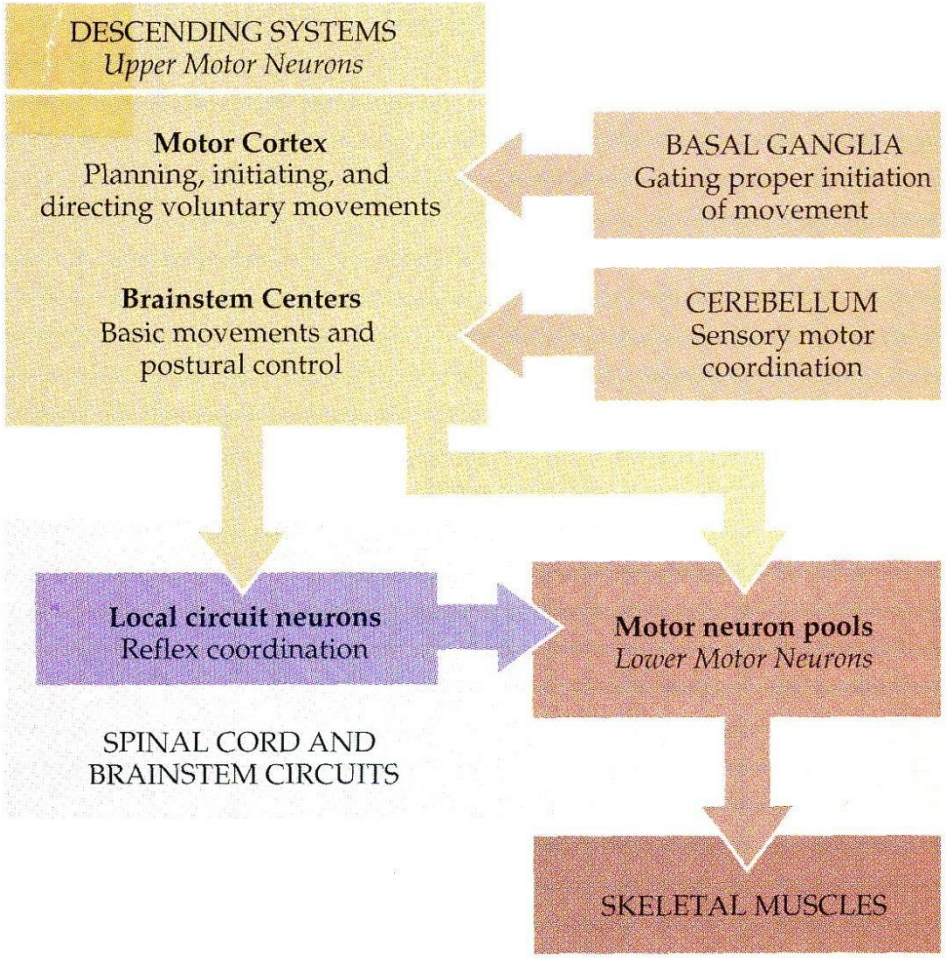
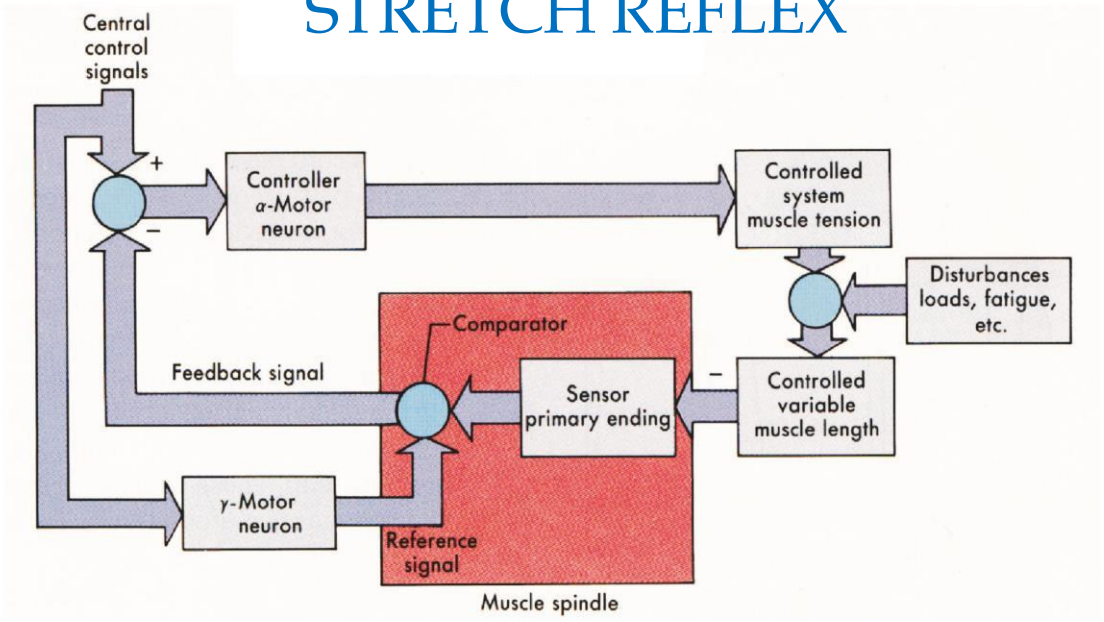
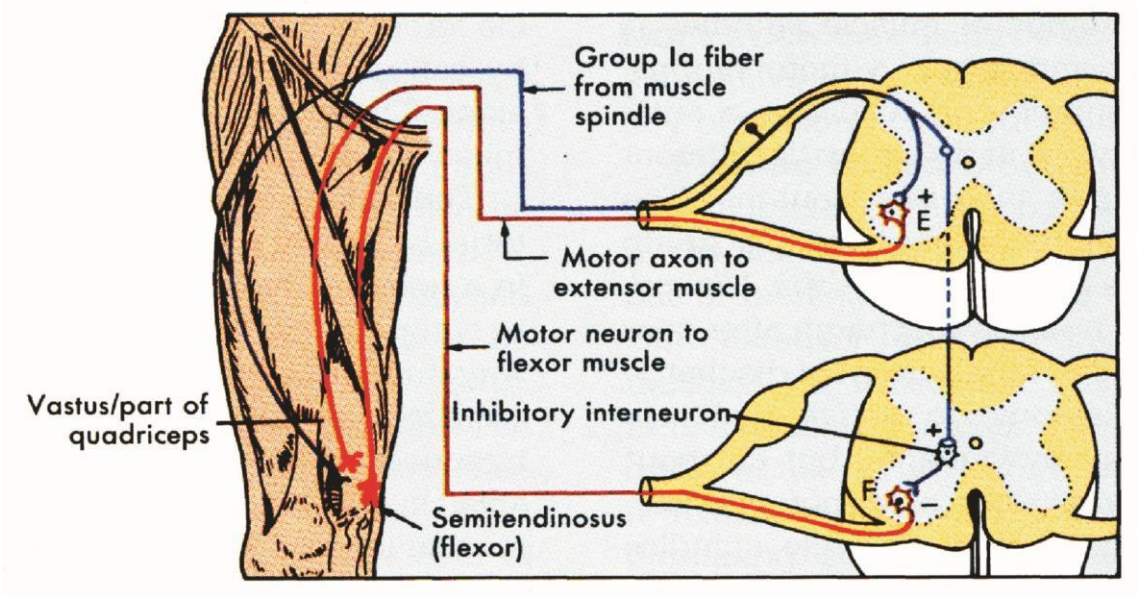
SPINAL AND LONG-LOOP STRETCH REFLEXES

MOTOR SYSTEM: STRUCTURE AND REFLEX CIRCUITS

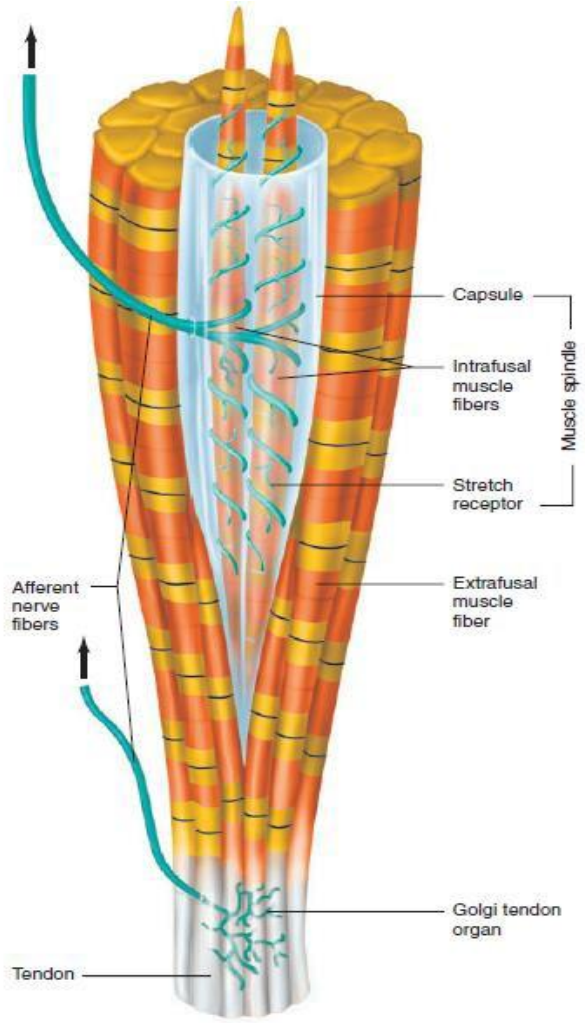


STRUCTURES INVOLVED INTO THE STRETCH REFLEX





LENGTH-MONITORING SYSTEMS

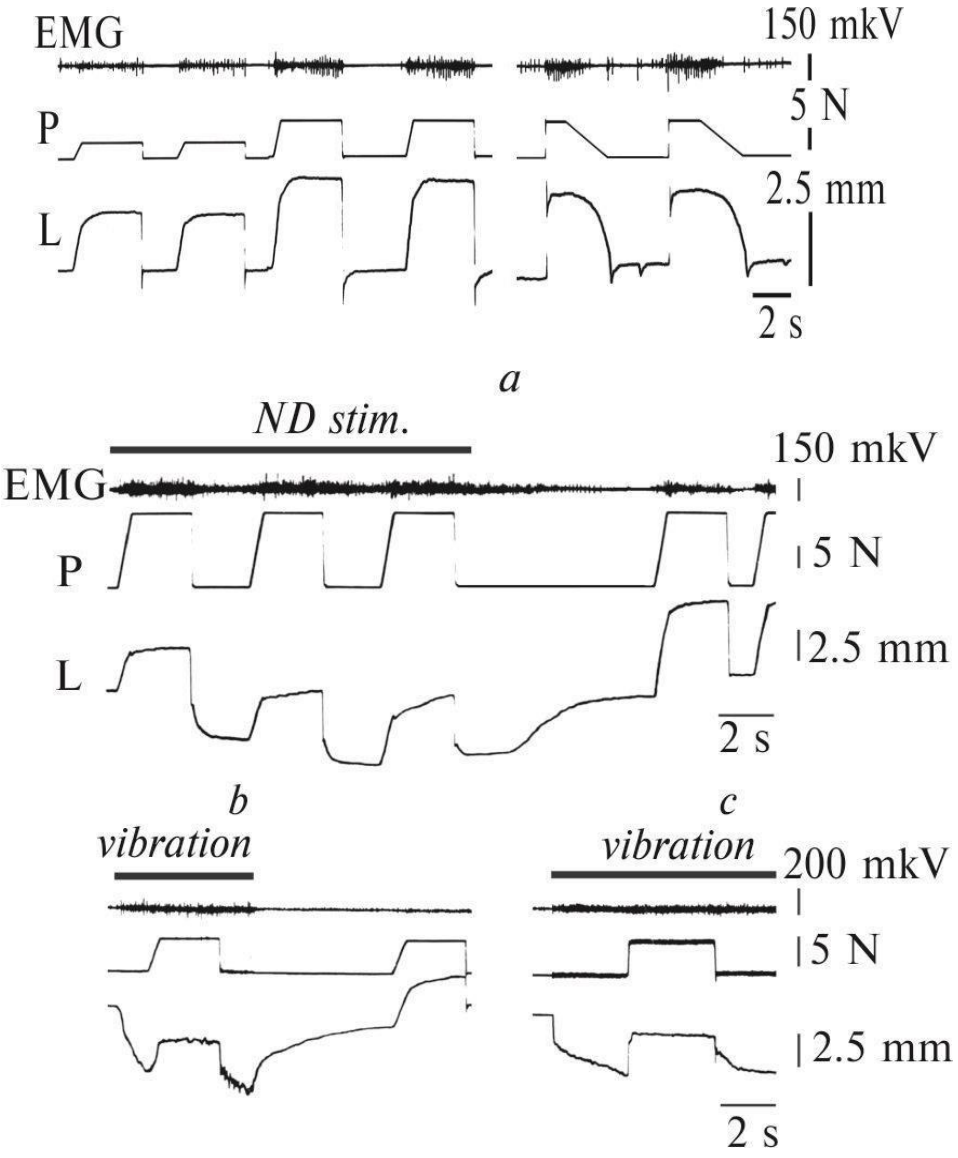


A muscle spindle and Golgi tendon organ

Absolute muscle length and changes in muscle length are monitored by stretch receptors embedded within the muscle. These receptors consist of peripheral endings of afferent nerve fibers that are wrapped around modified muscle fibers, several of which are enclosed in a connective-tissue capsule. The entire structure is called a **muscle spindle**. The modified muscle fibers within the spindle are known as ***intrafusal*** fibers. The skeletal muscle fibers that form the bulk of the muscle and generate its force and movement are the ***extrafusal*** fibers. Within a given spindle, there are two kinds of stretch receptors: One responds best to how much the muscle has been stretched, the other to both the magnitude of the stretch and the speed with which it occurs. Although the two kinds of stretch receptors are separate entities, they will be referred to collectively as the muscle-spindle stretch receptors.

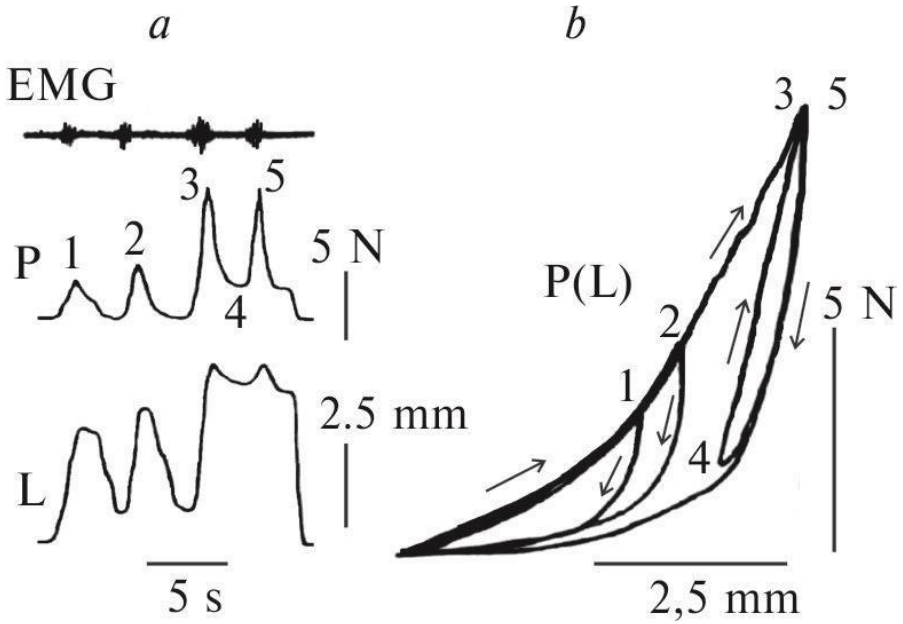
STRETCH REFLEX IN DECEREBRATE CATS

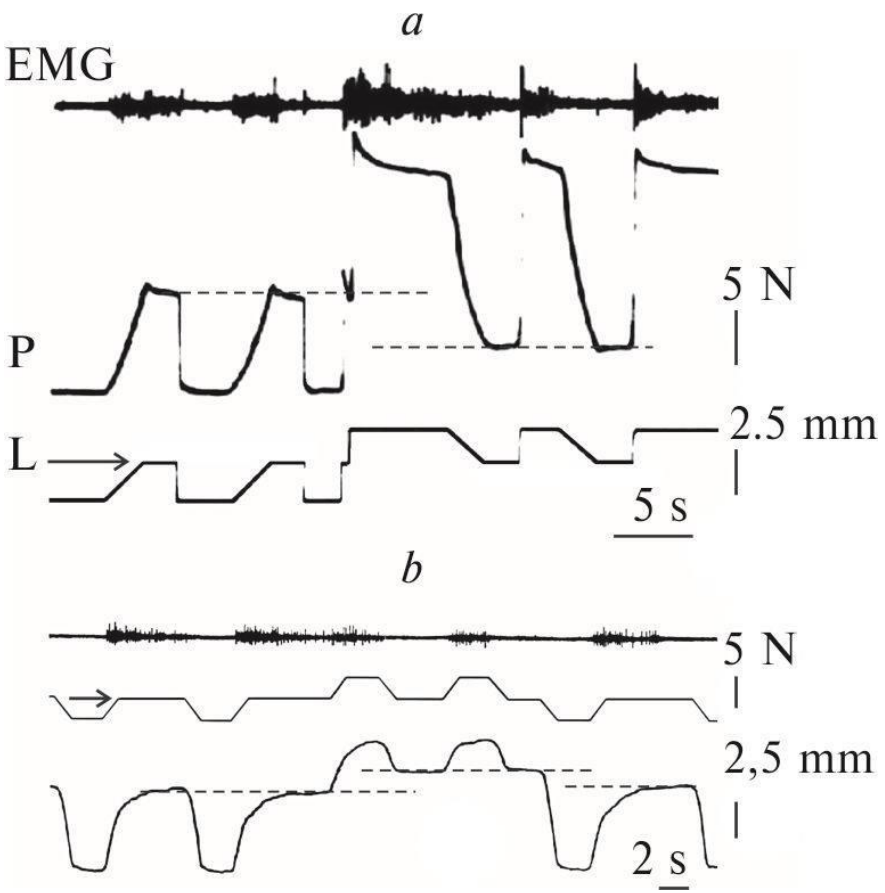
The muscle spindles are parallel to the extrafusal fibers. Thus, stretch of the muscle by an external force also pulls on the intrafusal fibers, stretching them and activating their receptor endings. The more the muscle is stretched or the faster it is stretched, the greater the rate of receptor firing. When the afferent fibers from the muscle spindle enter the central nervous system, they divide into branches that take different paths. A directly stimulates motor neurons that go back to the muscle that was stretched, thereby completing a reflex arc known as ***the stretch reflex.***



EMG – electromyogram;
L – length of G-S (gastrocnemius - soleus) muscle;
P – force generated by the muscle
ND – nucleus of Deiters

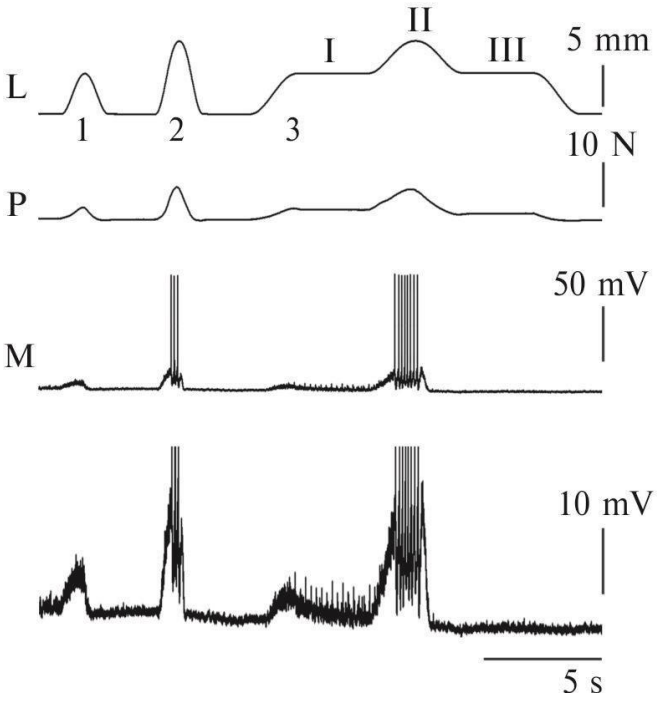
HYSTERESIS AND UNCERTAINTY EFFECTS IN THE STRETCH REFLEX

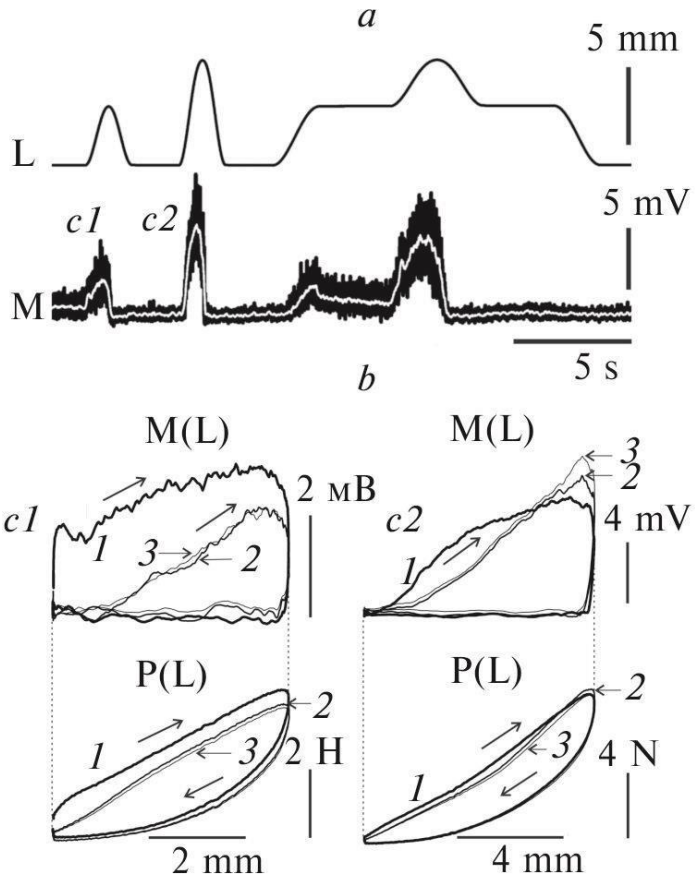




EMG – electromyogram;
L – length of G-S (gastrocnemius - soleus) muscle;
P – force generated by the muscle

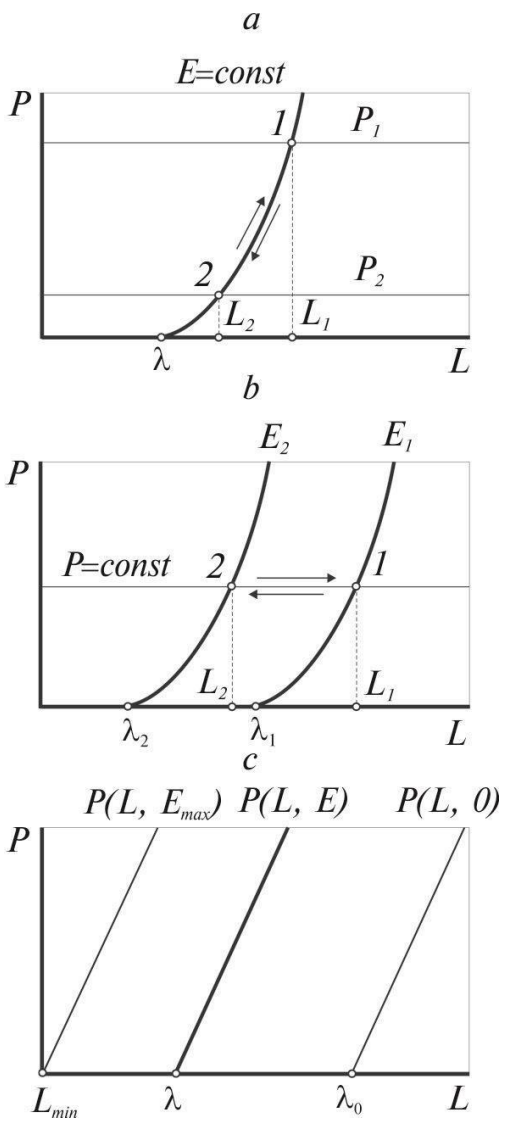
ACTIVITY OF MOTONEURONS IN THE STRETCH REFLEX SYSTEM





M – membrane potential recorded in G-S motoneuron by intrasomatic microelectrode;
L – length of G-S (gastrocnemius - soleus) muscle
P – force generated by the muscle

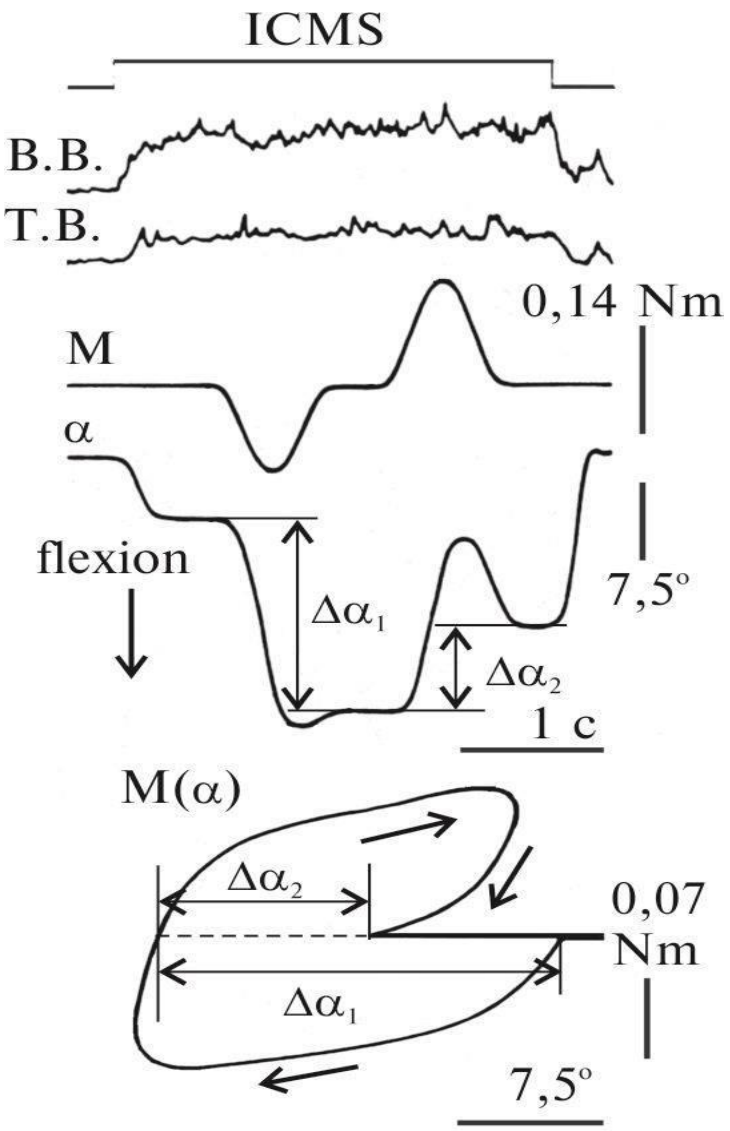
EQUILIBRIUM POINT HYPOTHESIS



The spring-like properties of muscle have been introduced into the so-called ***equilibrium point hypothesis*** (EPH). In the EPH, a single-valued relation is supposed to exist between the efferent activity level and the muscle length and tension. The muscle is considered as an executive element for the reflex circuits originating in the muscle proprioceptors and being closed at the level of the spinal cord and supraspinal motor centers. The reflexes are usually connected with a change of muscle length in one of two possible directions (lengthening vs. shortening), so the stretch and unloading reflexes must be distinguished. For simplicity these reflexes are often named by the common term "stretch reflex". The threshold of the tonic stretch reflex has been introduced into the EPH to define the state of muscle in a single-valued fashion; the model assumes that the muscle force for slow movements is invariant in respect to movement direction

L– muscle length;
P – muscle tension;
E – intensity of the descending activity
λ – threshold of the stretch reflex

MOVEMENTS EVOKED IN UNANAESTHETIZED CATS BY STIMULATION OF THE MOTOR CORTEX

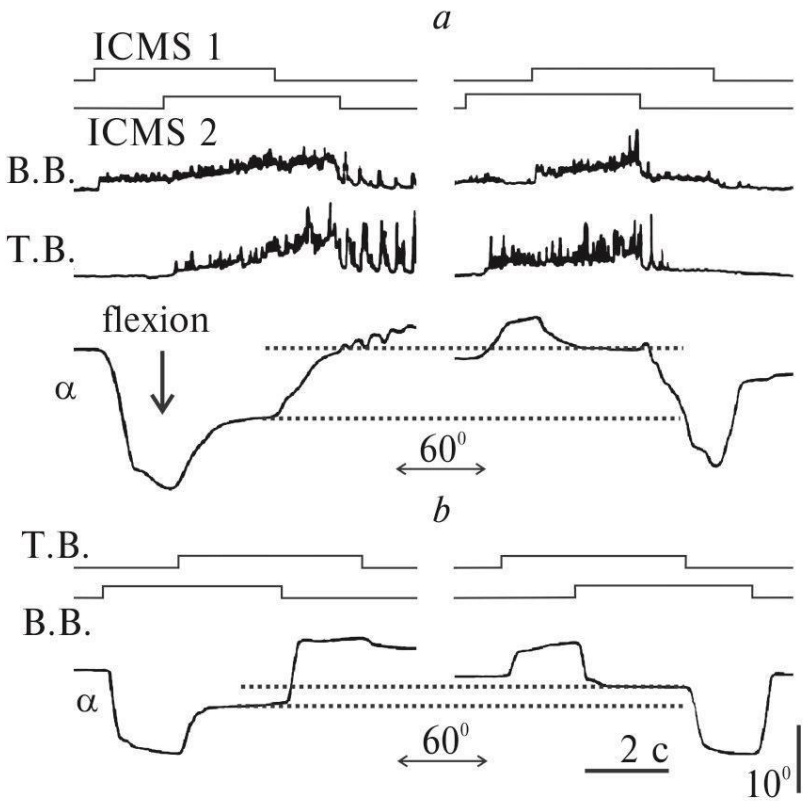


Powerful hysteresis effects in the stretch reflex system make this assumption unacceptable; hence the EPH should be essentially revised. The muscle hysteresis cannot be compensated for at the level of stretch reflex system, these hysteresis effects lead to clear uncertainty in the muscle equilibrium states. Hysteresis of muscle contraction and hysteresis properties of the muscle spindle activity seem to be the main reasons for a pronounced asymmetry of the stretch and unloading reflexes.

ICMS – intracortical microstimulation;

B.B., T.B. – EMG records from biceps and triceps;
M – external torque applied to cat's elbow joint;
α – joint angle

AFTER-EFFECTS IN THE CORTICALLY-EVOKED MOVEMENTS



awake animal

EMG recordings

direct muscle stimulation
In anaesthetized animal

ICMS – intracortical microstimulation (two points of the motor cortex);
B.B., T.B. – EMG recordings from biceps and triceps;
M – external torque applied to cat's elbow joint;
α – joint angle

REVIEW QUESTIONS

- Formulate the equilibrium point hypothesis (EPH).
- Explain, why the stretch reflex is better expressed in decerebrate preparations?
- What are differences between extra- and intrafusal muscle fibers?
- Explain possible significance of the stretch reflex for everyday behavior in humans.
- Explain appearance of uncertainty effects in the muscle withi the stretch reflex circuit.
- Enumerate the structures involved into the stretch reflex.