

# Science and education

## NEUROSCIENCE

The neurophysiological explains movement and learning.

# Author Guido Marcangeli



Union of professionals Ki Life (U.P.K.L) aisbl  
Siège social, 4 rue de la Presse 1000 Bruxelles (BE)  
N..E 0545921938  
U.P.K.L. est reconnue AISBL par l'Arrêté Royal WL 22/16394

## GENERAL VIEW

The motor action is :

- a PHYSICAL event of a mechanical nature; it has to do with the biomechanics of the gesture and concerns those muscular components, joint and bony, that change shape in space, according to a specific time.

- a BIOLOGICAL event, organic; it concerns the functionality of large apparatuses, cardio-circulatory, respiratory, endocrine, and energetic, to preserve homeostasis in all situations.

- a MENTAL event, of nervous nature; it concerns the intervention of the central and peripheral nervous system, interested both at the peripheral level, with perception; at the central level with the areas of perceptive and motor association; still at the peripheral level with motor neuronal activation; it concerns the representation of the action and its innumerable transformations.

To perform and understand a movement, you must refer to 3 areas:

- PERCEPTIVE: facilitating the extraction of the signal.
- SELECTIVE RESPONSE: decreasing the number of alternatives to be chosen based on motor memory.
- MOTORIA: allowing the appropriate neuromuscular response on a co-ordinative basis.

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For each action, the problem cannot be reduced to the simple casual relationship NEUROLOGIC INPUT - MUSCULAR EXECUTION.

To perform a movement YOU MUST HAVE LEARNED IT, which means having learned a complex set.

This learning includes the modalities of processing incoming and outgoing INFORMATION related to the action and the dynamic relationships with other learning and emotional dimensions.

We use what we have learned in the execution, but the learning can undergo continuous fine-tuning.

**MOTOR LEARNING:** a set of processes associated with exercise and experience determine a relatively permanent change in performance or behavioral potential (Schmidt - Lee 2014).

According to these two authors, who will be, along with Wrisberg, the reference points of these guidelines, we speak of:

- **PERFORMANCE:** observable behavior in a given moment, temporary and influenced by factors such as fatigue and motivation;

- **LEARNING: STABLE CHANGE IN BASIC PROCESSES** the specific motor skills.

These two topics are distinct and not always coincident.

According to the two most influential motor learning theories, **COGNITIVE** and **DYNAMIC**, there are three successive stages in the transition from initial execution to an expert step; the differences are the didactic indications. In both contexts, **COGNITIVISTICS** emphasizing cognitive processes, and **DYNAMICS** emphasizing motricity, the theoretical reference is always cognitivist:

- **COGNITIVE VERBAL STAGE** (development of rough coordination);
- **MOTOR STAGE** (development of fine coordination);
- **AUTONOMOUS STAGE** (development of variable availability).

## COGNITIVE THEORY (Wrisberg - Schmidt - Lee)

### ASPECTS OF THEIR APPLICATION:

Learning explained the increase in INFORMATION stored in long-term memory by developing effective software engines through precise control of the Central Nervous System. Each stage of motor learning addresses specific problems. The role of memory and cognitive processes are decisive in solving them.

- VERBAL COGNITIVE PHASE  
(DEVELOPMENT OF GENERAL COORDINATION)

In the first phase of learning, you must understand the action's objectives and what needs to be done to solve the problem. There are numerous errors in movement and response time. To help, can use internal verbalizations to tell what to do and think about effective strategies. Acquiring basic movements is usually fast. The transition to the next stage is rapid in athletes and adults, slow in young people with limited complex skills and abilities baggage. The transition to the next stage is rapid in athletes and adults, slow in young people with limited complex skills and abilities baggage. You can use adequate instructions and demonstrations if you face an utterly foreign task. This solution you can adopt during an early stage to get a general idea, and it has to be abandoned as soon as you become more experienced.

## **DIDACTICS - PRACTICAL VISION:**

Build a basic idea of the skill to learn in terms of goals and means to achieve them.

The coach must provide data to provide a first mental representation of the gesture, which will guide the execution (motor program).

The coach initially has to control the action step by step through the athlete's verbalizations.

The acquisitions gradually evolve, starting from what the subject knows how to do, introducing increasing difficulties, highlighting similarities between the skills possessed and acquiring.

Provide adequate instructions through verbal instructions and demonstrations, help identify and distinguish appropriate and irrelevant sources of environmental information, provide verbal feedback on serious errors, help maintain a sufficient level of motivation.

### **• ASSOCIATIVE-MOTOR PHASE (DEVELOPMENT OF GOOD COORDINATION)**

The action is perfected and becomes more precise, fluid, and fluid, thanks to a better intervention of the kinesthetic analyzer.

The energy costs are reduced, the voice guidance takes less importance, decreases the frequency of errors, the execution corresponds more and more to the theoretical technical model, the sensations resulting, from the movement, are more precise, the movements are faster and more automatic.

In complex or unforeseen situations, errors typical of the previous stage still emerge, with the tension of the antagonistic muscles.

The changes are slower and more gradual than the previous phase because a first technical improvement is sought.

With rapid movements (open skills), the motor program is built to meet the demands of the movement, with the diversification of actions in response to variable conditions; with slow movements (closed skills) to control the action it processes and uses the feedback from the execution of the movement.

With the discovery of the regularity of the environment, it develops anticipation and timing, with better detection and correction of errors.

## **DIDACTIC - PRACTICAL ASPECTS:**

Attention is paid to critical execution points to avoid continuous and wasteful control over the individual components of the action.

The ability to predict events (anticipation) improves thanks to regularity in performance (specific results correspond to a particular action).

The supply of multisensory information enriches the mental representation and permits the kinesthetic analyzer to acquire more relevance.

Relevant environmental and situation characteristics are understood and integrated, and sensory information is linked to appropriate motor responses.

Help identify and respond to changes in environmental situations, rather than providing instructions on how to implement them.

Open and closed skills propose different executive speeds, requiring rapid and diversified reactions to sudden stimuli and often changing space.

Progressively reduce the amount and type of feedback to develop the ability to evaluate their execution, identify errors alone and correct them, favoring introspection and analysis of execution.

## **AUTONOMOUS STAGE (DEVELOPMENT OF VARIABLE AVAILABILITY)**

This stage is reached after much practice, and the action is carefully controlled, with minimal energy expenditure, fast execution, coordinated, and effective even in unforeseen and difficult situations.

The technical gesture is performed appropriately, and with few errors, the recognition of errors and their correction is quick, the sensations resulting from the movement are accurate.

In this phase, there is the ability to shift attention to external stimuli, performing the technical action simultaneously and correctly.

This phase is typical of high-level performance, with slow and minor improvements compared to previous phases. In addition to considerable practice, high-quality technique, and strong motivation, they are necessary and have a specific motor and cognitive prerequisites.

The movements are performed in automated form with the programming of longer sequences; not all programs are activated, leading to a decrease in the demand for attention. The increase in the automatism of sensory analysis allows rapid changes in movements and strategies, and the effect is an increase in safety and the ability to detect errors.

## **DIDACTIC - PRACTICAL ASPECTS:**

Great is the ability to perform the technique in an automated manner by paying little attention to the control of movements.

The motor programs are highly refined.

The sensations are easily connected to theoretical explanations.

The multisensory mental representation corrects the movement by comparing expected and tangible results.

The improvements are becoming less evident. Further progress, even minimal, takes a long time. The fundamental objective is to support motivation, give instructions on the accuracy and refinement of the technique, adapt the technical gestures to different situations.

## **COGNITIVE THEORY LEARNING ABOUT MOVEMENT**

A movement, to be executed appropriately, must be learned beforehand.

As we have seen, the first stage leads to coarse coordination, aided and guided by conscious feelings, including visual information that is the most important at the beginning, to see, understand, try to imitate, and correct a movement.

In a second time, the coordination becomes more refined; the information comes from the cutaneous, vestibular, kinesthetic, auditory, tactile receptors; in this way, different motor units are selectively recruited, the antagonist and agonist contraction is timed, reducing the energy cost of movement.

When the coordination is maximum, then control passes from the cerebral cortex to the cerebellum and the basal ganglia, the movement becomes automated, with the cortex's role in order to intervene in unexpected situations.

Therefore, the cognitive approach foresees centralized mechanisms of elaboration of the information, postulates the existence of motor programs that guide the action, with great importance assigned to the memory in the attribution of meaning to some stimuli.

The decision-making, therefore, follows the perception and precedes the action; one has read of the situation, recall from the memory the past experiences and the various possible solutions. The function and the deep meaning of the S.N.C. in the motor program are valued to the maximum, proceeding for three successive stages:

- PERCEPTION
- DECISION TAKEN,
- RESPONSE PROGRAMMING

(Schmidt 1975 - Schmidt, Lee 2014). SCHEMA THEORY (Schmidt - Wrisberg 2000, Schmidt - Lee 2014):

After identifying the information coming from the sense organs, in the successive stages of elaboration, through the memory take place decision-making processes of selection of the motor program and programming of the answer.

The motor program is chosen to solve the task at the response selection stage. In long-term memory, the motor program is considered a mental representation of an action, which drives execution even without feedback.

There is also a generalized motor output program with this theory, referring to a class of similar actions. The characteristics of motor responses are:

- **ORDER OF ELEMENTS:**  
the sequence of muscle contractions;
- **TIME STRUCTURE (TIMING):**  
the proportion of time for individual segments of movement (rhythmic structure of the gesture);
- **RELATIVE STRENGTH:**  
the constant proportion of the forces expressed by the various first motor muscles.

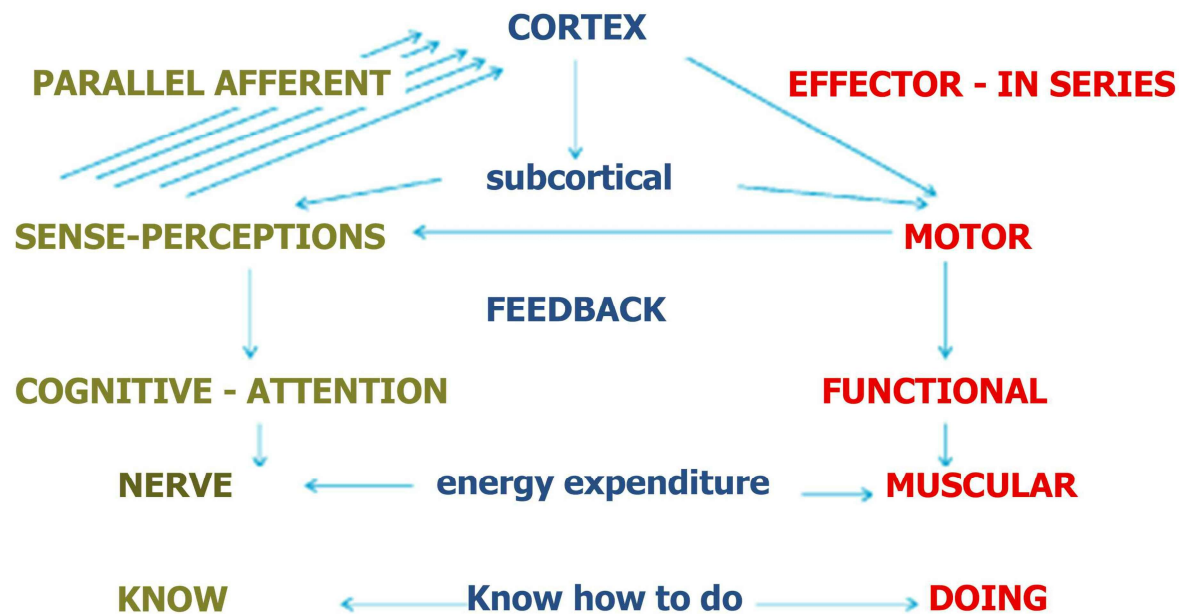
The generalized exit program can then be adapted through performance parameters such as force - overall duration - width - direction - involved musculature.

Through learning, the motor program is perfected consolidated based on identifying the differences found between the desired end and the result achieved.

With experience, acquire action programs and sets of rules, or schemes, that adapt a specific response to each circumstance.

Learning takes place through memorizing the movement parameters, the conditions preceding the action, the results achieved, the sensory consequences of the responses; this information allows to identify and correct the error (motor and sensory feedback play a key role in identifying the error).

## THE COGNITIVE NEUROPHYSIOLOGICAL MODEL



According to this scheme, during voluntary learning, five perceptions (visual, auditory, tactile, kinesthetic, vestibular) affect in parallel from nerve receptors to areas of sensory association; they are identified to select the response, which starts from the motor association areas (4 pyramidal mono-synaptic, and six extrapyramidal multi-kinetic), which affects in series three times per second to muscle fibers. Each motor action generates feedback, external and internal, essential for the recognition and correction of any errors. When the movement is automated, the levels of processing and choice pass to the subcortical level (brain stem and cerebellum), with sensory and motor automatisms. So there is a consumption of energy at the level of the brain for cognitive and functional activity.

(glucose for neuronal metabolism) which is functional (anaerobic and aerobic muscle mechanisms). So the functional system has three components:

- AFFERENT COMPONENT; and
- CENTRAL REGULATORY COMPONENT;
- EFFERENT COMPONENT.

### AFFERENT COMPONENT

It is represented by the elaboration of the affective synthesis by the Central Nervous System, which represents the stimulus to adaptation. Thanks to the complex interaction between motivation, memory, current and initial information, it happens.

### PERCEPTION

Through experience, we acquire skills that give quality and meaning to other experiences; the subject becomes an expert when he can mediate the experience. Perception has a dynamic character: it is up to the subject to possess the ability to represent himself and carry out the necessary changes at the conscious level (orientation of his attention, ability to discriminate, conscious recognition of what he chooses). The perception is an interpretive task, for which a complex and intelligent system of interferences is necessary. Sensitivity is subject to cortical control (Guyton 1984).

Perception is the attribution of meaning to the collected data with the sensitivity and processing of information, both active and intentional processes. The basis of perception is information from the sensory organs. Visual information is dominant in the early stages of learning, while kinesthetic sensitivity is more significant in the advanced states of acquisition and improvement of the gesture. The interaction of the different systems allows refining the perception of time, as there is no specific receptor for this. Estimation of time durations is facilitated by the experience and formation of a mental reference representation. The stimuli enter in parallel. There is a succession of:

- stimulus identification
- Selection of response
- Programming the response.

#### EXPERT PERCEPTION OF THE SITUATION:

the experienced athlete uses PERCEPTUAL NARROWING to pay attention only to important perceptions in that context that provide essential information. It stores relevant information representing knowledge, guiding its search for information, and is then retrieved automatically during the situation to read it correctly.

## ANALYSERS OF THE MOVEMENT

They are nerve receptors of different types:

Three exteroceptors (visual, auditory, tactile),

1) proprioceptor,

1) analyzer with integrated operation with others (vestibular).

### KINESTHETIC ANALYSER MEANS:

proprioceptors, stimulated by the movement in its muscle components - tendons, joints, bones (neuromuscular spindles, tendon organs of Golgi, Pacini, and Ruffini receptors, free terminations).

It is indispensable for the PERCEPTION SPACE - TIME to recognize distances and heights.

The combination of space and time gives the speed: an action is performed slowly or quickly, leading to a different evaluation of the body and the object in motion and to programming and execution of the response in proper time (Jonassen, Meinel, Blume 1978).

A TACTILE ANALYSER shall: provides information on the shape and surface of objects/soil.

There are receptors on the skin's surface to detect touch, pressure, and temperature; it plays an essential role in controlling fine motion and the gradation of the vital force pulses.

The tactile-pressure information is present mainly on the plantar area (distribution of pressure on the ground, equilibrium, transmission of forces from the body to the ground, and vice versa; also information on water and air).

#### VISUAL ANALYSER MEANS:

gives information on the beginning, course, and end of the movement; visual information refers to the relative displacements of the environment with respect to the body, to have information on distances and space; to build or modify the image of the action of others.

#### FOCAL VIEW:

for object identification, with the central field of view (WHAT IT IS).

#### ENVIRONMENTAL VISION:

for motion control, central and peripheral visual field (WHERE IT IS).

The information is first processed through peripheral vision and then supplemented by a more precise central analysis. This can be accomplished if one educates one's attention: the visual focus on information involves a focus of the attention on it, reducing the attention on all that surrounds it.

## AUDITORY ANALYSER MEANS:

gives information from the outside (verbal) and typical movement (noise).

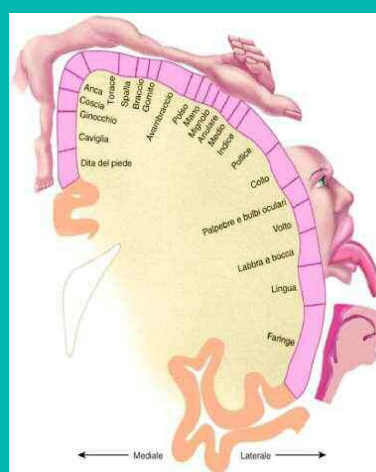
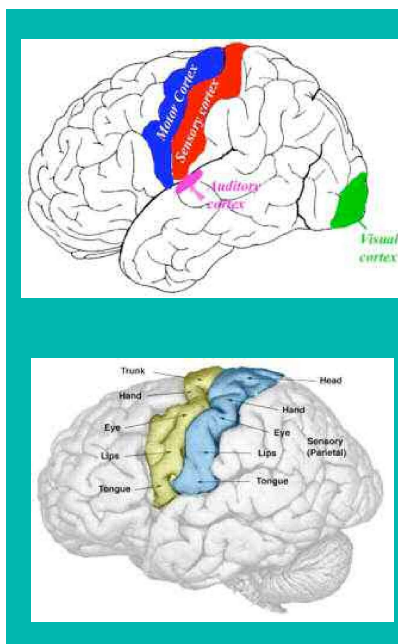
## VESTIBULAR ANALYSER:

through the inner ear labyrinth's semicircular channels, giving information on balance in linear and angular (dynamic) and static movements.

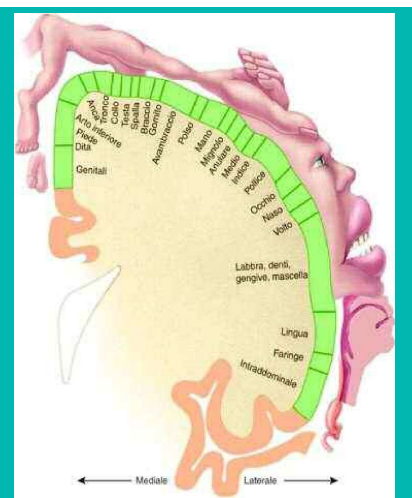
The labyrinthine information is related to the linear and rotational accelerations the labyrinth is subjected to.

The balance comes from a continuous tonic-postural-co-ordinative adaptation and is determined by kinesthetic information (continuous adaptation of the musculature and articulations to modification of the posture) and tactile, visual, vestibular.

## CENTRAL REGULATORY COMPONENT



**HOMUNCULUS  
MOTORIUS**



**HOMUNCULUS  
SENSITIVUS**

## HEMISPHERES OF THE BRAIN:

with frontal, parietal, occipital, temporal lobe.

The excitations on one side come from the contralateral motor area, with crossing at the bulb level. Each hemisphere is connected to the motor and psychic contralateral, both connected by the corpus callosum.

The sensitive and motor cortex areas are vast for hand and mouth. (homunculus motorius and sensitive).

Sensorimotor stimuli that arrive in and depart from the cerebral cortex may be associated with homunculus, with a distorted reflected image of the body (Penfield, Boldrey 1937).

There is a relationship between the size of these brain areas and the accuracy of motor control.

## IMAGES OF THE TWO HEMISPHERES AND OF THE MOTOR AND SENSITIVE HOMUNCULUS

### FRONTAL LOBE:

the decision-making capacities, the attention, the planning of the strategies are the center; it is the elective seat for the development of the thought.

### PARIETAL LOBE:

there is a sense of spatial orientation and perception.

### OCCIPITAL LOBE: view;

Stimulating visual perception promotes learning and memorization.

### LEFT FRONTAL LOBE:

language center (for expression, Broca area).

### TEMPORAL LOBE LEFT:

language center (for understanding, Wernicke area).

### TEMPORAL LOBE: seat of memory:

immediate (sensory storage), short-term (working memory), long-term (relatively permanent storage of information).

Memory is a set of dynamic processes, including recording-storage-retrieval of information. An emotionally relevant stimulus is processed more intensely by the brain.

Emotionally charged events persist in memory and are recalled with greater precision. It involves the prefrontal cortex, the cingulum, the amygdala (rich in dopamine, released by an emotionally important event: necessary for memory and information processing).

#### HEMISPHERES OF THE BRAIN:

the left is in motor and sensitive connection with the right (pyramidal beams, afferent tactile-proprioceptive, and thermal-dolorific pathways, hearing); the smell is homolateral, the sight is mixed.

#### SX-HEMISPHERE:

analytical, rational, information processing in series.

RIGHT HEMISPHERE: synthetic, creative.

No mental process is organized by just one hemisphere or one region of the brain, and the hemispheres do not function separately but require interaction and synergy.

Both define DOMINANCE, a cortical neurological reality. LATERALITY is the predominance and habitual use of a part of the body.

## EFFERENT COMPONENT

The levels of movements are:

- THE VOLUNTEERS,
- AUTOMATED AND AUTOMATED
- REFLECTIONS. VOLUNTARY MOVEMENTS:

Slow, careful, serial processing, thought, controlled, cortical, with continuous feedback intervention, with trial and error procedure.

The voluntary movement is carried out with constant activation of the attentive mechanisms.

The reafferences (feedback) are judged from time to time and proceed by trial and error.

Feedback is the real-time perceptual reentry of the execution, the comparison with the prototype of the action, the evaluation (confirmation, modification, annulment): intrinsic feedback.

Extrinsic feedback is the delayed return of information that indirectly informs us about the action performed.

## AUTOMATED MOVEMENTS ARE CHARACTERIZED WITH:

fast processing, attention to more detail, subcortical (cerebellum, brainstem), with feedback and feedforward intervention, with the process for internalization and mental representation.

According to proven and established procedures, it is performed with confidence as evidence of a previous learning process.

It is an economical, optimized, and thoroughly learned execution. Automating movements is needed from hundreds (Gataulin 2006) to thousands of repetitions (Larsen 2005).

The number of repetitions required depends on motor experiences, on the complexity of movements to be learned or perfected.

The feedforward (proactive control) is the anticipatory control that is implemented by sending information that prepares the muscles for the arrival of a future program of action and presents the sensory system to wait for specific return signals.

Mental representation is the condition of anticipation of action.

## REFLEX MOVEMENTS

The scope is not cortical or subcortical but medullary.

The stimulus proceeds from the sensitive nerve to the spinal cord creates a diastaltic arc, and triggers a muscle response movement without the intervention of consciousness; stereotypical movements that cannot be trained and repeated voluntarily.

### ERROR:

In biological terms, behavior and related cognitive mechanisms are counterproductive in terms of well-being, safety, and organic functionality.

## SYSTEM OF RESPONSE CHOICE OF RESPONSE:

closely related to the ability to choose relevant clues in the environment, to filter from long-term memory as few helpful answers as possible from which to choose the cheapest strategies (automation).

The answer depends on how the information is used, on its perception, of the interaction with environmental inputs (open skills), or with internalized models (closed skills), however in a complex mixture (hybrid control systems).

**OPEN SKILLS:** open circuit, with changing environment, complex, unpredictable, utmost importance to visual and kinesthetic information, cognitive ability, significant decision-making, and little feedback.

**CLOSED SKILLS:** closed circuit, stable conditions, utmost importance to kinesthetic information, motor skills, excellent control, excellent feedback presence.

## **AUXOLOGY SENSITIVE PHASES OF THE PROCESS:**

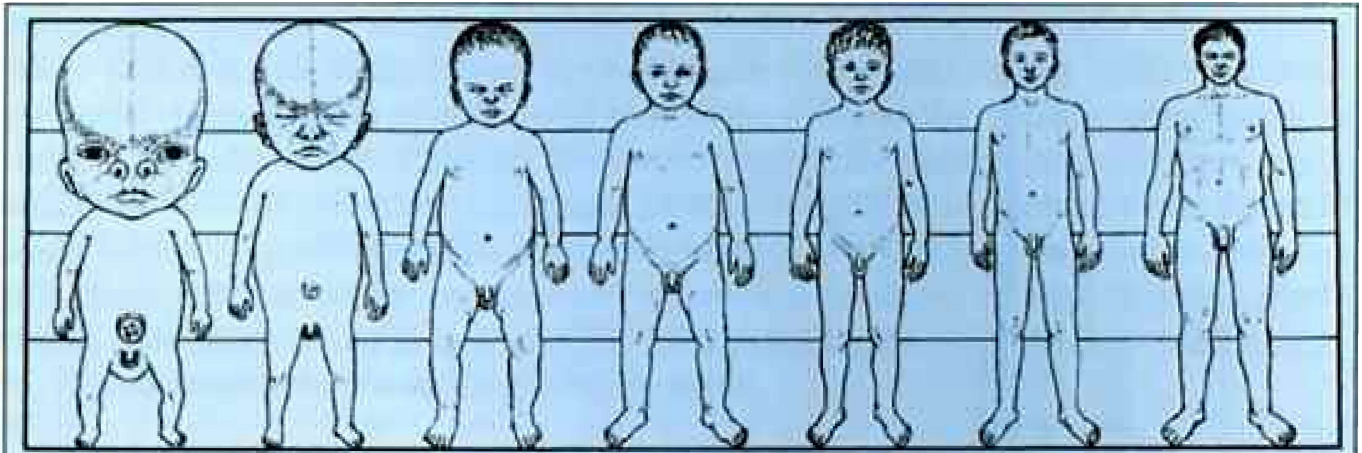
periods of life in which specific patterns of behavior are acquired very quickly and in which there is an excellent sensitivity of the organism towards specific experiences (Hahn). Chronologically limited periods in which cellular systems react more sensibly to environmental stimuli (Winter).

Predetermined periods in which fitness is favorable for specific motor skills (Harre).

The optimal sensitive phase for the nervous system covers the first years of life: the golden age of motor learning of the evolutionary age.

According to the Scammon chart, the maturation curve of the nervous system is fast and early, and the subject in evolutionary age has excellent possibilities to be stimulated adequately on the motor coordinating abilities.

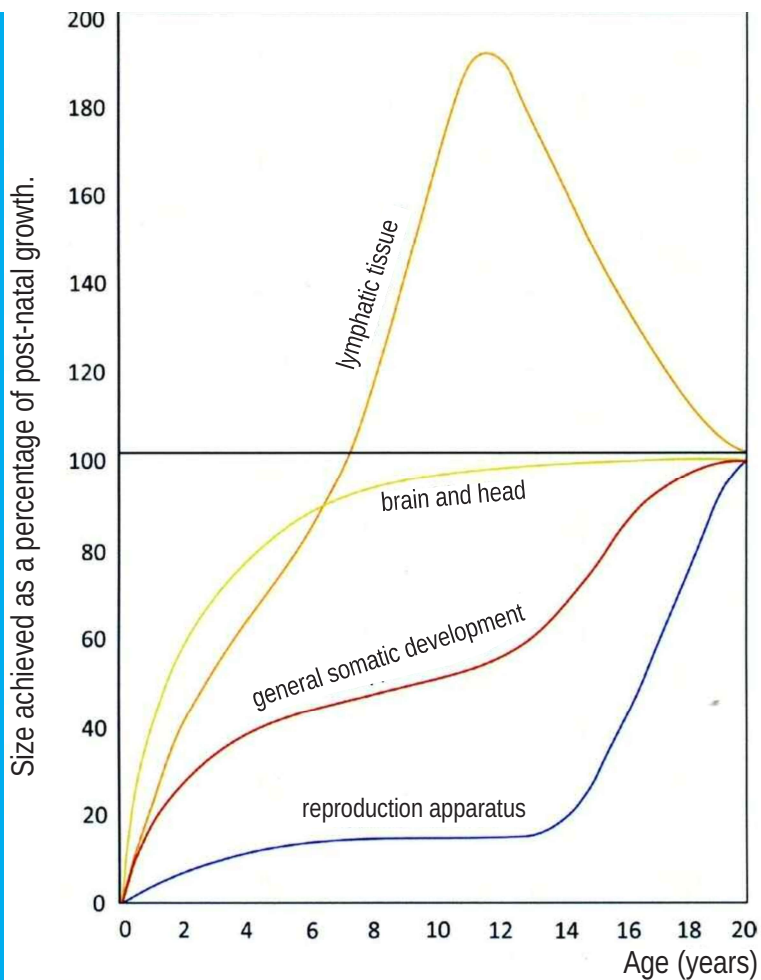
The conditional capacities, in correlation with the maturation curve of the Somatic Systems, will have to be stimulated starting from puberty, seeing the remarkable increase of both male and female hormones.



Fetus of 2 Month    Fetus of 3 Month    Newborn    Baby old 2 year    Baby old 5 year    Teenager old 13 year    Adult

### The morphological change that accompanies growth

Source "Atlante a colori dell'esame fisico del paziente" published by Mediserve Editor, 1991 author prof. Seidel HM



Growth trends - Key models by Scammon R.E.