Theories Of Motor Control

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Theories Of Motor Control

- **A Theory of motor control** is a group of abstract ideas about the control of movement.
- **A Theory** is a set of interconnected statements that describe unobservable structures or processes and relate them to each other and to observable events.

- Theories often reflect differences in opinion about the relative importance of various neural components of movement.
- For example, some theories stress peripheral influences, central influences, environmental information.
- Thus, motor control theories are more than just an approach to explaining action. Often they stress different aspects of the organization of the underlying neurophysiology and neuroanatomy of that action.

Value of Theory to Practice:

- ✓A framework for interpreting behavior;
- ✓A guide for clinical action;
- ✓New ideas; and
- ✓Working hypotheses for examination and intervention.

Theories Of Motor Control

I. Reflex Theory

II. Hierarchical Theory

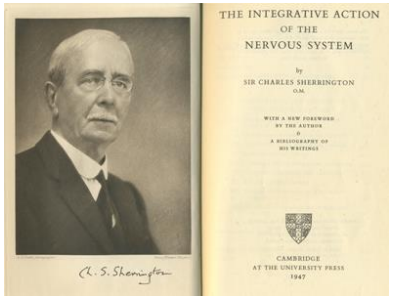
III. Motor Programming Theories

IV. Systems Theory

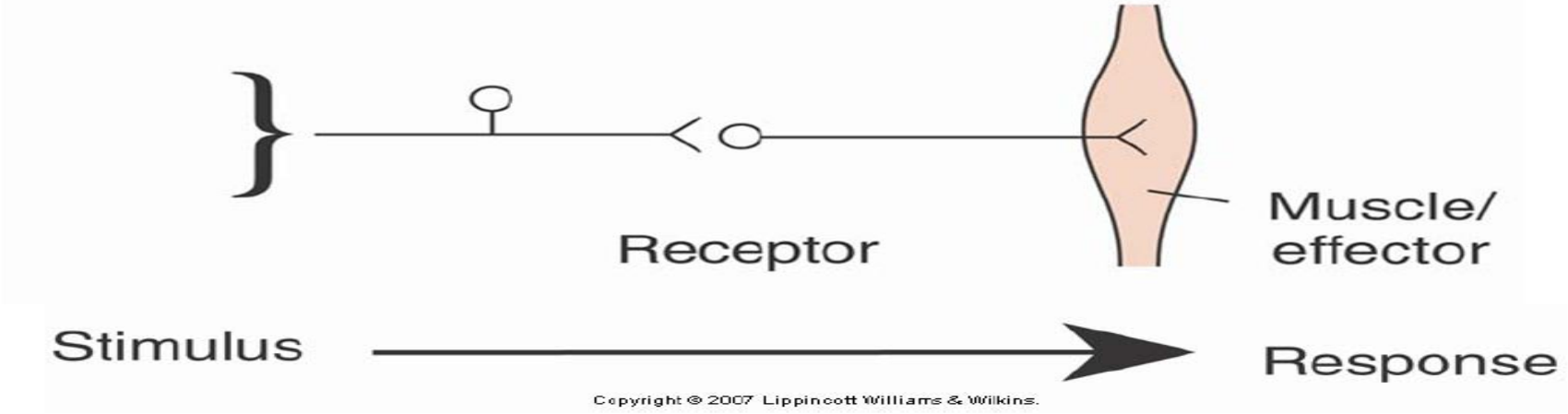
V. Dynamic Systems Theory

VI. Ecological Theory

I. Reflex Theory



- Reflexes are the building blocks of complex motor behaviors or movements
- Sensory stimulus is essential to produce a movement.



Reflex Theory

- Sir Charles Sherrington, *the integrative action of the nervous system*
  - –Reflex chaining: complex movements are a sequence of reflexes elicited together (interaction of many sensory stimulus).
- This is based on the observation that monkeys were unable to their arm after resection of one side of dorsal root ganglia. → Therefore, sensory inputs must be essential in initiating movements.

Limitations of Reflex Theory

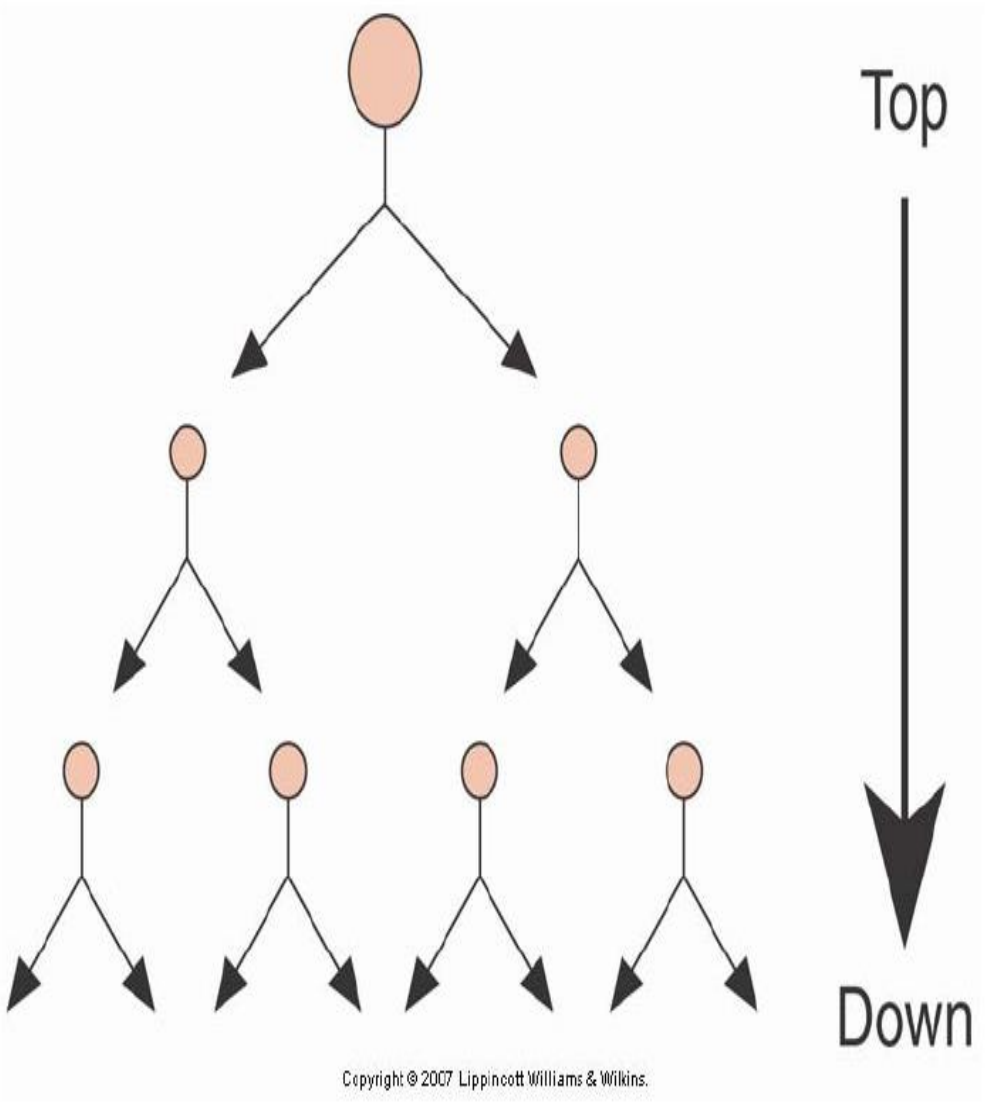
- Unable to explain
  - –Spontaneous and voluntary movements
  - –Movement can occur without a sensory stimulus
  - –Fast sequential movements, e.g. typing
  - –A single stimulus can trigger various responses (reflexes can be modulated)
  - –Novel movements can be carried out.

Clinical Implications of reflex theory

- Chained or compounded reflexes are the bases for functional movement, clinical strategies designed to test reflexes should allow therapists to predict function.
- Patient's movement behaviors would be interpreted in terms of the presence or absence of controlling reflexes.
- Finally, retraining motor control for functional skills would focus on enhancing or reducing the effect of various reflexes during motor tasks.

II. **Hierarchical Theory**

- **Jackson**, an English physician, argued that the brain has higher, middle, and lower levels of control.
- Hierarchical control in general has been defined as organizational control that is **top down.**



II. **Hierarchical Theory**

- **In 1920s magnus** found that reflexes controlled by lower centers are present only when higher centers are damaged.
- Higher centers are always control lower centers. Higher centers inhibit the reflexes controlled by lower centers.

II. **Hierarchical Theory**

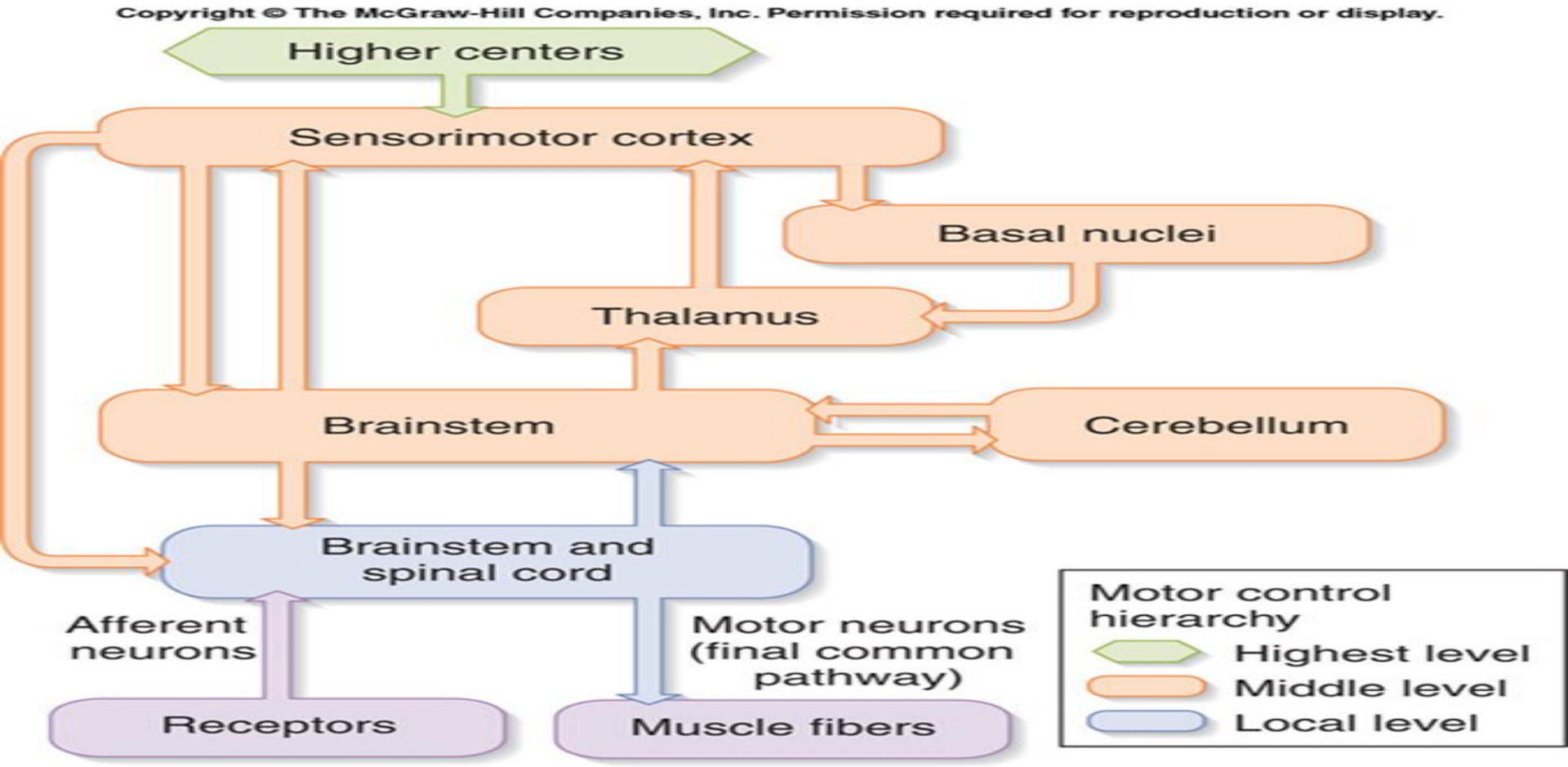
- Later, **Georg (1928)**

➢ pathology of the brain may result in the persistence of primitive lower level reflexes.

➢ He suggested that a complete understanding of all the reflexes would allow the determination of the neural age of a child or of a patient with motor control dysfunction.

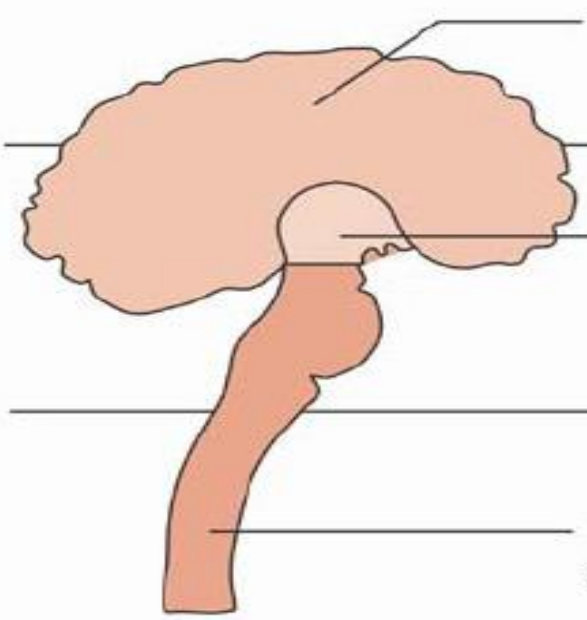
A reflex/hierarchical theory (1938)

This theory suggests that motor control emerges from reflexes that are nested within hierarchically organized levels of the CNS.



Neuro-maturational theory of development (Gesell, 1950's)

- **This theory assumes that CNS maturation is the primary agent for change in development.**

Neuroanatomical structures	Postural reflex development	Motor development
	Equilibrium reactions	Bipedal function
	Righting reactions	Quadrupedal function
	Primitive reflex	Apedal function

Current Concepts Related to Hierarchical Theory

- recognize the fact that each level of the nervous system can act on other levels (higher and lower), depending on the task.
- Reflexes are not considered the sole determinant of motor control, but only as one of many processes important to the generation and control of movement.

Limitation of Hierarchical Theory

- One of the limitations of a reflex/hierarchical theory of motor control is that it cannot explain the dominance of reflex behavior in certain situations in normal adults.

e.g. stepping on a pin .

- one must be cautious about assumptions that all low-level behaviors are primitive, immature, and non adoptive, while all higher level (cortical) behaviors are mature, adaptive, and appropriate.

Clinical Implications of Hierarchical Theory

Brunnstrom "When the influence of higher centers is temporarily or permanently interfered with, normal reflexes become exaggerated and so called pathological reflexes appear".

Berta Bobath "The release of motor responses integrated at lower levels from restraining, influences of higher center, especially that of the cortex, leads to abnormal postural reflex activity"...depend on normal postural activation (verticalization and midline orientation).

III. Motor Programming Theory

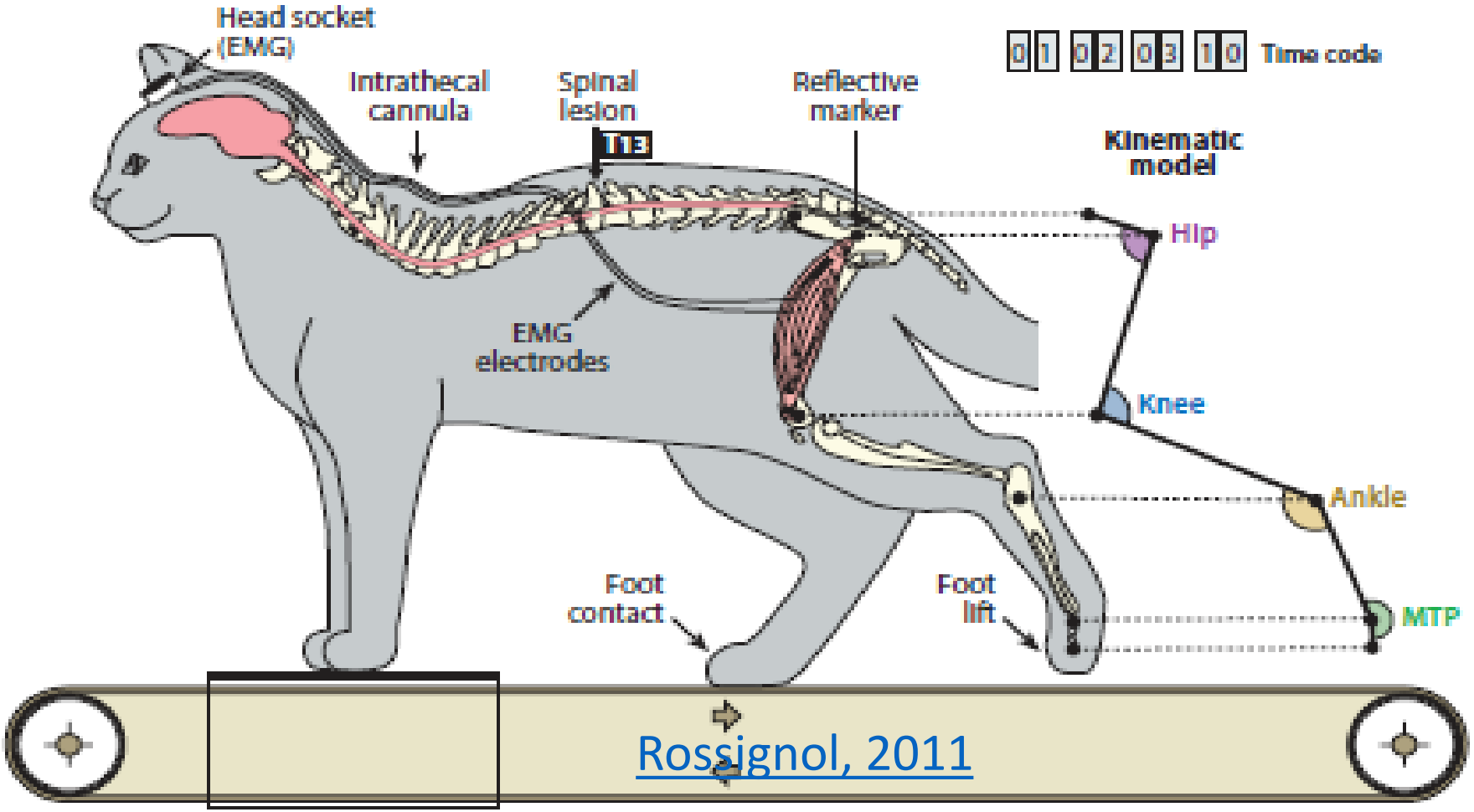
- Concept of a **central motor pattern or motor program**
- Explore physiology of actions rather than physiology of reactions.
- Movement is possible even **in the absence of stimuli or sensory input** but they are important in **adapting and modulating the movement**

III. **Motor Programming Theory**

- **Central motor pattern**, is more flexible than the reflex concept because it can either be activated by sensory stimuli or by central processes.
- **Spinal neural networks** could produce a locomotors rhythm with neither sensory inputs nor descending patterns from the brain. By changing the intensity of stimulation to the spinal cord, it could be made to walk, trot, or gallop.
- Thus, it was again shown that reflexes do not drive action, but that **Central Pattern Generators** (spinally mediated motor programs) by themselves can generate such complex movements as the walk, trot, and gallop.

Central Pattern Generator (CPG)

Neural connections are stereotyped and hard wired result in a specific neural circuit for generating walking in the cat



III. **Motor Programming Theory**

- Motor program is also used to describe the higher level motor programs that represent actions in more abstract terms.
- A significant amount of research in the field of psychology has supported the existence of hierarchically organized motor programs that store the rules for generating movements so that we can perform the tasks with a variety of

Limitation of motor program theory

- Central pattern generator concept was never intended to replace the concept of the importance of **sensory input** in controlling movement.
- Limitation of the motor program concept is that a central motor program cannot be considered to be the sole determinant of action
- The motor program concept does not take into account that the nervous system must deal with both musculoskeletal and environmental variables in achieving movement

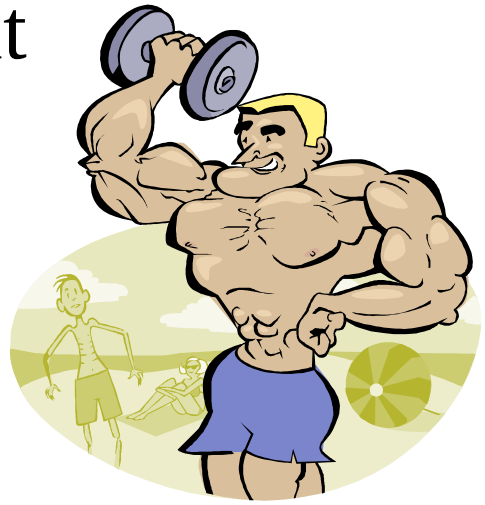
Clinical Implications of motor program theory

- Explanation for abnormal movements have been expanded to include problems resulting **from abnormalities in central pattern generators or higher level motor program**
- In patients whose higher levels of motor programming are affected, motor program theory suggests the importance of helping patients relearn the correct rules for action.
- In addition, intervention should focus on retraining movements important **to a functional task, not just on reeducating specific muscles in isolation**.

IV. Systems Theory (Degree of Freedom Problem)

- How does the CNS select a solution from an infinite number of possibilities for a task?
- **Solution**

  Higher levels activate lower levels while lower levels activate synergies, i.e. groups of muscles that are constrained to act together as a unit



- In describing the body as **a mechanical system**, **Bernstein** noted that we have many degrees of freedom that need to be controlled(not extreme/ uncontrolled/abnormal movement).
- Bernstein looked at the whole body as a mechanical system, with **mass**, and subject to both **external forces** such as **gravity** and **internal forces** such as both **inertia.**
- Bernstein suggested that **control of integrated movement** was probably distributed throughout **many interacting systems working** cooperatively to **achieve movement** (concept of a distributed model of motor control).

- He said, "**Coordination of movement**" is the process of mastering the redundant degrees of freedom of the moving organism"
- Thus, for example, when the demands of **a task increase**, the **control signal to the synergy increases**, leading to parallel **increases in the activation in all muscles in the synergy**.
- Thus, Bernstein believed that synergies play **an important role in solving the degrees of freedom problem**. This is achieved by constraining certain muscles to work together as a unit.

Latash's Principle of Abundance

- He proposed a new definition of the term ***synergy.*** (synergies are not used by the nervous system to eliminate redundant degrees of freedom, but instead to ensure flexible and stable performance of motor tasks.

V. Dynamic Systems Theory: Principle of Self-Organization

- Movement emerges as a result of **interacting elements**. No needs for specific neural commands or motor programs.
- Variability of movement is normal. Optimal amount of variability allows for flexible, adaptive strategies to meet the environmental demand

- Dynamic theory suggests that the new movement emerges because of a critical change in one of the systems, called a "control parameter." A **control parameter** is a variable that regulates change in the behavior of the entire system(e.g. Velocity)**(critical elements may change motor performance).**
- The dynamic action perspective has **de-emphasized** the notion of commands from **the central nervous system** in controlling movement and has sought **physical explanations** that may contribute to movement characteristics as well

- The role of variability in motor control differ between theories of motor control.
- **In motor program theory,** variability is considered to be the **consequence of errors** in motor performance, with the assumption that as performance improves during skill acquisition, error—and consequently variability decrease.
- **In dynamic systems theory**, variability is viewed as a critical element of normal function, therapists will encourage patients to explore variable and flexible movement patterns that will lead to success in achieving performance goals.

- Variability of movement is normal. Optimal amount of variability allows for flexible, adaptive strategies to meet the environmental demand.

- Too little variability can lead to injury (as in repetitive-strain problems), while too much variability leads to impaired movement performance, such as occurs in persons with ataxia

- **Kelso and Tuller (1984)** have shown that stable movement patterns become more variable, or unstable, just prior to a transition to a new movement pattern.
- For example, if persons are asked to move their two index fingers of the right and left hand out of phase, while making the movements faster and faster, an abrupt **phase transition** occurs between the two fingers.
- Researchers have documented an increase in variability prior to the emergence of new, more stable patterns of behavior during the acquisition of new movement skills in both children and adults

Why systems Theory (including the dynamic systems) is considered discussed the broadest of the approaches.?

- Because dynamic systems theory takes into account not only the contributions of the **nervous system to action,** but also the contributions of the **muscle and skeletal systems**, as well as the **forces of gravity and inertia**. It predicts actual behavior much better than did previous theories.
- This theory reminds us that **the nervous system in isolation will not allow the prediction of movement**

Clinical Implications of Systems Theory

- Body is a mechanical system. Consider musculoskeletal factors underlying a patient's movement problem
- Movement emerges from the interaction of multiple elements that self-organize based on certain dynamic properties of the elements themselves
- Changes in movements may not necessarily result from neural changes, e.g. faster vs. slow gait, speed during sit to stand
- Encourage the patient to explore variable movements

Limitation of systemic theory

- Nervous system is fairly unimportant.
- How do we apply mathematics and body mechanics to clinical practice ?

VI. Ecological Theory: Gibson's Perception-Action Coupling

- Actions require perceptual information that is specific to a desired goal-directed action performed within a specific environment.
- The organization of action is specific to the task and the environment in which the task is being performed.
- Perceptual information of the environmental factors relevant to the task goal is necessary to guide the action
- Attention to "perception" and its link to "action".

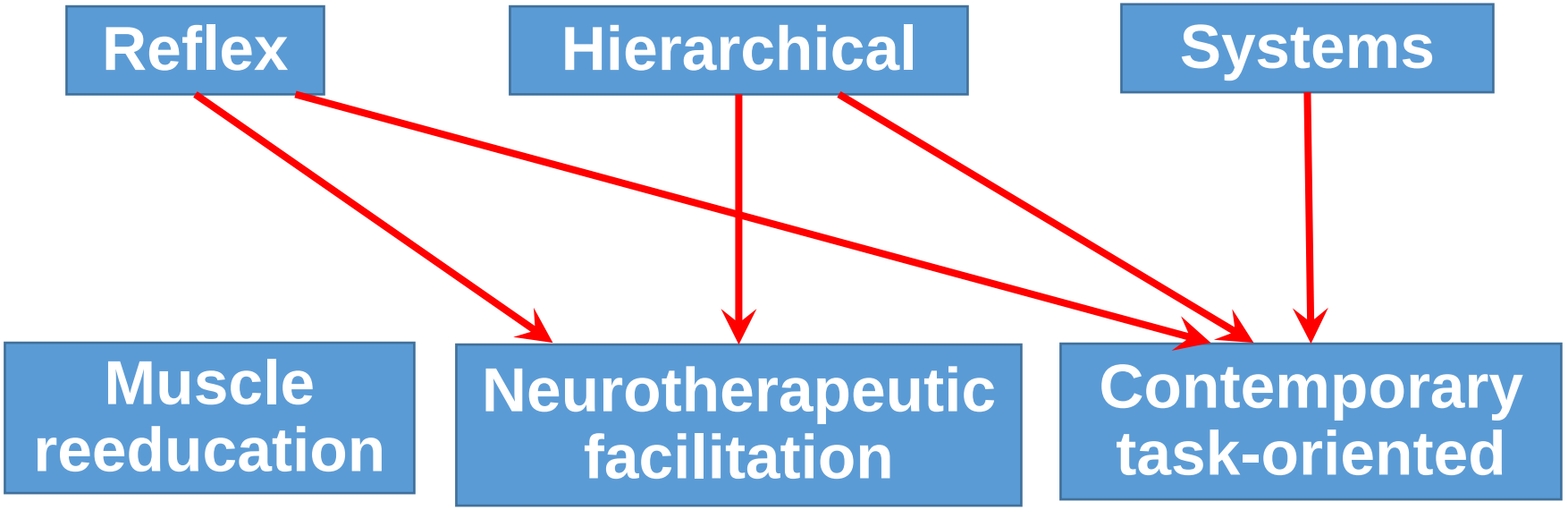
- **From an ecological perspective**:
- How an organism detects information in the environment that is relevant to action and how this information is used to modify and control movement.
- Broadened our understanding of nervous system function from that of **a sensory/motor system,** reacting to environmental variables, to that of a **perception/action system** that actively explores the environment to satisfy its own goals.
- **Limitation:** less emphasis to the organization and function of the nervous system

Clinical Implications of ecological Theory

- Individual is an active explorer of the environment for learning.
- Individual discovers multiple ways to solve movement problems in environment(variability).
- Fundamental to the play-based therapy for pediatric patients (sensory integration system).

Neurologic rehabilitation approaches

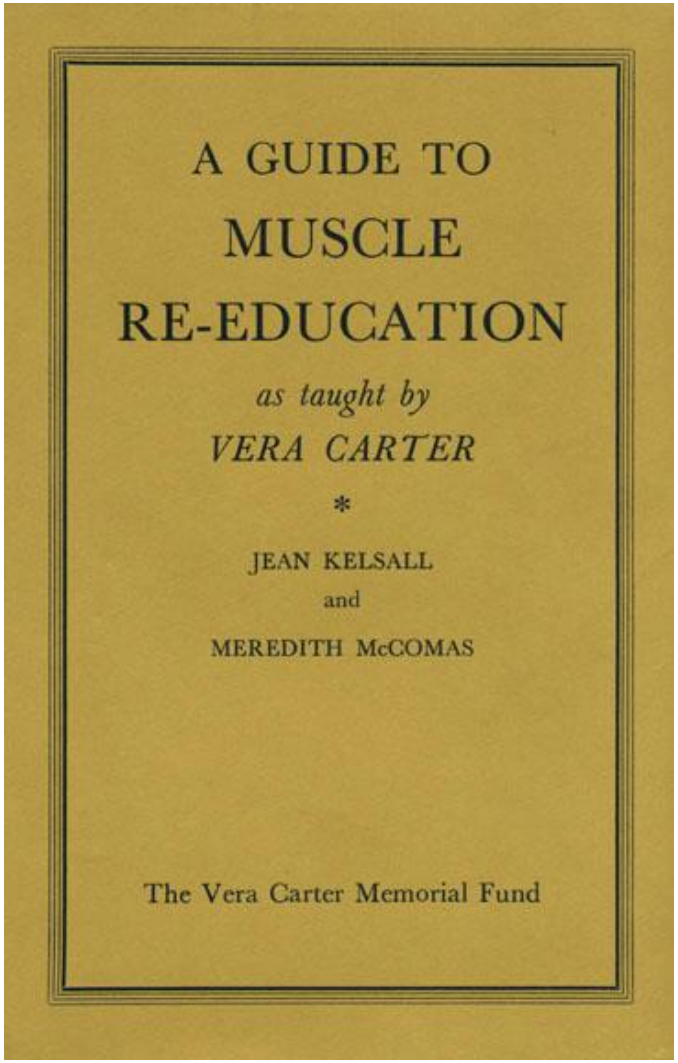
Motor control models



Neurologic rehabilitation models

Muscle reeducation

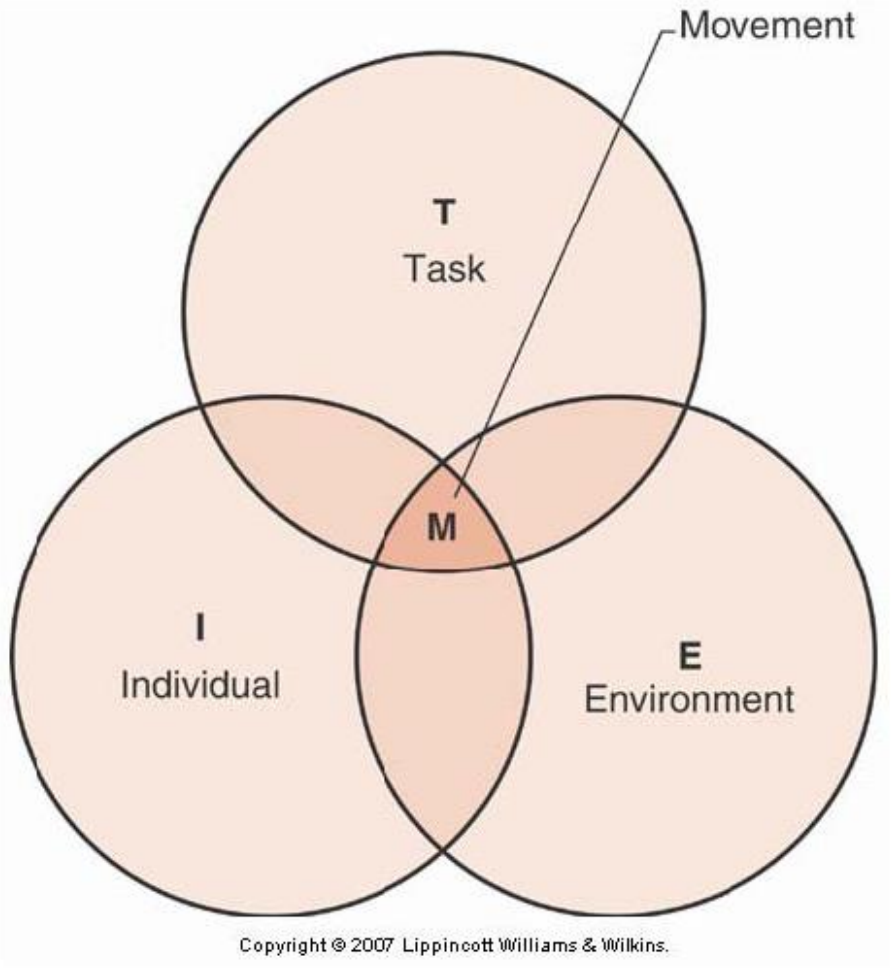
- Prior to the development of the neurofacilitation approaches, therapy for the patient with neurologic dysfunction was directed largely at changing function at the level of the muscle itself.
- This has been referred to as a muscle reeducation approach to intervention (Gordon, 1987; Horak, 1992).



Reflex-based Neurofacilitation Approaches

- Brunnstrom, Bobath-Neurodevelopmental treatment (NDT), PNF
- Top-down control of movement (i.e. corticalization)
- Abnormal movement is a direct result of neural lesion
- Recovery requires higher centers regain control
- Inhibit abnormal movement patterns to facilitate return of motor skills
- Repetition of normal movement patterns will automatically transfer to functional tasks

Task-Oriented Approach (motor control of motor learning approach)



Task-Oriented Approach

- Movement is organized around a behavioral goal and is constrained by the environment
- Patients learn by actively attempting to solve the movement problem rather than by repetitively practicing normal patterns of movement.

constraint-induced movement therapy.