INTERNUNCIAL NEURONS

SECONDARY HYPERALGESIA ASSOCIATED WITH DEEP OR SUPERFICIAL INJURY CAUSES INCREASED EXCITABILITY IN THE NETWORK OF INTERNUNCIAL NEURONS, WHICH RECEIVE CONVERGENT NOXIOUS IMPULSES FROM **CUTANEOUS** AND DEEP SOMATIC OR **CUTANEOUS** AND DEEP VISCERAL TISSUE STRUCTURES

INJURY TO SKIN PRODUCES HYPERALGESIA AND AS A RESULT, NERVE ENDINGS BECOME HYPEREXCITABLE, CONSEQUENTLY BARRAGING THE DORSAL HORN WITH **NOXIOUS IMPULSES** THAT SENSITIZE THE DORSAL HORN HEURONS TO SUCH AN EXTENT THAT THEY WOULD BE EXCITED BY **SUBLIMINAL STIMULI**.

SECONDARY HYPERALGESIA [**ALLODYNIA**, **PAIN CAUSED BY NONNOXIOUS STIMULUS TO NORMAL SKIN THAT DOES NOT NORMALLY PROVOKE PAIN**] IS CAUSED BY SENSITIZATION OF WIDE DYNAMIC RANGE NEURONS IN THE DORSAL HORN.

CHANGES TAKE PLACE IN THE SPINAL CORD IN PRIMARY AFFERENT AND SPINAL NEURONS THAT CAN PRODUCE SUCH CHANGES IN NOCICEPTIVE RESPONSES, COLLECTIVELY TERMED ***CENTRAL SENSITIZATION***, WHICH MAY LAST **MANY MINUTES TO HOURS** AFTER A REPEATED AFFERENT INPUT CEASES OR IS BLOCKED.

THIS ALSO APPLIES TO **CHRONIC PAIN MODELS**: INFLAMMATORY DUE TO TISSUE INJURY AND NEUROPATHY FROM DAMAGE TO NERVES.

THE **INTERACTION BETWEEN THE IMMUNE AND NERVOUS SYSTEMS** MAKES THIS A **SOMEWHAT ARBITRARY DISTINCTION** IN THAT **IMMUNE CELLS CAN MEDIATE NERVE DAMAGE** AND **NERVE DAMAGE MAY ACTIVATE IMMUNE CELLS**. **[THE NEUROIMMUNE SYSTEM]**

INFLAMMATORY AGENTS GIVEN ON THE **SKIN** SUCH AS ACETIC ACID [**VINEGAR**], CARRAGEENAN [A SUBSTANCE EXTRACTED FROM RED AND PURPLE SEAWEEDS, CONSISTING OF **A MIXTURE OF POLYSACCHARIDES**, USED AS A THICKENING OR EMULSIFYING AGENT IN FOOD PRODUCTS], **CAPSAICIN**, FORMALIN [IN CLOTHES , CARPET, DRAPES, FURNATURE, ETC.] AND **MUSTARD OIL** **HAVE ALL BEEN GIVEN ON THE SKIN OR VISCERA TO PRODUCE PAIN RESPONSES OR FACILITATIONS IN PAIN RESPONSES DEVELOPING WITHIN SECONDS TO DAYS**.

THESE RESULT IN ONGOING WITHDRAWAL PATTERNS IN **CENTRAL SENSITIZATION** FROM ONGOING **PERIPHERAL MECHANISMS** CONTRIBUTING TO **PAIN BEHAVIORS** FROM INITIATION OF SEVERAL **SECOND MESSENGERS** CAUSING THE LINGERING EFFECTS, LEADING TO PATIENTS **"LEARNING TO HURT"**.

HEALTHY INDIVIDUALS GENERALLY DON'T PERCEIVE LIGHT DIGITAL PRESSURE STIMULUS TO BE PAINFUL. THEREFORE, THIS FINDING IN **FIBROMYALGIA SYNDROME** [**FMS**] SEEMS TO REPRESENT A LOWER-THAN-NORMAL PAIN THRESHOLD AND MEETS THE CLINICAL DEFINITION OF **ALLODYNIA**.

FOR THAT REASON IT WAS PROPOSED THAT FMS COULD BE VIEWED MECHANISTICALLY AS **"CHRONIC, WIDESPREAD ALLODYNIA"**.

TWO STUDIES CONDUCTED IN CANADA AND THE UNITED STATES FOUND THAT APPROXIMATELY 65% OF THE GENERAL POPULATION ARE FREE OF PAIN, **5% TRANSIENT, 20% REGIONAL AND 10% HAVE WIDESPREAD PAIN**.

CHIROPRACTORS SEE **ABOUT 17% OF THE POPULATION ANNUALLY AND HAVE SEEN ABOUT 75% AT SOME POINT IN THEIR LIVES**.

2% OF THE GENERAL POPULATION HAVE **FMS** SUFFICIENT TO MEET AMERICAN COLLEGE OF RHEUMATOLOGY CRITERIA.

6-10% OF PATIENTS IN A TYPICAL PHYSICIAN'S WAITING ROOM MEET CRITERIA FOR FMS, ***ABOUT 1 IN 10***.

GROSS ANATOMY **GIVES LITTLE INDICATION OF THE FUNCTIONS** OF THE CENTRAL NERVOUS SYSTEM BEYOND THOSE ***INFERRED*** **FROM THE PERIPHERAL CONNECTIONS** OF THE VARIOUS NERVES.

KNOWLEDGE OF FUNCTIONAL SIGNIFICANCE OF THE VARIOUS PARTS OF THIS SYSTEM ***BASED ON THEIR STRUCTURE*** CAN ONLY BE OBTAINED WITH ANY CERTAINTY FROM **A STUDY OF THE CONNECTIONS OF THE GROUPS OF CELLS**, BUT ***NO COMPLETE PICTURE OF THE CONNECTIONS OF THE CELLS IN THE NERVOUS SYSTEM IS AVAILABLE***, AND THE ANATOMICAL APPROACH TO THE STUDY OF ITS FUNCTION CANNOT YET PRODUCE MORE THAN ***A VERY SKETCHY OUTLINE***.

THE DIVISIONS OF THE CENTRAL NERVOUS SYSTEM, BASED ON GROSS ANATOMY, **REPRESENT PARTS OF A UNIT** CONCERNED WITH ***INTEGRATING THE ACTIVITY OF EVERY PART OF THE BODY***.

THIS SYSTEM **REQUIRES A HIGH DEGREE OF INTEGRATION OF ITS PARTS** ATTAINED BY NERVE **FIBERS CONNECTING THE VARIOUS REGIONS OF THE CENTRAL NERVOUS SYSTEM RECIPROCALLY**.

THE CENTRAL NERVOUS SYSTEM CONSISTS OF 3 TYPES OF CELLS:

SENSORY, CONNECTOR/INTERNUNCIAL AND MOTOR

SENSORY NEURONS HAVE **2 PROCESSES**, **ONE** OF WHICH PASSES TO A SENSORY ENDING, THE CELL BODY LYING OUTSIDE THE CNS EITHER IN:

- SPINAL **GANGLION** OF A DORSAL ROOT

OR IN CORRESPONDING:

- **GANGLION** OF CRANIAL NERVES **ADJACENT TO THE BRAIN**
- **RETINA**
- **OLFACTORY MUCOUS MEMBRANE**

THE OTHER PROCESS ENTERS THE CENTRAL NERVOUS SYSTEM AND EXTENDS FOR A VARIABLE DISTANCE **GIVING RISE TO A NUMBER OF BRANCHES** THROUGH WHICH IT CAN ACTIVATE SEVERAL **INTERNUNCIAL NEURONS**.

INTERNUNCIAL NEURONS

THESE ARE **IMPOSED BETWEEN THE SENSORY** AND **MOTOR CELLS** AND ARE **NOT *DIRECTLY* CONNECTED EITHER WITH A SENSORY ENDING OR WITH AN EFFECTOR ORGAN**.

THEY **COMPRISE ALMOST ALL THE GREY MATTER** OF THE CNS, INCLUDING LARGE STRUCTURES SUCH AS THE:

- CEREBRUM
- CEREBELLUM
- THALAMUS
- CORPUS STRIATUM
- MANY SMALL NUCLEI
- MORE SCATTERED GROUPS OF NERVE CELLS

THEY LIE **ENTIRELY WITHIN THE CNS**, ***EXCEPTING*** THE **PREGANGLIONIC CELLS** OF THE AUTONOMIC NERVOUS SYSTEM **SENDING AXONS TO THE PERIPHERAL AUTONOMIC GANGLIA** CONSISTING OF 'MOTOR' CELLS.

THEY FORM THE **PATHWAYS THROUGH WHICH IMPULSES PASS FOR PRODUCTION OF LOCAL REFLEXES** AND **LINK TOGETHER THE PARTS OF THE CNS**.

AT **ALL LEVELS OF THE CNS** IN **LOCAL AND DISTANT CONNECTIONS** THEY **ACT TOGETHER** IN **CONSTANTLY CHANGING PATTERNS**

DEPENDING MAINLY ON THE **VARYING SENSORY IMPULSES ENTERING THE NERVOUS SYSTEM**.

THEIR INTERACTIONS RESULT IN THE **FREE PASSAGE OF IMPULSES THROUGH CERTAIN NERVOUS PATHWAYS**, WHILE **OTHER PATHWAYS** ARE **BLOCKED OR INHIBITED** SO ***INAPPROPRIATE REACTIONS DON'T TAKE PLACE***.

THE **CONTINUOUS INTERPLAY** OF **FACILITATION** AND **INHIBITION WITHIN THE COMPLEX NETWORK** OF INTERNUNCIAL NEURONS **EVENTUALLY AFFECTS MOTOR CELLS TO PRODUCE** OVERT REACTIONS SUCH AS:

- MUSCULAR CONTRACTION OR INHIBITION
- VASOCONSTRICTION OR DILATATION
- GLANDULAR SECRETION OR INHIBITION
- ETC.

THEY ***INTERRELATE*** **THE VAST NUMBERS OF SENSORY IMPULSES POURING INTO THE NERVOUS SYSTEM OVER A WIDE AREA**, TRANSMITTING THIS SENSORY INFORMATION TO ***EVERY PART OF THE NERVOUS SYSTEM*** [AN ESSENTIAL PART OF ANY **INTEGRATING SYSTEM**]

ONLY ***CERTAIN*** 'SENSORY' REGIONS SEEM TO BE CAPABLE OF EVOKING ***SUBJECTIVE AWARENESS*** OF SENSATION IN MAN-**THE CEREBRAL CORTEX**.

AXONS OF INTERNUNCIAL NEURONS FROM TRACTS/BUNDLES CONVEYING IMPULSES **HEADWARD** TO THE 'SENSORY' REGIONS FROM THE SPINAL MEDULLA AND BRAIN STEM ARE FREQUENTLY CALLED 'SENSORY' TRACTS, THOUGH THEY ONLY DIFFER FROM SIMILAR FIBERS ***CARRYING THE SAME INFORMATION TO OTHER REGIONS*** LIKE THE

CEREBELLUM, IN THAT **THEIR DESTRUCTION INTERFERES WITH THE *CONSCIOUS* AWARENESS** OF ***CERTAIN SENSATIONS***.

ALL THE VARIOUS REGIONS OF THE CNS ARE CONNECTED WITH **THOSE LYING CAUDAL TO THEM**, AND SUCH DESCENDING CONNECTIONS **PRODUCE EFFECTS ON THE CAUDAL PARTS** OF THE NERVOUS SYSTEM ***SIMILAR TO*** **THE EFFECTS OF THE ASCENDING CONNECTIONS ON THE MORE CRANIAL PARTS**.

HOWEVER, SINCE **ALL THE MOTOR CELLS LIE IN THE BRAIN STEM** AND **SPINAL MEDULLA**, ACTIVITY IN DESCENDING PATHWAYS LIKE THE CEREBRAL CORTEX OFTEN RESULTS IN **PRODUCTION OF A MOVEMENT** OR **OTHER ACTIVITY** WHICH **CAN READILY BE OBSERVED**, FOR WHICH REASON THE DESCENDING PATHWAYS AND CELLS WHICH GIVE RISE TO THEM ARE **FREQUENTLY CALLED 'MOTOR'**.

HOWEVER, ASCENDING PATHWAYS CONNECTING VARIOUS SEGMENTS OF THE SPINAL MEDULLA **WITH EACH OTHER** OR **WITH THE BRAIN STEM** MAY EQUALLY **PRODUCE 'MOTOR' EFFECTS THROUGH MOTOR CELLS AT THOSE LEVELS**.

ANY ***MOVEMENT*** PRODUCED BY ACTIVITY IN **INTERNUNCIAL** NEURONS AT THE **SAME OR A DIFFERENT LEVEL** OF THE CNS CALLS FOR **INHIBITION OF LOCAL ACTIVITY AT VARIANCE WITH THE MOVEMENT** WHICH THE 'MOTOR' PATHWAY IS PRODUCING IN ADDITION TO THE **INHIBITION OF THE ANTAGONIST MUSCLES**.

THE **'MOTOR' PATHWAYS** COMPOSED OF **INTERNUNCIAL NEURONS** ARE THEREFORE ***OF NECESSITY ALSO INHIBITORY*** IN THEIR ACTIONS.

THE TERMS **'SENSORY'** AND **'MOTOR'** MUST THEREFORE BE **APPLIED WITH CAUTION** TO THE PATHWAYS COMPOSED OF THE AXONS OF **INTERNUNCIAL** NEURONS SINCE **THEY ARE NOT EQUIVALENT TO THE SAME TERMS APPLIED TO NERVE CELLS ATTACHED TO EITHER**

SENSORY ENDINGS [***TRUE*** SENSORY NEURONS] OR TO **EFFECTOR ORGANS** [***TRUE*** MOTOR NEURONS].

SENSORY INFORMATION FROM THE RECEPTORS OF THE *ENTIRE BODY SURFACE* AND FROM SOME DEEP STRUCTURES…ENTERS THE CENTRAL NERVOUS SYSTEM **THROUGH THE PERIPHERAL NERVES** AND IS CONDUCTED TO ***MULTIPLE*** SENSORY AREAS…SIGNALS ARE THEN **RELAYED TO ESSENTIALLY ALL OTHER PARTS OF THE NERVOUS SYSTEM**…

THE MOST IMPORTANT ULTIMATE ROLE OF THE NERVOUS SYSTEM IS **TO CONTROL THE VARIOUS BODILY ACTIVITIES**. THIS IS ACHIEVED BY CONTROLLING…CONTRACTION OF SKELETAL MUSCLES…CONTRACTION OF SMOOTH MUSCLE IN THE INTERNAL ORGANS, AND…**SECRETION BY BOTH EXOCRINE AND ENDOCRINE GLANDS**…COLLECTIVELY CALLED ***MOTOR FUNCTIONS*** OF THE NERVOUS SYSTEM…CALLED ***EFFECTORS*** BECAUSE THEY PERFORM THE FUNCTIONS DICTATED BY THE NERVE SIGNALS…

THE MAJOR FUNCTION OF THE NERVOUS SYSTEM IS TO **PROCESS INCOMING INFORMATION IN SUCH A WAY THAT *APPROPRIATE* MOTOR RESPONSES OCCUR**.

POSITION SENSORY RECEPTORS

KNOWLEDGE OF POSITION, BOTH STATIC AND DYNAMIC, DEPENDS ON KNOWING **THE DEGREES OF ANGULATION OF ALL JOINTS IN ALL PLANES** AND **THEIR RATES OF CHANGE**. THEREFORE, MULTIPLE DIFFERENT TYPES OF RECEPTORS HELP TO DETERMINE JOINT ANGULATION AND ARE USED TOGETHER FOR POSITION SENSE. **BOTH SKIN TACTILE RECEPTORS AND DEEP RECEPTORS NEAR THE JOINTS ARE USED**. IN THE CASE OF THE FINGERS, WHERE SKIN RECEPTORS ARE IN GREAT ABUNDANCE, **AS MUCH AS *HALF OF POSITION RECOGNITION* IS BELIEVED TO BE DETECTED THROUGH THE SKIN RECEPTORS**…FOR

MOST OF THE LARGER JOINTS OF THE BODY, DEEP RECEPTORS ARE MORE IMPORTANT.

AFTER THE IMPORTANT SENSORY INFORMATION HAS BEEN SELECTED, IT IS THEN **CHANNELED INTO PROPER MOTOR REGIONS OF THE BRAIN** TO CAUSE THE DESIRED RESPONSES, CALLED THE ***INTEGRATIVE FUNCTION*** OF THE NERVOUS SYSTEM.

THUS, IF A PERSON PLACES A HAND ON A HOT STOVE, THE DESIRED RESPONSE IS TO LIFT THE HAND [FLEXION REFLEX], AND OTHER ASSOCIATED RESPONSES, SUCH AS **MOVING THE ENTIRE BODY AWAY FROM THE STOVE**…

THE STORAGE OF INFORMATION IS THE PROCESS WE CALL ***MEMORY***, A FUNCTION OF THE SYNAPSES: EACH TIME CERTAIN TYPES OF SENSORY SIGNALS PASS THROUGH SEQUENCES OF SYNAPSES, THESE SYNAPSES BECOME MORE CAPABLE OF TRANSMITTING THE SAME SIGNALS THE NEXT TIME, WHICH PROCESS IS CALLED ***FACILITATION***. AFTER THE SENSORY SIGNALS HAVE PASSED THROUGH THE SYNAPSES A LARGE NUMBER OF TIMES, THE SYNAPSES BECOME SO FACILITATED THAT SIGNALS GENERATED WITHIN THE BRAIN ITSELF CAN ALSO CAUSE TRANSMISSION OF IMPULSES THROUGH THE SAME SEQUENCES OF SYNAPSES ***EVEN THOUGH THE SENSORY INPUT HAS NOT BEEN EXCITED***.

THIS GIVES THE PERSON A ***PERCEPTION*** OF EXPERIENCING THE ***ORIGINAL*** SENSATION, ALTHOUGH, IN EFFECT, ***THEY ARE ONLY MEMORIES OF THE SENSATIONS***.

NONADAPTING NATURE OF PAIN RECEPTORS

IN CONTRAST TO MOST OTHER SENSORY RECEPTORS OF THE BODY, PAIN RECEPTORS ADAPT VERY LITTLE AND SOMETIMES NOT AT ALL…BECAUSE IT ALLOWS THEM TO KEEP THE PERSON APPRISED OF A

DAMAGING STIMULUS THAT CAUSES THE PAIN AS LONG AS IT PERSISTS.

INHIBITION OF PAIN TRANSMISSION BY TACTILE SENSORY SIGNALS

LARGE TYPE AB SENSORY FIBERS FROM THE PERIPHERAL **TACTILE** RECEPTORS CAN DEPRESS THE TRANSMISSION OF PAIN SIGNALS, RESULTING FROM A TYPE OF LOCAL LATERAL INHIBITION.

THE SPINAL CORD…A CONDUIT FOR SIGNALS FROM THE PERIPHERY OF THE BODY TO THE BRAIN OR IN THE OPPOSITE DIRECTION…NEURONAL CIRCUITS IN THE CORD CAN CAUSE…**WALKING MOVEMENTS…REFLEXES THAT WITHDRAW PORTIONS OF THE BODY FROM PAINFUL OBJECTS…REFLEXES THAT STIFFEN THE LEGS TO SUPPORT THE BODY AGAINST GRAVITY, AND…REFLEXES THAT CONTROL LOCAL BLOOD VESSELS, GASTROINTESTINAL MOVEMENTS, AND SO FORTH, IN ADDITION TO MANY OTHER FUNCTIONS**.

MANY FUNCTIONS OF THE NERVOUS SYSTEM SUCH AS THE PROCESS OF MEMORY REQUIRES PROLONGED CHANGES IN NEURONS FOR SECONDS TO **MONTHS AFTER THE INITIAL TRANSMITTER SUBSTANCE IS GONE**. THE ION CHANNELS ARE NOT SUITABLE FOR CAUSING PROLONGED POSTSYNAPTIC NEURONAL CHANGES BECAUSE THESE CHANNELS CLOSE WITHIN MILLISECONDS AFTER THE TRANSMITTER SUBSTANCE IS NO LONGER PRESENT. IN MANY INSTANCES, PROLONGED NEURONAL ACTION IS ACHIEVED BY ACTIVATING A "SECOND MESSENGER" CHEMICAL SYSTEM INSIDE THE POSTSYNAPTIC NEURONAL CELL ITSELF, AND THEN **THE *SECOND MESSENGER* CAUSES THE PROLONGED EFFECT**.

MECHANORECEPTORS…DETECT MECHANICAL **DEFORMATION**…NOCICEPTORS…DETECT DAMAGE OCCURRING IN THE TISSUES.

PAIN RECEPTORS IN THE SKIN ARE **ALMOST** NEVER STIMULATED BY ***USUAL TOUCH OR PRESSURE STIMULI*** BUT DO BECOME HIGHLY ACTIVE THE MOMENT TACTILE STIMULI BECOME SEVERE ENOUGH TO DAMAGE THE TISSUES.

IF A PAIN FIBER IS STIMULATED, THE PERSON PERCEIVES PAIN REGARDLESS OF WHAT TYPE OF STIMULUS EXCITES THE FIBER. LIKEWISE, IF A TOUCH FIBER IS STIMULATED BY **EXCITING A TOUCH RECEPTOR** IN ANY WAY, THE PERSON PERCEIVES TOUCH BECAUSE TOUCH FIBERS LEAD TO SPECIFIC TOUCH AREAS IN THE BRAIN.

ALL SENSORY RECEPTORS HAVE ONE FEATURE IN COMMON. WHATEVER THE TYPE OF STIMULUS THAT EXCITES THE RECEPTOR, ITS IMMEDIATE EFFECT IS TO ***CHANGE THE MEMBRANE POTENTIAL*** OF THE RECEPTOR. THIS CHANGE IN POTENTIAL IS CALLED A *RECEPTOR POTENTIAL*…**MECHANICAL DEFORMATION OF THE RECEPTOR… STRETCHES THE RECEPTOR MEMBRANE AND OPENS ION CHANNELS**.

THE **PACINIAN CORPUSCLE** HAS A CENTRAL NERVE FIBER EXTENDING THROUGH ITS CORE. SURROUNDING THIS ARE MULTIPLE CONCENTRIC CAPSULE LAYERS, SO THAT **COMPRESSION** ANYWHERE ON THE OUTSIDE OF THE CORPUSCLE WILL ELONGATE, INDENT, OR OTHERWISE **DEFORM** THE CENTRAL FIBER.

THE MECHANISM BY WHICH A RECEPTOR POTENTIAL IS PRODUCED IN THE PACINIAN CORPUSCLE..THE SMALL AREA OF THE TERMINAL FIBER THAT HAS BEEN **DEFORMED BY COMPRESSION** OF THE CORPUSCLE…NOTE THAT **ION CHANNELS HAVE OPENED IN THE**

MEMBRANE, ALLOWING POSITIVELY CHARGED SODIUM IONS TO DIFFUSE TO THE INTERIOR OF THE FIBER. THIS CREATES INCREASED POSITIVITY INSIDE THE FIBER, WHICH IS A "RECEPTOR POTENTIAL." THE RECEPTOR POTENTIAL IN TURN INDUCES A *LOCAL CIRCUIT* CURRENT FLOW…THAT SPREADS ALONG THE NERVE FIBER…THE LOCAL CURRENT FLOW DEPOLARIZES THE FIBER MEMBRANE AT THE NODE, AND THIS THEN SETS OFF TYPICAL ACTION POTENTIALS THAT ARE **TRANSMITTED ALONG THE NERVE FIBER TOWARD THE CENTRAL NERVOUS SYSTEM**.

RECEPTORS…CALLED ***RATE* RECEPTORS**, ***MOVEMENT* RECEPTORS**, OR ***PHASIC* RECEPTORS**…IN THE CASE OF THE PACINIAN CORPUSCLE, **SUDDEN** PRESSURE APPLIED TO THE TISSUE EXCITES THIS RECEPTOR …THE PACINIAN CORPUSCLE IS EXCEEDINGLY IMPORTANT IN APPRISING THE NERVOUS SYSTEM OF **RAPID TISSUE DEFORMATIONS**.

POSITIVE STRETCH REFLEX

THE SIMPLEST MANIFESTATION OF MUSCLE SPINDLE FUNCTION IS THE ***MUSCLE STRETCH REFLEX*** (ALSO CALLED **MYOTATIC REFLEX [MUSCLE SPINDLE STRETCH REFLEX]**) – THAT IS, WHENEVER A MUSCLE IS STRETCHED, EXCITATION OF THE SPINDLES CAUSES REFLEX CONTRACTION OF THE **LARGE SKELETAL MUSCLE FIBERS** OF THE SAME MUSCLE **AND CLOSELY ALLIED SYNERGISTIC MUSCLES**.

THE STRETCH REFLEX CAN BE DIVIDED INTO TWO COMPONENTS…THE ***DYNAMIC*** *STRETCH REFLEX* IS ELICITED BY THE POTENT DYNAMIC SIGNAL TRANSMITTED FROM THE PRIMARY ENDINGS OF THE MUSCLE SPINDLES, CAUSED BY **RAPID** STRETCH OF THE MUSCLE. THAT IS, WHEN A MUSCLE IS **SUDDENLY** STRETCHED [REFLEX HAMMER], A STRONG SIGNAL IS TRANSMITTED TO THE SPINAL CORD, AND THIS CAUSES AN INSTANTANEOUS STRONG REFLEX **CONTRACTION** OF THE SAME MUSCLE FROM WHICH THE SIGNAL ORIGINATED THUS, THE REFLEX

FUNCTIONS TO OPPOSE **SUDDEN** CHANGES IN THE LENGTH OF THE MUSCLE BECAUSE THE MUSCLE CONTRACTION OPPOSES THE STRETCH.

THE DYNAMIC STRETCH REFLEX IS OVER ***WITHIN A FRACTION OF A SECOND*** AFTER THE MUSCLE HAS BEEN STRETCHED TO ITS NEW LENGTH, BUT THEN A WEAKER ***STATIC*** *STRETCH REFLEX* **CONTINUES FOR A PROLONGED PERIOD THEREAFTER**…IT CONTINUES TO CAUSE MUSCLE CONTRACTION AS LONG AS THE MUSCLE IS MAINTAINED AT EXCESSIVE LENGTH. THE MUSCLE CONTRACTION IN TURN OPPOSES THE FORCE THAT IS CAUSING THE EXCESS LENGTH.

NEGATIVE STRETCH REFLEX

WHEN A MUSCLE IS **SUDDENLY SHORTENED**, EXACTLY OPPOSITE EFFECTS OCCUR BECAUSE OF DECREASED NERVE IMPULSES FROM THE SPINDLES. IF THE MUSCLE IS ALREADY TAUT, ANY SUDDEN RELEASE OF THE LOAD ON THE MUSCLE THAT ALLOWS IT TO SHORTEN WILL ELICIT BOTH DYNAMIC AND STATIC REFLEX *MUSCLE* ***INHIBITION*** RATHER THAN REFLEX EXCITATION. THUS, *THIS* ***NEGATIVE*** *STRETCH REFLEX* OPPOSES THE SHORTENING OF THE MUSCLE IN THE SAME WAY THAT THE **POSITIVE** STRETCH REFLEX OPPOSES LENGTHENING OF THE MUSCLE. THEREFORE, ONE CAN BEGIN TO SEE THAT **THE STRETCH REFLEX TENDS TO MAINTAIN THE STATUS QUO FOR THE LENGTH OF A MUSCLE**.

FLEXOR REFLEX AND THE WITHDRAWAL REFLEXES

CUTANEOUS SENSORY STIMULUS ON A LIMB IS LIKELY TO **CAUSE THE FLEXOR MUSCLES OF THE LIMB TO CONTRACT**, THEREBY WITHDRAWING THE LIMB FROM THE STIMULATING OBJECT…THE ***FLEXOR REFLEX***.

IN ITS CLASSIC FORM, THE FLEXOR REFLEX IS **ELICITED MOST POWERFULLY BY STIMULATION OF PAIN ENDINGS**, SUCH AS BY A **PINPRICK** OR HEAT, FOR WHICH REASON IT IS ALSO CALLED A

NOCICEPTIVE REFLEX OR SIMPLY ***PAIN REFLEX***. STIMULATION OF THE ***TOUCH RECEPTORS*** CAN ALSO ELICIT A WEAKER AND ***USUALLY*** LESS PROLONGED FLEXOR REFLEX.

IF SOME PART OF THE BODY BESIDES ONE OF THE LIMBS IS PAINFULLY STIMULATED, THIS PART, IN A SIMILAR MANNER, WILL BE ***WITHDRAWN*** *FROM THE STIMULUS*, BUT THE REFLEX MAY NOT BE CONFINED TO FLEXOR MUSCLES EVEN THOUGH IT IS BASICALLY THE SAME TYPE OF REFLEX. THEREFORE, THE **MANY PATTERNS OF REFLEXES OF THIS TYPE** IN THE DIFFERENT AREAS OF THE BODY ARE CALLED THE ***WITHDRAWAL REFLEXES***.

THE PATHWAYS FOR ELICITING THE FLEXOR REFLEX DO NOT PASS DIRECTLY TO THE ANTERIOR MOTOR NEURONS BUT INSTEAD PASS **FIRST INTO THE *INTERNEURON POOL* OF NEURONS** AND ONLY SECONDARILY TO THE MOTOR NEURONS…DIVERGING CIRCUITS TO SPREAD THE REFLEX TO THE NECESSARY MUSCLES FOR WITHDRAWAL…CIRCUITS TO INHIBIT THE ANTAGONIST MUSCLES, CALLED ***RECIPROCAL INHIBITION CIRCUITS***…CIRCUITS TO CAUSE A **PROLONGED** REPETITIVE AFTER DISCHARGE ***EVEN AFTER THE STIMULUS IS OVER***.

PATTERN OF WITHDRAWAL

"DURING THIS TIME, OTHER REFLEXES AND ***ACTIONS OF THE CENTRAL NERVOUS SYSTEM*** CAN MOVE THE **ENTIRE BODY** AWAY FROM THE PAINFUL STIMULUS.

THE **PATTERN OF WITHDRAWAL** THAT RESULTS WHEN THE FLEXOR REFLEX (OR THE **MANY OTHER TYPES** OF WITHDRAWAL REFLEXES) IS ELICITED **DEPENDS ON THE SENSORY NERVE THAT IS STIMULATED**. THUS, A PAINFUL STIMULUS **ON THE INSIDE OF THE ARM** NOT ONLY ELICITS A FLEXOR REFLEX IN THE ARM BUT ALSO **CONTRACTS THE ABDUCTOR MUSCLES** TO PULL THAT CAN **MOST EFFECTIVELY REMOVE**

THE PAINED PART OF THE BODY FROM THE OBJECT THAT CAUSES PAIN. THIS SAME PRINCIPLE, CALLED **THE PRINCIPLE OF "LOCAL SIGN," APPLIES TO ANY PART OF THE BODY** BUT ESPECIALLY TO THE LIMBS BECAUSE THEY HAVE HIGHLY DEVELOPED FLEXOR REFLEXES.

CROSSED EXTENSOR REFLEX

ABOUT **0.2 TO 0.5 SECOND AFTER A STIMULUS** ELICITS A FLEXOR REFLEX IN ONE LIMB, THE **OPPOSITE LIMB BEGINS TO EXTEND**. THIS IS CALLED THE ***CROSSED EXTENSOR REFLEX***. EXTENSION OF THE OPPOSITE LIMB CAN PUSH THE **ENTIRE BODY AWAY** FROM THE OBJECT CAUSING THE PAINFUL STIMULUS IN THE WITHDRAWN LIMB.

IT IS CERTAIN THAT **MANY INTERNEURONS ARE INVOLVED** IN THE CIRCUIT BETWEEN THE INCOMING SENSORY NEURON AND THE MOTOR NEURONS OF **THE OPPOSITE SIDE OF THE CORD** RESPONSIBLE FOR THE CROSSED EXTENSION. FURTHERMORE, AFTER THE PAINFUL STIMULUS IS REMOVED, **THE CROSSED EXTENSOR REFLEX CONTINUES FOR AN EVEN LONGER PERIOD OF AFTERDISCHARGE THAN THAT FOR THE FLEXOR REFLEX**.

THE PROLONGED AFTERDISCHARGE WOULD BE OF BENEFIT IN HOLDING THE BODY AWAY FROM A PAINFUL OBJECT UNTIL **OTHER NERVOUS REACTIONS** COULD CAUSE THE BODY TO MOVE AWAY.

RECIPROCAL INHIBITION AND RECIPROCAL INNERVATION

EXCITATION OF ONE GROUP OF MUSCLES IS USUALLY ASSOCIATED WITH INHIBITION OF ANOTHER GROUP. FOR INSTANCE, WHEN A **STRETCH REFLEX EXCITES ONE MUSCLE, IT OFTEN, AT THE SAME TIME, INHIBITS THE ANTAGONIST MUSCLES**. THIS IS THE PHENOMENON OF ***RECIPROCAL INHIBITION***, AND THE NEURONAL CIRCUIT THAT CAUSES THIS RECIPROCAL RELATION IS CALLED ***RECIPROCAL INNERVATION***.

LIKEWISE, RECIPROCAL RELATIONS OFTEN EXIST ***BETWEEN THE TWO SIDES OF THE CORD***, AS EXEMPLIFIED BY THE FLEXOR AND EXTENSOR REFLEXES DESCRIBED ABOVE.

REFLEXES OF POSTURE AND LOCOMOTION

PRESSURE ON THE FOOTPAD…CAUSES THE LIMB TO EXTEND AGAINST THE PRESSURE BEING APPLIED TO THE FOOT…THIS REFLEX IS CALLED THE ***POSITIVE SUPPORTIVE REACTION***…INVOLVES A COMPLEX CIRCUIT IN THE **INTERNEURONS** SIMILAR TO THOSE RESPONSIBLE FOR THE FLEXOR AND CROSS EXTENSOR REFLEXES. **THE LOCUS OF THE PRESSURE ON THE PAD OF THE FOOT DETERMINES THE DIRECTION IN WHICH THE LIMB WILL EXTEND; PRESSURE ON THE ONE SIDE CAUSES EXTENSION IN THAT DIRECTION, AN EFFECT CALLED THE *MAGNET REACTION*. THIS KEEPS AN ANIMAL FROM FALLING TO THAT SIDE.**

LAID ON ITS SIDE…WILL MAKE…MOVEMENTS THAT INDICATE…TRYING TO RAISE…TO THE STANDING POSITION. THIS IS CALLED A ***CORD RIGHTING REFLEX***. SUCH A REFLEX DEMONSTRATES THAT RELATIVELY COMPLEX REFLEXES ASSOCIATED WITH POSTURE ARE **INTEGRATED** IN THE SPINAL CORD.

OSCILLATION BACK AND FORTH BETWEEN THE FLEXOR AND EXTENSOR MUSCLES…SEEMS TO RESULT MAINLY FROM **MUTUALLY RECIPROCAL INHIBITION CIRCUITS THAT OSCILLATE BETWEEN THE NEURONS CONTROLLING AGONIST AND ANTAGONIST MUSCLES WITHIN THE MATRIX OF THE CORD ITSELF**.

THE SENSORY SIGNALS **FROM THE FOOTPADS** AND FROM THE **POSITION SENSORS AROUND THE JOINTS** PLAY A STRONG ROLE IN CONTROLLING **FOOT PRESSURE** AND **RATE OF STEPPING** WHEN THE FOOT IS ALLOWED TO WALK ALONG A SURFACE. IN FACT, **THE CORD**

MECHANISM FOR CONTROL OF STEPPING CAN BE STILL MORE COMPLEX. FOR INSTANCE, IF DURING THE FORWARD THRUST OF THE FOOT THE TOP OF THE FOOT ENCOUNTERS AN OBSTRUCTION, THE FORWARD THRUST WILL STOP TEMPORARILY, BUT THEN IN RAPID SEQUENCE, THE FOOT WILL BE LIFTED HIGHER AND PROCEED FORWARD TO BE PLACED OVER THE OBSTRUCTION. THIS IS THE ***STUMBLE REFLEX***. THUS, THE CORD IS AN INTELLIGENT WALKING CONTROLLER.

EVERY TIME **STEPPING OCCURS IN THE FORWARD DIRECTION IN ONE LIMB, THE OPPOSITE LIMB ORDINARY STEPS BACKWARD**. THIS EFFECT RESULTS FROM **RECIPROCAL INNERVATION BETWEEN THE TWO LIMBS**.

IN GENERAL, STEPPING OCCURS DIAGONALLY BETWEEN THE FORELIMBS AND HINDLIMBS. SUCH A WALKING PATTERN IS CALLED A ***MARK TIME REFLEX***. [CALLED ***CROSS-CRAWL*** *IN APPLIED KINESIOLOGY]*

A MUSCLE REFLEX THAT MAY FURTHER STIMULATE THE SYMPATHETIC NERVOUS SYSTEM

ASIDE FROM THE SYMPATHETIC STIMULATION CAUSED BY DIRECT SIGNALS FROM THE BRAIN, **REFLEX SIGNALS FROM THE CONTRACTING MUSCLES** PASS UP THE SPINAL CORD TO THE VASOMOTOR CENTER AND TO **EXCITE THE SYMPATHETIC NERVES** STILL FURTHER. THESE SIGNALS ARE INITIATED BY **METABOLIC ENDPRODUCTS** ACTING ON SMALL SENSORY NERVE ENDINGS IN THE MUSCLE TISSUE.

VESTIBULAR POSTURAL REFLEXES

SUDDEN CHANGES IN THE ORIENTATION OF AN ANIMAL IN SPACE ELICIT VESTIBULAR REFLEXES THAT HELP TO MAINTAIN EQUILIBRIUM AND POSTURE. FOR INSTANCE, IF AN ANIMAL IS **SUDDENLY PUSHED TO**

THE RIGHT, EVEN BEFORE IT CAN FALL MORE THAN A FEW DEGREES, ITS RIGHT LEGS EXTEND INSTANTANEOUSLY.

ANOTHER TYPE OF VESTIBULAR POSTURAL REFLEX OCCURS WHEN THE ANIMAL **SUDDENLY FALLS FORWARD**. WHEN THIS OCCURS, THE FORELEGS EXTEND FORWARD, THE EXTENSOR MUSCLES TIGHTEN, AND THE MUSCLES IN THE BACK OF THE NECK STIFFEN TO PREVENT THE ANIMAL'S HEAD FROM STRIKING THE GROUND.

VESTIBULAR MECHANISM FOR STABILIZING THE EYES

WHEN A PERSON **CHANGES DIRECTION OF MOVEMENT RAPIDLY** OR EVEN LEANS THE HEAD SIDEWAYS, FORWARD, OR BACKWARD, IT WOULD BE IMPOSSIBLE TO MAINTAIN A STABLE IMAGE ON THE RETINAE OF THE EYES UNLESS THE PERSON HAD SOME AUTOMATIC CONTROL MECHANISM TO STABILIZE THE DIRECTION OF GAZE OF THE EYES…EACH TIME THE **HEAD IS SUDDENLY ROTATED**, SIGNALS FROM THE **SEMICIRCULAR DUCTS CAUSE THE EYES TO ROTATE** IN A DIRECTION **EQUAL AND OPPOSITE TO THE ROTATION OF THE HEAD**.

NECK PROPRIOCEPTORS

THE **VESTIBULAR APPARATUS** DETECTS THE ORIENTATION AND MOVEMENTS ***ONLY OF THE HEAD***. THEREFORE, IT IS ESSENTIAL THAT THE NERVOUS CENTERS ALSO RECEIVE APPROPRIATE INFORMATION DEPICTING THE **ORIENTATION OF THE HEAD WITH RESPECT TO THE BODY**. THIS INFORMATION IS TRANSMITTED FROM THE **PROPRIOCEPTORS OF THE NECK** AND BODY **DIRECTLY TO THE VESTIBULAR AND RETICULAR NUCLEI OF THE BRAIN STEM** AND INDIRECTLY BY WAY OF THE CEREBELLUM.

AMONG THE MOST IMPORTANT PROPRIOCEPTIVE INFORMATION NEEDED FOR MAINTENANCE OF EQUILIBRIUM IS THAT TRANSMITTED BY THE ***JOINT RECEPTORS OF THE NECK***. **WHEN THE HEAD IS LEANED IN ONE DIRECTION** BENDING THE **NECK IMPULSES FROM THE NECK**

PROPRIOCEPTORS KEEP THE VESTIBULAR APPARATUS FROM GIVING THE PERSON A SENSE OF MAL-EQUILIBRIUM…**SIGNALS THAT EXACTLY OPPOSE THE SIGNALS TRANSMITTED** FROM THE VESTIBULAR APPARATUSES. HOWEVER *WHEN THE ENTIRE BODY* LEANS IN ONE DIRECTION, THE IMPULSES FROM THE VESTIBULAR APPARATUSES *ARE NOT OPPOSED* BY SIGNALS FROM THE NECK.

IMPORTANCE OF VISUAL INFORMATION IN THE MAINTENANCE OF EQUILIBRIUM

PROPRIOCEPTIVE INFORMATION FROM OTHER PARTS OF THE BODY BESIDES THE NECK IS ALSO IMPORTANT IN THE MAINTENANCE OF EQUILIBRIUM….**PRESSURE SENSATIONS FROM THE FOOTPADS** TELL WHETHER **WEIGHT IS DISTRIBUTED EQUALLY BETWEEN THE TWO FEET** AND **WEIGHT IS MORE FORWARD OR BACKWARD ON THE FEET**.

MAN WALKS IN AN UPRIGHT POSITION AND **HIS LIMBS HAVE BECOME STRAIGHTENED TO THE POINT THAT ALMOST NO MUSCULAR STRENGTH IS REQUIRED TO MAINTAIN THE WEIGHT OF THE BODY AGAINST GRAVITY**. FOR INSTANCE, THE DIRECT LINE BETWEEN THE CENTER OF MASS OF THE BODY AND THE DIRECTION OF GRAVITATIONAL PULL RUNS **SLIGHTLY BEHIND** THE AXES OF THE HIP JOINTS SO THAT GRAVITY TENDS TO EXTEND THE HIPS AND SO THAT **THE LIGAMENTS OF THE HIP JOINTS, RATHER THAN THE MUSCLES, SUPPORT THE BODY AGAINST GRAVITY**.

THE **STRETCH REFLEX** IS CONSIDERED **ESSENTIAL IN MAINTAINING MUSCLE TONUS** AND CAN PRODUCE INCREASED TENSION OF CERTAIN MUSCLE GROUPS SO AS TO PROVIDE A BACKGROUND OF POSTURAL MUSCLE TONUS AGAINST WHICH VOLUNTARY MOVEMENTS CAN OCCUR.

MOST REFLEX ARCS INCLUDE AT LEAST ONE **INTERNUNCIAL NEURON** BETWEEN THE AFFERENT AND EFFERENT FIBERS, THE **STRETCH REFLEX HAS NO SUCH INTERNUNCIAL OR INTERMEDIARY NEURON** AND THE **AFFERENT NEURON MAKES DIRECT CONTACT WITH THE EFFERENT NEURON ACROSS A SINGLE SYNAPSE IN THE SPINAL CORD**.

STRETCHING A MUSCLE STIMULATES ITS MUSCLE SPINDLES. AFFERENT NERVE FIBERS FROM MUSCLE - SPINDLES ENTER THE SPINAL CORD THROUGH DORSAL ROOT NERVES AND GO ANTERIORLY **THROUGH THE GRAY MATTER OF THE SPINAL CORD** TO REACH THE ANTERIOR HORN, WHERE SYNAPSES WITH MOTOR CELLS ARE MADE. HIGHER SUPRASPINAL MOTOR CENTERS ARE BELIEVED TO SEND IMPULSES TO SKELETAL MUSCLE BY 2 ROUTES-ONE INVOLVING LARGE ALPHA MOTONEURON CELLS AND THE OTHER SMALL **GAMMA MOTONEURONS**.

THE **GAMMA NEURON** MAY BE STIMULATED BY AFFERENT DORSAL ROOT FIBERS COMING FROM THE MUSCLE SPINDLES SO AS TO CAUSE **CONTRACTION OF INTRAFUSAL MUSCLE FIBERS** VIA A **STRETCH REFLEX**. THIS APPEARS ADEQUATE TO ACTIVATE THE MAIN MUSCLE MASS SO THAT GAMMA INNERVATION MAY SERVE AS A "STARTER" FOR ACTIVATION OF **ALPHA MOTONEURONS** AND THE MAIN MUSCLE MASS.

PROPRIOCEPTORS: THERE ARE TWO MAIN TYPES OF PROPRIOCEPTORS IN JOINT CAPSULES: **RUFFINI** END ORGANS/CORPUSCLES, AND PACINIAN CORPUSCLES. RUFFINI END ORGANS APPEAR TO BE MAINLY RESPONSIVE TO TENSION. **PACINIAN** CORPUSCLES APPEAR TO BE RESPONSIVE TO COMPRESSION.

THE PROPRIOCEPTORS IN ***SKIN*** ARE SIMILAR TO THOSE FOUND IN JOINT CAPSULES.

TENSION IN SKIN CAN BE **CAUSED BY MOVEMENT IN A NUMBER OF DIRECTIONS** AND PROPRIOCEPTORS MAY MAKE A **SIGNIFICANT CONTRIBUTION TO JOINT STABILIZATION** IN REFLEXIVE MUSCULAR ACTIVITY.

* AND ***SKIN PROPRIOCEPTORS***, INCLUDING **MEISSNER'S** CORPUSCLES, ARE **LOCATED SUPERFICIALLY IN THE SKIN AND RESPOND RAPIDLY TO TRANSIENT MOVEMENTS OF THE SKIN** BETWEEN 5 HZ AND 40 HZ.[3] **PACINIAN** CORPUSCLES ARE **FOUND DEEPER IN THE SUBDERMAL LAYER OF THE SKIN**. ***PACINIAN CORPUSCLES*** **RESPOND QUICKLY TO HIGH-FREQUENCY TRANSIENT *MOVEMENTS OF THE SKIN*** BETWEEN 60 HZ AND 300 HZ.[4] IT IS BELIEVED THAT THESE ***MECHANORECEPTORS CONNECT TO THE CORTEX AND MODIFY ACTIVITY OF THE LIMBS***. **JOINT** AND **SKIN RECEPTORS** ALSO **FACILITATE THE VESTIBULAR APPARATUS TO STABILIZE THE EXTREMITIES DURING GAIT BY STIMULATING THE NECESSARY MUSCLES TO CONTRACT MORE FORCEFULLY AND EFFICIENTLY**.*

SKIN PROPRIOCEPTORS** IDENTIFY ENVIRONMENTAL CHANGES AND ***PROVIDE INFORMATION ABOUT YOUR BODY'S POSTURAL ALIGNMENT.*

THE ***RUFFINI CORPUSCLES*** ARE ORIENTED WITH THEIR LONG AXES PARALLEL TO THE SURFACE OF THE SKIN AND ARE ***MOST SENSITIVE TO SKIN STRETCH***. **STRETCHING THE SKIN** (FIGURE 2.17) STRETCHES THE COLLAGEN FIBERS WITHIN THE RUFFINI CORPUSCLE, WHICH ***COMPRESSES THE AXON TERMINALS***. AS THE COLLAGEN FIBERS REMAIN STRETCHED AND THE AXON TERMINALS REMAIN COMPRESSED DURING THE SKIN STRETCH, THE RUFFINI CORPUSCLE'S 1° AFFERENT AXON PRODUCES A SUSTAINED SLOWLY ADAPTING DISCHARGE TO MAINTAINED STIMULI.

RUFFINI CORPUSCLES **IN SKIN ARE CONSIDERED TO BE **SKIN STRETCH SENSITIVE RECEPTORS** OF THE **DISCRIMINATIVE TOUCH SYSTEM**. THEY ALSO **WORK WITH THE PROPRIOCEPTORS IN JOINTS** AND MUSCLES TO **INDICATE THE POSITION AND MOVEMENT OF BODY PARTS**.**

RUFFINI ENDINGS ARE **LOCATED IN THE DEEP LAYERS OF THE SKIN**, AND **REGISTER MECHANICAL DEFORMATION WITHIN JOINTS, MORE SPECIFICALLY ANGLE CHANGE**, WITH A SPECIFICITY OF UP TO 2 DEGREES, AS WELL AS CONTINUOUS PRESSURE STATES. THEY ALSO ACT AS THERMORECEPTORS THAT RESPOND FOR A LONG TIME, SO IN CASE OF DEEP BURN THERE WILL BE NO PAIN AS THESE RECEPTORS WILL BE BURNED OFF. **[SKIN STIMULATION CHANGES MUSCLE TONE AND JOINT ANGULATION]**

MEISSNER'S: SUPERFICIAL

PACINIAN: INTERMEDIATE

RUFFINI: DEEP