers controlling the pupillary function are superficial and spared from ischemic injuries typical of diabetes. On the converse, an aneurysm which leads to compression of the oculomotor nerve affects the superficial fibers and manifests as a third nerve palsy with loss of the pupillary reflex (in fact, this third nerve finding is considered to represent an aneurysm—until proven otherwise—and should be investigated)

BLOOD SUGAR REGULATION:

Blood sugar regulation is the process by which the levels of blood sugar, primarily glucose, are maintained by the body. Glucose regulation in the body is a process of keeping the body in homeostasis. Insulin and glucagon are the main hormones involved

Mechanisms of blood sugar regulation

Blood sugar levels are regulated by negative feedback in order to keep the body in homeostasis. The levels of glucose in the blood are monitored by the cells in the pancreas's Islets of Langerhans.

Glucagon

If the blood glucose level falls to dangerous levels (as in very heavy exercise or lack of food for extended periods), the Alpha cells of the pancreas release glucagon, a hormone whose effects on liver cells act to increase blood glucose levels. They convert glycogen into glucose (this process is called glycogenolysis). The glucose is released into the bloodstream, increasing blood sugar. Hypoglycemia, the state of having low blood sugar, is treated by restoring the blood glucose level to normal by the ingestion or administration of dextrose or carbohydrate foods. It is often self-diagnosed and self-medicated orally by the ingestion of balanced meals. In more severe circumstances, it is treated by injection or infusion of glucagon.

Insulin

When levels of blood sugar rise, whether as a result of glycogen conversion, or from digestion of a meal, a different hormone is released from beta cells found in the Islets of Langerhans in the pancreas. This hormone, insulin, causes the liver to convert more glucose into glycogen (this process is called glycogenesis), and to force about 2/3 of body cells (primarily muscle and fat tissue cells) to take up glucose from the blood through the GLUT4 transporter, thus decreasing blood sugar. When insulin binds to the receptors on the cell surface, vesicles containing the GLUT4 transporters come to the plasma membrane and fuse together by the process of endocytosis, thus enabling a facilitated diffusion of glucose into the cell. As soon as the glucose enters the cell, it is phosphorylated into Glucose-6-Phosphate in order to preserve the concentration gradient so glucose will continue to enter the cellInsulin also provides signals to several other body systems, and is the chief regulator of metabolic control in humans.

There are also several other causes for an increase in blood sugar levels. Among them are the 'stress' hormones such as epinephrine (also known as adrenaline), several of the steroids, infections, trauma, and of course, the ingestion of food.

Diabetes mellitus type 1 is caused by insufficient or non-existent production of insulin, while type 2 is primarily due to a decreased response to insulin in the tissues of the body (insulin resistance). Both types of diabetes, if untreated, result in too much glucose remaining in the blood (hyperglycemia) and many of the same complications. Also, too much insulin and/or exercise without enough corresponding food intake in diabetics can result in low blood sugar (hypoglycemia).The term diabetes mellitus includes several different metabolic disorders that all, if left untreated, result in abnormally high concentration of a sugar called glucose in the blood. Diabetes mellitus type 1 results when the pancreas no longer produces significant amounts of the hormone insulin, usually owing to the autoimmune destruction of the insulin-producing beta cells of the pancreas. Diabetes mellitus type 2, in contrast, is now thought to result from autoimmune attacks on the pancreas and/or insulin resistance. The pancreas of a person with type 2 diabetes may be producing normal or even abnormally large amounts of insulin. Other forms of diabetes mellitus, such as the various forms of maturity onset diabetes of the young, may represent some combination of insufficient insulin production and insulin resistance. Some degree of insulin resistance may also be present in a person with type 1 diabetes.

The main goal of diabetes management is, as far as possible, to restore carbohydrate metabolism to a normal state. To achieve this goal, individuals with an absolute deficiency of insulin require insulin replacement therapy, which is given through injections or an insulin pump. Insulin resistance, in contrast, can be corrected by dietary modifications and exercise. Other goals of diabetes management are to prevent or treat the many complications that can result from the disease itself and from its treatment.

Continuous Glucose Monitoring

Main article: Blood glucose monitoring

The first CGM device made available to consumers was the GlucoWatch biographer in 1999. This product is no longer sold. It was a retrospective device rather than live. Several live monitoring devices have subsequently been manufactured which provide ongoing monitoring of glucose levels on an automated basis during the day, for example:

The Minimed Paradigm REAL-Time by Minimed, is a continuous glucose monitoring system (CGMS) that provides blood glucose measurements to be made every five minutes over a three-day period. The patient can thus adjust an insulin infusion pump immediately and mimic the "feed-back" mechanism of a pancreas. This is no longer sold. The Enlite Sensor is what they currently sell.

The Dexcom Seven by Dexcom, is another blood glucose monitoring device. likeMinimeds Paradigm it provides measurement every 5 minutes. The sensors lasts 7 days (against medtronics 3 day sensor) before they have to be changed. This is no longer sold. The G4 with Share is what they currently sell.

Freestyle Libre, a Flash Glucose Monitor.

Abbott FreeStyle Navigator

Medtronic Guardian

The US Food and Drug Administration first approved a non-invasive blood glucose monitoring device, the GlucoWatch G2 Biographer. This allows checking blood glucose levels, while puncturing the skin as little as twice a day. Once calibrated with a blood sample, it pulls body fluids from the skin using small electrical currents, taking six readings an hour for as long as thirteen hours. It has not proven to be reliable enough, or convenient enough to be used in lieu of conventional blood monitoring. Other non-invasive methods like radio waves, ultrasound and energy waves are also being tested. The accuracies of these non-invasive devices are at the current stage behind the devices that are inserted or operated into the body.