

Neurodevelopment and Learning - Relevance of Early Child Interactions

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Received: June 26, 2019; **Published:** August 22, 2019

The first years of a child's life, more specifically the period between gestation and 3 years of age, are critical to create the foundations of future learning. Health fostering care, starting with pre-natal care, will promote the necessary conditions for the organic structure of the human being who is being generated, thus structuring and organizing the brain circuits that will encourage the development of various functional systems in the brain [1].

Neurosciences' findings came to strengthen arguments in favor of early care, requiring that practices adopted until very recently be reviewed and adjusted. Evidence shows that investments to improve early childhood life conditions lead to the formation of individuals who will build societies that are more harmonious, hospitable and respectful of human beings. Providing a good early environment also creates opportunities for people to better acquire and develop their humanitarian potential, resulting in greater economic productivity [2,3].

Children's neurologic development in early life includes functional aspects ranging from elementary acquisitions, as sustaining his/her head, to progressively more complex learning, making for a continuous process in which early stages are key to promoting new developments [4].

Each skill learned is the basis for the next

Elementary learning occurs in different functional areas. To understand how learning builds on things learned before, let's take the example of motor development.

Each phase relies on a previous one. Children will not be able to walk independently if they do not have a good control of their posture and hip balance. More complex activities, like sensorial and perceptive functions - auditory and visual discrimination, for example, as well as higher nervous functions as language and attention, for example, take longer periods of time to install themselves and are highly dependent on previous pillars. In development there is no "olympic jumps". It is learning from experience from early life to adult ages [5].

It is important to highlight that these advances do not occur automatically, they require stimuli from prior learning which are recorded in the brain circuits.

There are three necessary interrelated conditions for the development to occur (Figure 1):

- Neurobiological structure: The nervous system, especially the brain, must be mature and ready for learning.
- Stimulus: Children must be encouraged to learn. Usually, such stimuli are promoted by parents, relatives and caregivers.
- Affection: A welcoming environment is key for the establishment and continuation of development.

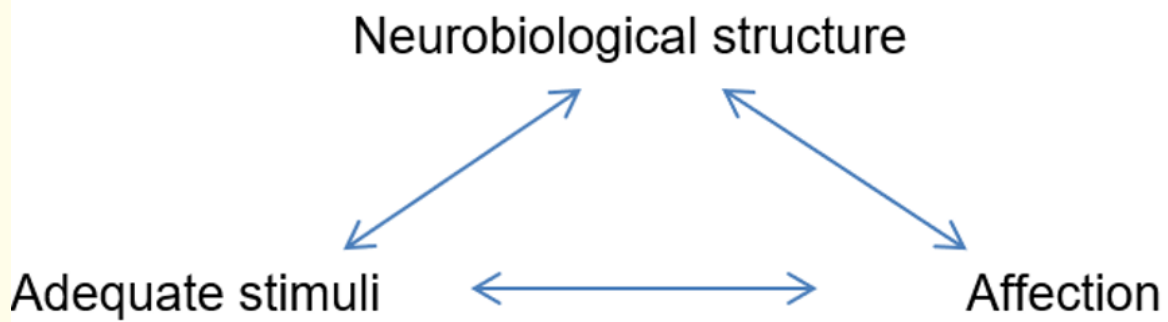


Figure 1: Interactional learning scheme.

Nervous system development - The brain

Focusing more directly on the nervous system and its intrauterine phase we see that the structuring starts a few weeks after conception with the formation of the neural tube [6,7], which will give origin to the encephalic structures, namely the brain, the brainstem and the spinal cord (Figure 2).

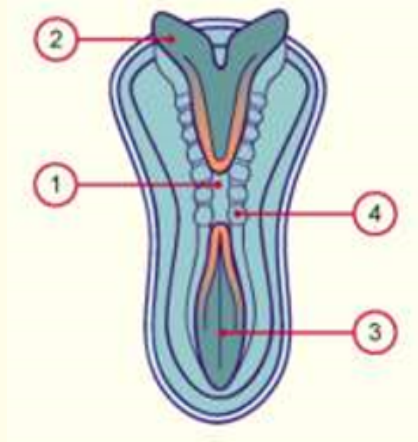


Figure 2: Neural tube: 1- Fused neural folds; 2- Prosencephalon; 3- Rhomboid sinus; 4- Somite.

As the weeks go by, visible modifications occur that will lead to differentiation of the several areas of the brain, with the progressive formation of the cerebral hemispheres (Figure 3).

Simultaneously, the brain's microstructures present ever more complex modifications, resulting in the organization of neural circuits and preparing individuals for the task of learning (Figure 4).

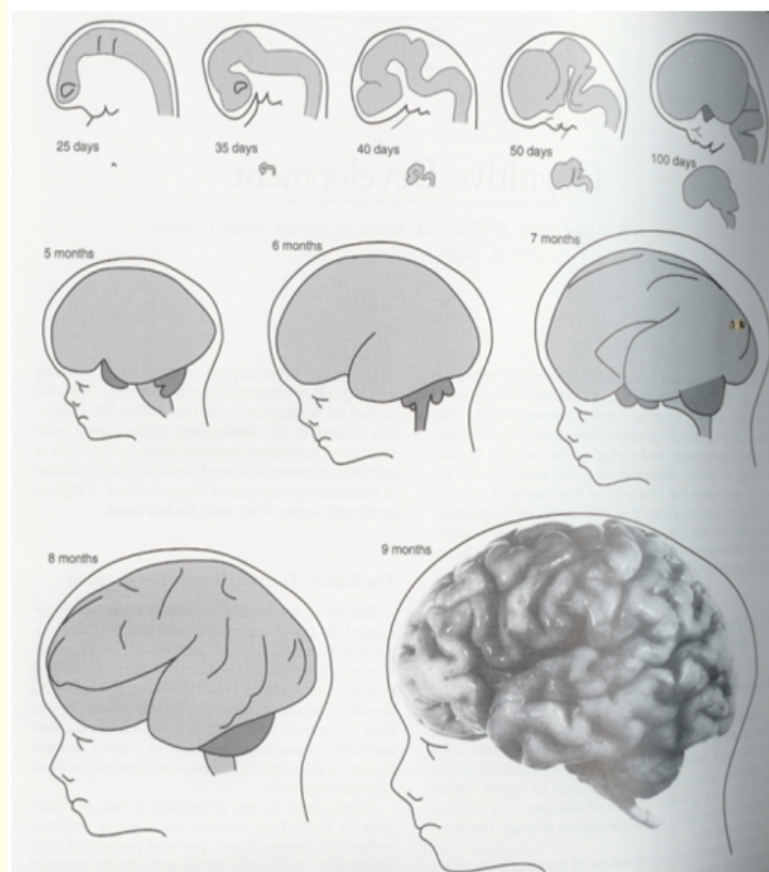


Figure 3: Brain development during pregnancy.

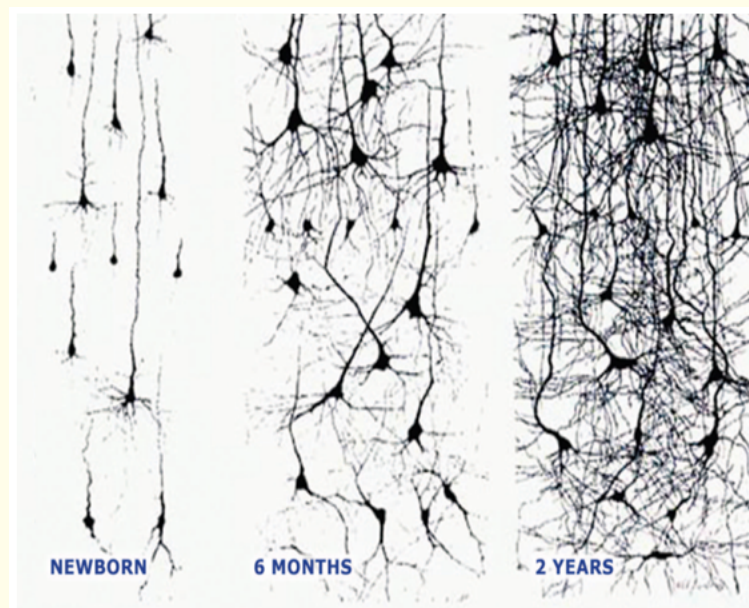


Figure 4: Brain circuits' organization evolution.

This maturation process of the brain is established according to a succession of phases:

- **Multiplication:** Between the 10th and the 14th weeks of pregnancy, young neurons start an exuberant process of multiplication originating around 90 billion new neurons (Figure 4).

Migration and organization of cell architecture: Once formed, neurons migrate to the different regions of the brain, in that their final location is predetermined. Each neuron’s “address” is defined. Each neuron is designed to a specific layer in the cerebral cortex, in one of the six existing layers, and must be correctly positioned to make up, on the whole, what is known as “grey matter” (the outermost layer of the brain).

Synapses (connections between neurons): Once they get to the place where they are designed to be, neurons start interacting with one another through ramifications, known as dendrites and axons (Figure 4 and 6). The contact established between these ramifications is what we call synapsis. These connections serve to receive, conduct and disseminate information, both for the regions that are nearby in the brain and to the distant ones, forming an ultra complex communication network. During the first year of life this network is formed at the incredible speed of 700 new connections per second. This structure will, later, enable wide circulation and dissemination of information to support individuals in more elaborate attitudes and choices.

Myelination (neuron coating): Neuron ramifications coated with a myelin sheath that provides for the neurons’ full functional activity. Myelination starts very early in life and continues for many decades offering individuals the possibility to continue always learning (Figure 5).

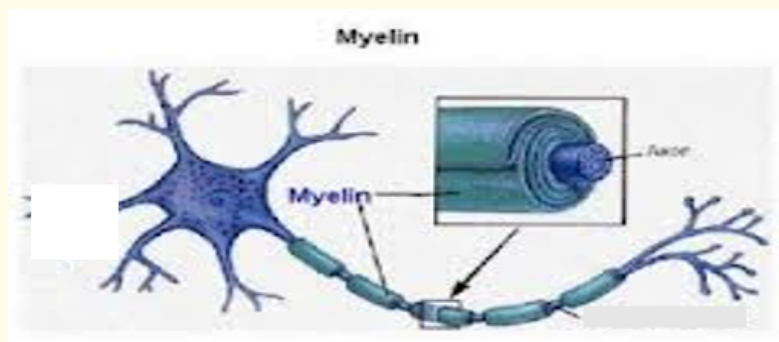


Figure 5: Neuron and axon with myelin sheath.

How brain communication occurs

In order for a neuron to transmit stimuli to another neuron it requires a neurotransmitter, i.e. a substance that facilitates the traffic of information between ramifications. promoting the best communication among circuits of different parts of the brain.

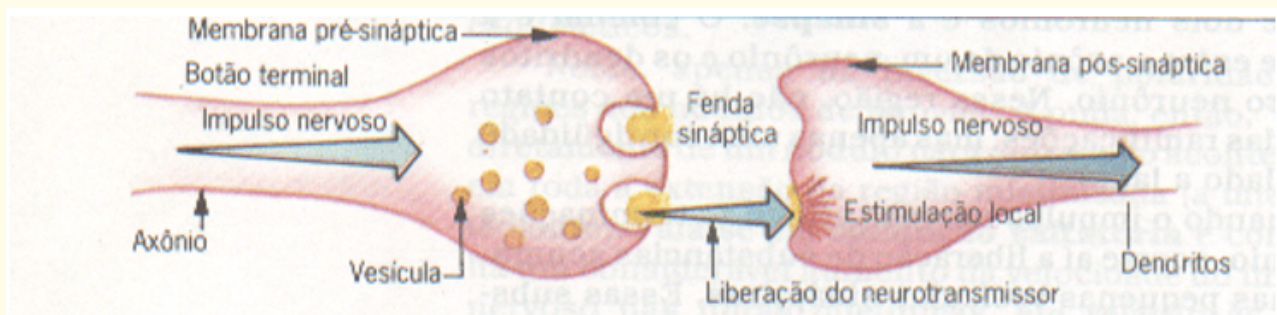


Figure 6: Synapse represented. (Presynaptic membrane, Terminal button, Nervous impulse, Axon, Vesicle, Synaptic cleft, Neurotransmitter release, Local stimulus, Nervous impulse, Dendrites, Postsynaptic membrane).

Genetics and epigenetics

The processes that modify brain structures during pregnancy until delivery are predominantly determined by genetics, the same is true for other organs such as heart and lungs.

The modifications that occur after the birth, epigenesis, are also influenced by the relationships that children establish with those around them, mainly caregivers, who are usually the child’s father and mother. These bonds have the capacity to model, adjust and reorganize genetic tendencies by DNA methylation, chromatin modification, non-coding RNAs and RNAs editing, Transformations resulting from external influences are called epigenetics [1,8]. Epigenetics results from the modifications that occur in the genes due to the influence of the environment in which the individual develops. So, what is experienced in the first years of life determines the future of people and, therefore, the future of society [9].

At the same time that it creates new neurons and connections, the brain also proceeds to do some “cleaning”, eliminating connections that are not being used, in a process called pruning. Pruning starts immediately after birth and extends itself until adolescence. This means that, in order to be permanent, learning (and its corresponding brain circuit) must be useful so that the brain understands its value. Otherwise it will lose importance and may be eliminated.

Development sensitive periods

As we said in the beginning of this article, learning always happens in a sequence, where the previous phase is the basis for the next one. Additionally, there is an adequate moment for each learning to occur. The adequate moment is when brain circuits present the most favorable condition for proper installation. These are called sensitive or critical periods. It is important to highlight that the sensitive periods of valuable functions in the full development of individuals start at very early stages in the child’s life [10]. Sensorial functions such as audition, begin to develop when the child is still in the uterus (Figure 7).

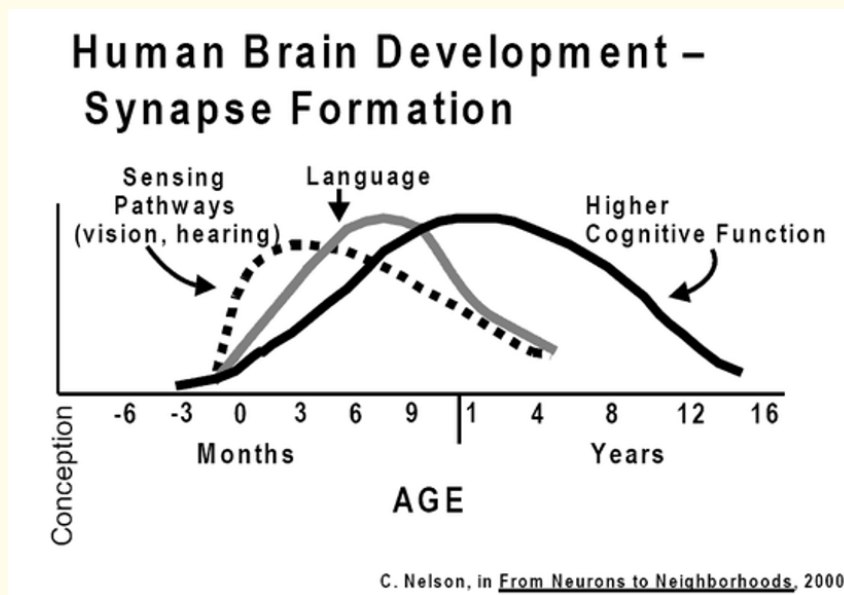


Figure 7: Initial periods of functional development.

This is not to say that children who do not receive the right stimuli during the sensitive period will never learn. Thanks to brain plasticity, which enables us to continue learning throughout our lives, these children will acquire the function, even though, possibly, qualitative and quantitative harm may occur.

If presenting stimuli too late in life may result in losses, presenting them too early is not good either, as the brain structure is still not ready to learn and assimilate the new acquisition. Early presentation of stimuli aiming at early acquisition as well as excessive amounts of information may lead to harmful results, generating exaggerated amounts of stress. This kind of stress, also called toxic stress, may generate emotional development disruption or even organic pathologies in the future [11-13].

Affection, rules, coexisting with frustration and development

At birth, both infants and their brains are ready to start operating and interacting with their surrounding, a key factor for development. From these early relationships - almost always with parents, relatives and caregivers - interaction between the newborn and people around him/her develops. And this interaction evolves to create the bond known as attachment [14-16]. At this point a long life cycle starts between a being who is totally dependent (a baby) and his/her caregivers, who provide protection and affection and try to foster his/her autonomy (Figure 8).

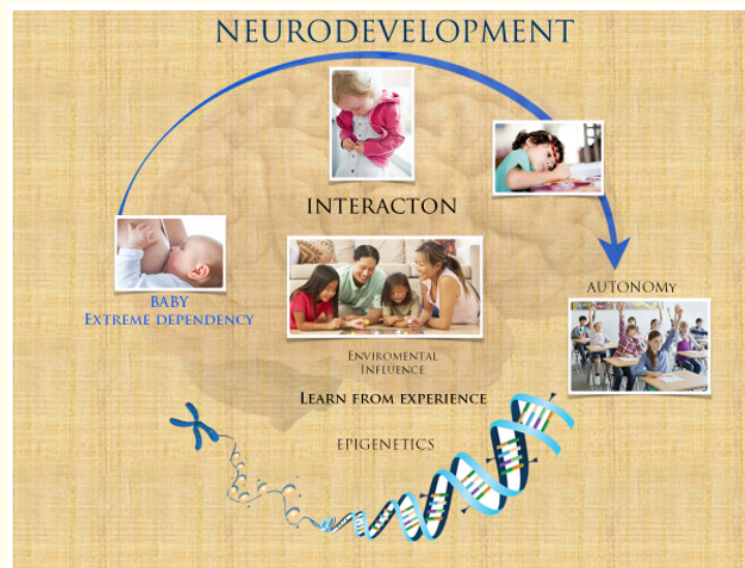


Figure 8: Developmental cycle - Environment Influence.

Autonomy is conquered progressively, showing specific characteristics at each age, and relying on learning and skills previously acquired, as well as emotions experienced at the time learning occurred. First things are learned right after birth. The newborns, albeit totally dependent on others, are capable of expressing their hunger intensely, to meet the need to survive. Crying, which may seem a simple reaction and comes as no surprise to anyone, actually requires a complex internal process, triggered by the brain [16,17].

The brain structures involved in early experiences ensuing from needs are the pre-frontal regions, stimulating the amygdala, located in the temporal lobe - yes, there is an amygdala in the brain.

The amygdala reacts to the stimuli that provoke risk, generating insecurity, fear and, consequently, anxiety.

Anxiety drives the hypothalamus-hypophysis-adrenal axis (HPA axis), which stimulates the suprarenal glands to release hormones: adrenalin, noradrenalin and cortisol.

These hormones make babies uncomfortable, accelerate their heart beat and make them blush and, finally cry, warning the mothers that they are hungry or uncomfortable.

Adaptation and hosting

As time goes by and infants realize that their needs are met, this information will be registered in their memory - they will be less anxious and will not request as many things. We might say that their amygdala is learning to 'behave better', as they feel reassured that their needs will be met and they will no longer feel threatened or at risk in these moments. During the next months, the baby will learn to wait when the mother is not available, i.e. putting up with and tolerating the first frustrations generated by the fact that their needs are not immediately met, without becoming desperate or feeling unattended.

Welcome to the future

Around one year of age, the babies are slowly encouraged to use a small spoon and feed themselves. Around age 2 the child is almost certainly capable of eating without being helped. Later, children will be able to dress up, wait for their turn when playing, winning and losing. And so it goes. Through the interaction and with active participation of family members, children develop the autonomy that one day will enable them to socialize in an adequate manner. Next comes school and the acquisition of more complex skills, along with the ability to deal with natural adversities of life during the growing process.

This preparation starts very early in life, with the most elementary rules and limits. Therefore, it is key that the child be exposed to the frustrations that occur naturally. Dealing with routine, rules about what one can or cannot do, learning to wait and that one cannot always get what one wants immediately are opportunities to prepare oneself for a more adequate social insertion in the future. Remember, these elementary learning will be the steps the more complex.

All these gains from skills learned are represented in brain circuits. Everything that is learned leaves a record in the brain, be it motor skills, emotional or any other kind of learning. Thus, it is key to have a balanced interrelation between genetics and the influence of the environment ("nature X nurture"), so that these circuits get organized in the most favorable manner for the child's optimal future performance.

Executive functions development: Autonomy

Babies begin developing skills and learning how to deal with environmental demands in accordance with their maturity levels [16]. By automatic imitation at first, they will gradually evolve and assimilate by elaborating and integrating the rules, values and attitudes of the outside world with their own resources.

Family members teach them daily routines, starting by the most simple ones, as putting on socks, to the most complex, such as putting the toys back in their places and brushing their teeth, among other things. This means that children have already acquired their organization capacity, which will lead to a healthy stage of autonomy.

Each of these actions may be considered an objective, or a target, similar to others that will come up in adult life, such as preparing for a trip, choosing the clothes one will wear, procuring air tickets and other items. To accomplish these tasks, adults need to have the capacity

to organize, monitoring all the steps and putting up with frustration, often having to make some corrections in order to reach the desired objective. This organizational capacity is structured during the development process and further enhanced during one’s life, making up what we call executive functions, primordial and unique characteristics of human beings [18-21].

Children start operating in this manner from a very early age and their actions have a purpose and a sequential organization which requires that they control several phases, correcting the course as needed and checking at the end to see whether the objective has been met. This process expands in complexity in the following next years, progressively setting up the child’s autonomy to each phase of life and promoting the development of the child’s capacity to think (Figure 9).

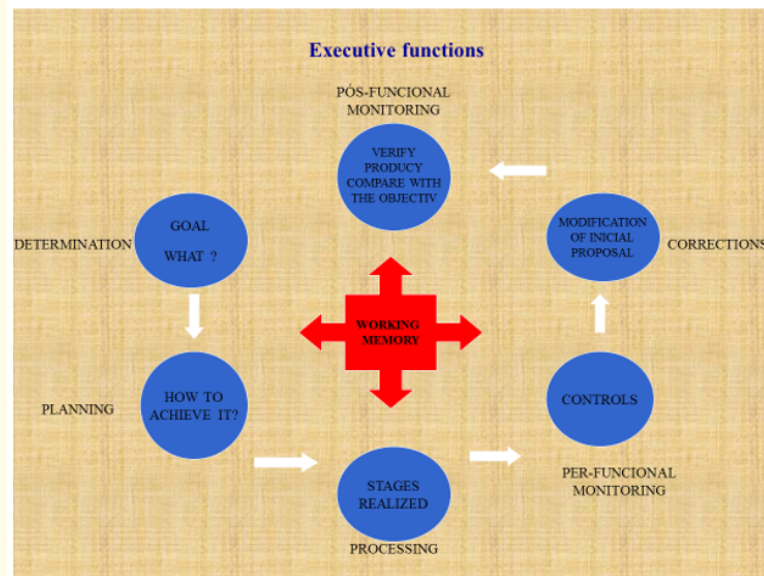


Figure 9: Sequential diagram of executive functions.

Physically, the circuits of the executive functions are organized in specific regions of the brain, namely the pre-frontal bilateral regions. They are aided by the senses (seeing, hearing, touching, smelling and tasting), which cerebral integration are located in different parts of the brain.

Work or operating memory

The good performance of a task requires that the individuals keep the latter in mind as an objective during the several actions that must be carried out before they achieve the goal. The work or operating memory is conceptually characterized by this capacity to keep an ultimate objective in mind. The lack of such capacity harms learning and personal development, causes organization and planning disruption and interferes with success when seeking to meet a goal [21].

This can be observed very early, when children ask for help with elementary activities that they should be able to carry out by themselves. In many cases these children have not been encouraged toward such learning, being always at the mercy of someone else’s help or do things for them. This is the reason why these children do not acquire the skills that they will need to acquire new learning and develop.

A good current example can be found in children who require help to dress or who need adults to be always around as they do their homework. This results from failures in the interaction process that would enable them to be more autonomous.

The brain and learning

Adequate brain architecture structure during the first years of life is therefore key to prepare individuals and provide the conditions to reach success in life. We might compare this process to a building, where the support of the different floors will be provided by the cornerstone and foundations, as well as the material employed. The floors are built one on top of another and the building comfort will depend on the quality of the finishing details (Figure 10).

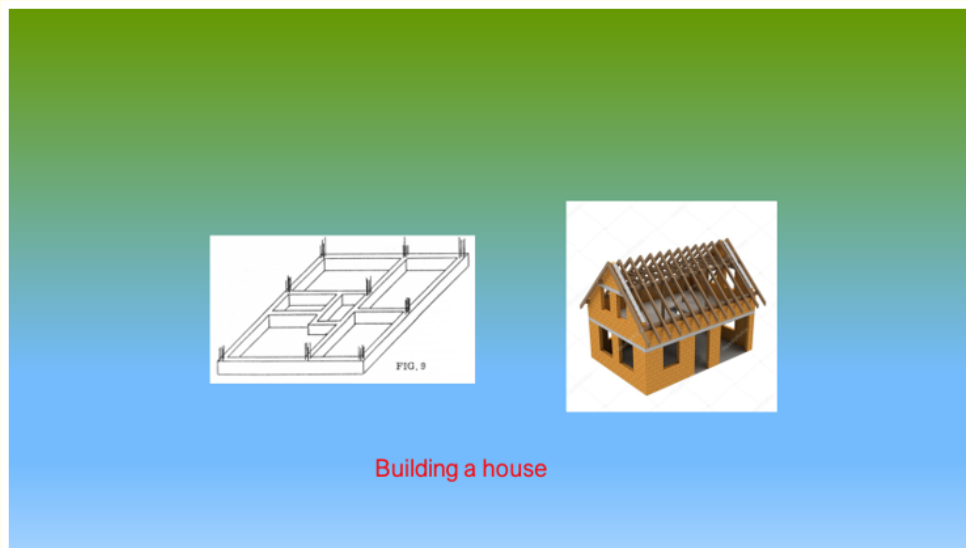


Figure 10: Building a house.

The same is true for a child during his/her development process: genetics provides the key parts for the operation, but the modeling and the characteristics will depend on the environment and the child's personal experiences [21,22].

For all of these reasons, it is fundamental that the knowledge be disseminated in a clear and understandable way to professionals, public managers and opinion makers, who in turn will convey this information to the families who, aware of the relevance of their role, may engage in the best form of participation for the global development of their children.

Being aware that the basis for the bio-psycho-social formation of individuals relies on the family and in the first years of life we may be able to plan for the concentration of investments and efforts towards this direction. Thus, during this period, we seek to offer the most favorable conditions for a family environment that fosters the building of an integral and integrated human being [23,24].

When the early the interpersonal relationships occur an appropriately, development occurs in a disadaptative manner through more difficult and exhaustive pathways.

If parents are not continent to shelter child's anguishes, care and comfort their anxiety and insecurity emotions are triggered by the amygdaloid nucleus not favoring the self-control the best adaptative behaviors.

With this objective in mind, it is mandatory to redeem the role of families as enablers of the development of individuals, until the latter can account for themselves, through their individuation and autonomy, their respect for others and for themselves, with civic engagement and solidarity in face of other people's suffering and the capacity to deal responsibly with their lives as well as the social and cultural aspects, protecting themselves from marginality and violence.

Humanization is the key way. Starting from pregnancy, dealing with the parents and their interpersonal relationship with the baby will be absolutely important as the investment in the future life.

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Volume 8 Issue 9 September 2019

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