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Modul 2
Development, Learning, and Developmental Risk

Disclaimer

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Modul 2 Development, Learning, and Developmental Risk

- Description of the module
- This module will provide a short overview of:
- Maturation of central nervous system
- Types of plasticity
- Development of voluntary movements
- Definitions biological and environmental risk factors.
- Definition of early childhood disabilities

Modul 2 Development and Learning and Developmental Risk

- 2.1 Development of Central Nervous System
- 2.2 Neuromaturation
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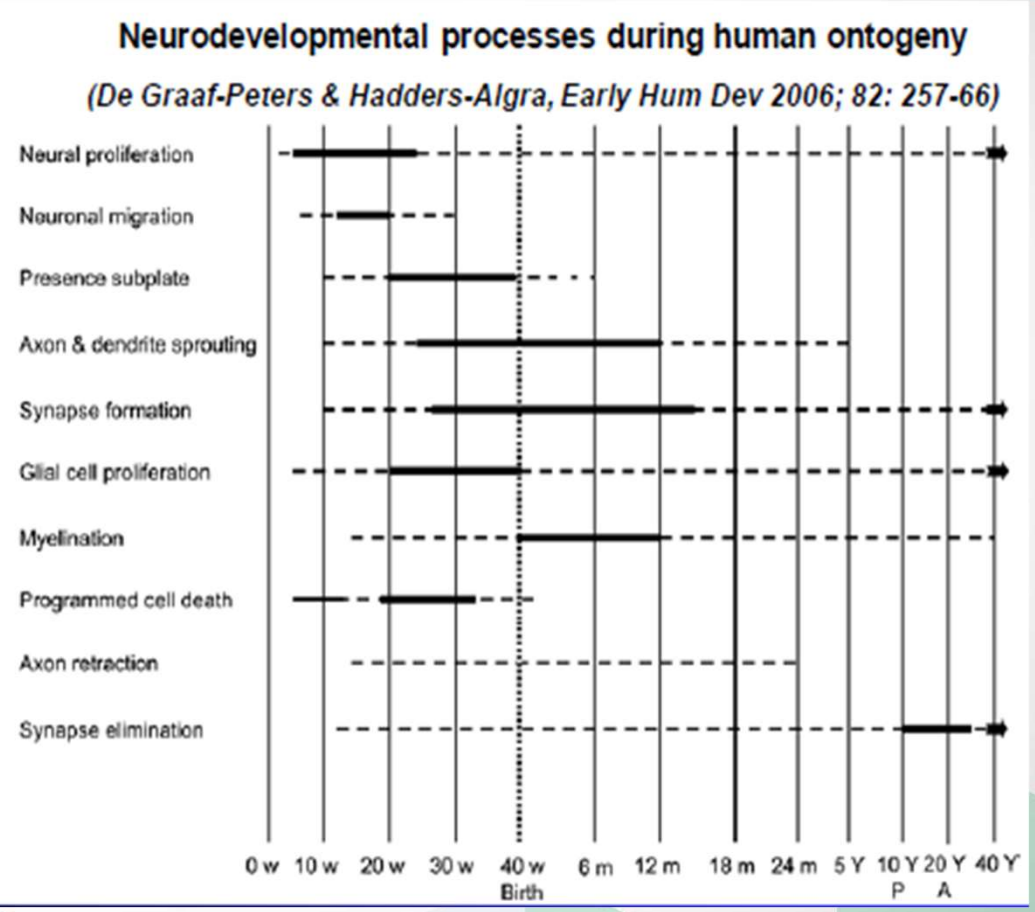
- 2.5.4 Prognosis

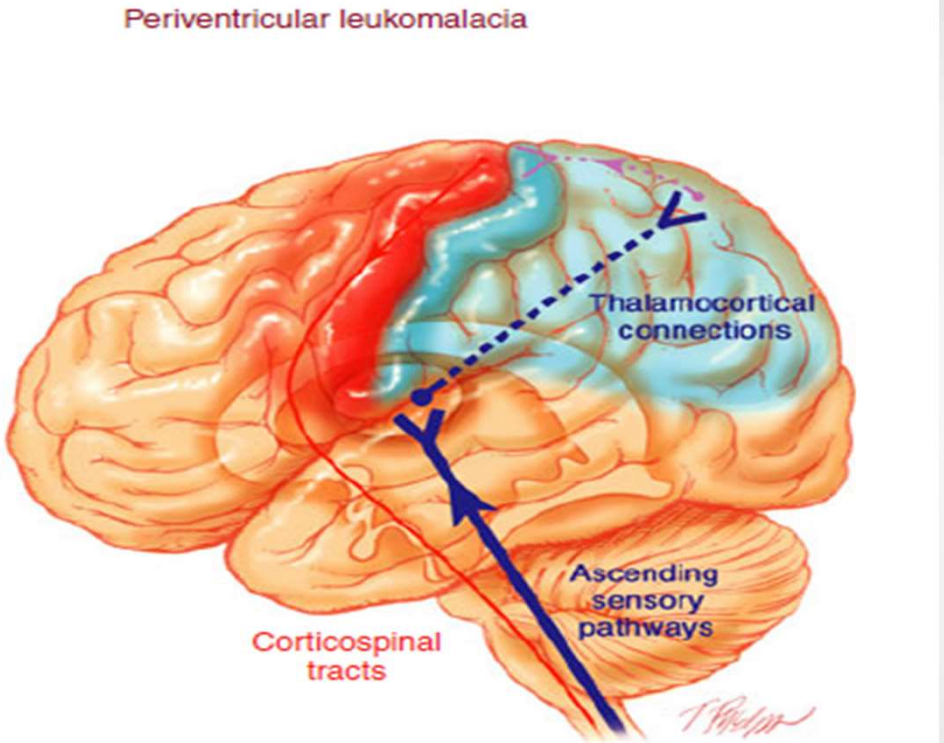
2.1 Development of Central Nervous System

- **Maturation** of Central Nervous System (CNS) such as proliferation, neuronal migration, axonal growth, synaptogenesis are genetically controlled in fetal and neonatal life.
- But **connectivity** of brain structures is depend of activity and environment.



2.1 Development of Central Nervous System

- The **thalamocortical connectivity** builds the framework sensory expectant organization and feed-forward prospective sensory modifications.
- On the other hand sensory stimulations also improve **thalamocortical connectivity** (Hoon 2009).



Hoon, A. H., Jr., Stashinko, E. E., Nagae, L. M., Lin, D. D., Keller, J., Bastian, A., . . . Johnston, M. V. (2009). Sensory and motor deficits in children with cerebral palsy born preterm correlate with diffusion tensor imaging abnormalities in thalamocortical pathways. *Dev Med Child Neurol, 51*(9), 697-704. doi: 10.1111/j.1469-8749.2009.03306.x

2.1 Development of Central Nervous System

- The development of thalamocortical connectivity is the main neurogenetic in late foetus and preterm infants.
- Structural substrates is created genetically for various sensory experiences.
- These processes is adversely affected by preterm birth, staying in neonatal intensive care unit (NICU), poor environmental stimulations, pain, stressful stimulations, ext.
- Studies have shown that these adverse conditions reduce the white and gray matter volume of the brain (Spittle et al., 2011).
- Sensory stimulations should produce stress as much as the baby can handle for optimal development. see module 2 for detailed information.

Spittle, A. J., Cheong, J., Doyle, L. W., Roberts, G., Lee, K. J., Lim, J., . . . Anderson, P. J. (2011). Neonatal white matter abnormality predicts childhood motor impairment in very preterm children. *Dev Med Child Neurol, 53*(11), 1000-1006. doi: 10.1111/j.1469-8749.2011.04095.x

2.2 Neuromaturation

- The timing and nature of central nervous system disruption call specific disorder such as spina bifida, migration anomalies, hydrocephalus or focal cortical dysplasia.
- Brain and neural tube formation occur third and fourth weeks of gestation.

Disorder	Incidence	Relatively Common Genetic Causes	Genetic Workup[a]	Notes
Neurulation				
Myelomeningocele	4.6/10,000[80]	Copy number variants	Chromosomal microarray	Increased risk with gestational diabetes mellitus, folate deficiency, maternal medications (valproic acid)

2.2 Neuromaturation

- The neuronal proliferation takes place third and forth months of gestation.
- Sixth week of gestation start to Prosencephalic development and the brain begins to take shape.

Disorder	Incidence	Relatively Common Genetic Causes	Genetic Workup[a]	Notes
Neuronal Proliferation				
Microcephaly	1.5/10,000[84]	Primary: *MCPH1, CENPJ, CDK5RAP2, NDE1, PNKP, PCNT* Microcephaly plus polymicrogyria: *NDE1, WDR62*	May choose individual gene sequencing or available panel sequencing test	Look for nongenetic causes such as cytomegalovirus, Zika infections, intrauterine injuries
Axonal Development				
Agenesis of the corpus callosum	1.8/10,000[85]	Copy number variants	Chromosomal microarray (17.3%)[85]	See if it is isolated or syndromic Look for associated brain malformations

2.3 Neuroplasticity

- Neuroplasticity is a complex and physiological process that is heightened during time-sensitive periods od pre and postnatal brain developments and continues, although a lesser degree adolescence and adulthood.
- Developmental plasticity is a complex genetically encoded, time dependent and sequenced maturational process that is closely regulated by intrinsic homeostatic and extrinsic environmental experiences.
- Developmental plasticity is an inclusive term fundamental changes of neurogenesis, neuronal cell migration, synapse formation and structural and functional neuronal networks.

2.3 Neuroplasticity

- The ability of neuroplasticity is strongly correlated with timing and type of central nervous system disruption.
- Neuroplasticity is a personal skill and no definite way to calculate the level of ability.
- Early intervention approaches should be use all opportunities to increase plasticity.
- The ability of plasticity decreases after completing thalamocortical pathways or myelination.
- Malformations and genetic problems could have specific plasticity ability (Kolb et all, 2017).

Kolb, B., Harker, A., & Gibb, R. (2017). Principles of plasticity in the developing brain. *Dev Med Child Neurol, 59*(12), 1218-1223. doi: 10.1111/dmcn.13546

2.3 Neuroplasticity

- There are three type of plasticity
- Experience-independent: The genome generates approximation of connectivity that is modified by internal and external events.
- Experience-expectant: This process occurs mostly early postnatal development. This is «Use it or lose it» plasticity. For example infants can discriminate speech sound of all languages, but over the first year of auditory system at early life it becomes to expert own language but loses discrimination of sounds (Kolb et all, 2017).

Kolb, B., Harker, A., & Gibb, R. (2017). Principles of plasticity in the developing brain. *Dev Med Child Neurol, 59*(12), 1218-1223. doi: 10.1111/dmcn.13546

2.3 Neuroplasticity

- Experience-dependent: Connections of neurons are modified by experiences. It's begin early postnatal life and continue lifetime.
- Enrichment environment is key point in this process.
- Activity dependent mechanisms which are core of developmental interventional strategies, may have a significant impact of the degree of functional recovery.

These study is the first evidence for plasticity is; Prolonged in vivo imaging of neurons in rodent cerebral cortex indicated that sensory experience drives to continuous sprouting and reaction of synapses (Colb et all, 2017). see module 4 and 6 for detailed information.

Kolb, B., Harker, A., & Gibb, R. (2017). Principles of plasticity in the developing brain. *Dev Med Child Neurol, 59*(12), 1218-1223. doi: 10.1111/dmcn.13546

2.3 Neuroplasticity

- Biological perspectives:
  - Neurogenesis, synaptogenesis, and synaptic pruning represents for building Central Nervous System (CNS). These process genetically programmed, time limited periods, called critical and sensitive periods during which the brain most amenable to change.

2.3 Neuroplasticity

- Commonly accepted developmental theories;
  - Dynamic Systems Theories
  - Dynamic System Theories are based on nature of complex systems following non-equilibrium rules. Development is not dictated by endogenously determined maturational processes.
  - Development is self organising process many intrinsic and extrinsic factors. For optimal development genetically programmed maturation of CNS, interaction family members, playing toys, environmental, social, cultural factors are should be optimal (Smith & Thelen, 2003).

Smith, L. B., & Thelen, E. (2003). Development as a dynamic system. *Trends in cognitive sciences, 7*(8), 343-348.

2.3 Neuroplasticity

- Neuronal Group Selection Theories
- Genetic instructions play a substantial role in the primary determination of the brain development. It's starting point for epigenetic cascades allowing for interaction with the environment and activity-dependent processes but doesn't include variation. Environment and experience improve variation of primary brain development.
- The active trial-and-error experiences which are unique to the individual support secondary variability functions for specific ages.
- As known according to literature sensory and motor experiences, language and cognitive experiences, prenatal, postnatal stress, parent child relationships, poverty, playing peers, siblings or parent, feeding, sleeping, chemical elements, gut bacteria, immune system, should be effect of plasticity (Hadders-Algra, 2000).

Hadders-Algra, M. (2000). The neuronal group selection theory: a framework to explain variation in normal motor development. *Developmental medicine & child neurology*, *42*(8), 566-572.

2.3 Neuroplasticity

- Following focal damage to the motor cortex and its descending pathways, the surviving portion of the brain usually undergoes a substantial structural and functional reorganization that occurs in perilesional areas, as well as in the ipsilesional and contralesional cortices in animal studies and human neuroimaging studies.
- These plastic changes reflect the capability of the brain, particularly the cerebral cortex, to alter the structure and function of neurons and their networks in response to damage caused by stroke.
- Motor recovery after stroke peaks approximately four weeks after damage then tapers off over 6 months.

2.3 Neuroplasticity

- **Stroke;**
- Early and intensive rehabilitation is very important after stroke.
- After unilateral brain damage, the ipsilateral or contralateral plasticity may occur.

- Constraint induced movement therapy,
- Bilateral hand therapy,
- Hybrid therapy (CIMT and bilateral therapy together) are commonly use after stroke (Li, 2017).

Li, S. (2017). Spasticity, motor recovery, and neural plasticity after stroke. *Frontiers in neurology, 8*, 120.

2.3 Neuroplasticity

- **Hypoxic-Ischaemic** brain injury induces an immediate inflammatory response, which has been shown to last days and even weeks following initial insult.
- HI does not result in a uniform or global brain injury but causes selective damage to different brain structures.
- **In preterm infants** periventricular white matter is particularly vulnerable HI resulting selective pattern of injury, called periventricular leukomalacia (PVL).
- Clinical findings of PVL mostly affected motor ability of legs, sensory, cognitive and cortical visual impairment.
- **In term infants** severe HI causes selective damage to the sensorimotor cortex, basal ganglia, thalamus, and brainstem.
- Clinical findings are severe motor disorder, rigidity, dyskinesia, impairment of mostly upper extremities, and speech difficulties (Rocha-Ferreira & Hristova, 2016).

Rocha-Ferreira, E., & Hristova, M. (2016). Plasticity in the neonatal brain following hypoxic-ischaemic injury. *Neural plasticity, 2016*.

2.3 Neuroplasticity

- Physiological reorganization is immediately start after brain damage.
- While managing therapeutic approaches for increasing plasticity we **should consider** time, type, location and size of brain damage.
- But health care provider **has to take into** account the social, cultural, environmental, and emotional characteristics of the family.

2.4 Typical Development of a Child

- Development is an adaptive change towards competence.
- How a child plays, learns, speaks, acts, and moves offer important clues about child's development.
- Developmental milestones are things most children can do by a certain age.
- Learning always occurs typically as a direct result of practice or experience.

2.4.1 Primitive Reflexes

- Primitive reflexes are brainstem-mediated, complex, automatic movement patterns that commence as early as the twenty-fifth week of gestation, are fully present at birth in term infants, and with central nervous system maturation become more and more difficult to elicit after the first half of the first year of life, when voluntary motor activity and thus cortical inhibition emerges and takes over.
- The major primitive motor reflexes or patterns that have been described include Moro, palmar and plantar grasp, rooting, sucking, Galant (or truncal incurvation), asymmetric tonic neck reflex, tonic labyrinthine reflex.

2.4.1.1 Moro Reflexes

- Method: Sudden head extension by light of the head.
- Response: Abduction followed by adduction and flexion of the upper extremity
- Appears: Birth
- Should integrate by: 2 to 4 Months

Figure 2: Moro reflex.

- Predictive meaning: Absence of Moro response has a high accuracy for deviant outcome.
- Present Moro reflex after **6 months** is high accuracy predictive for **cerebral palsy**.
- Purpose of reflex: protective response and first extension experience.
- Signs of retention: Hyper sensitivity and reactivity, poor impulse control, sensory overload, social & emotional immaturity

2.4.1.2 Asymmetric Tonic Neck Reflex

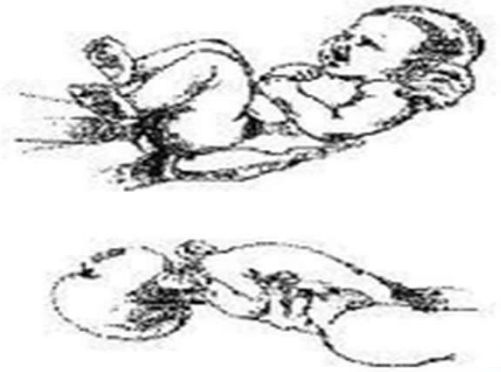
- Method: Rotation of the infant's head to one side for 15 s
- Response: Extension of the extremities on the chin side and flexion of those on the occipital side
- Appears: Birth
- Should integrate by: 6 Months

Figure 5: Asymmetrical tonic neck reflex.

- Purpose of reflex: To assist baby through birth canal of develop cross pattern movements
- Signs of retention: Poor eye-hand coordination, difficulty with handwriting, trouble crossing vertical midline, poor visual tracking for reading and writing

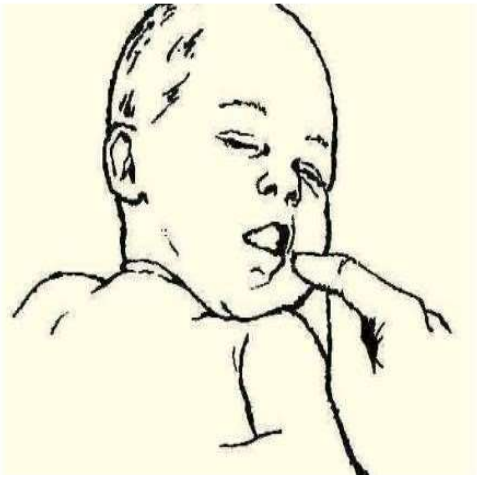
2.4.1.3 Symmetric Tonic Neck Reflex

- Method: Head leans forward (neck flexion) or Head backward (neck extension)
- Response: Flexion at the upper extremities, extension at the lower extremities with neck flexion. Extension at the upper extremities, flexion at the lower extremities with neck extension.
- Appears: 6 to 9 Months
- Should By Integrate: 9 to 11 Months
- Purpose of reflex: Preparation of crawling
- Signs of retention: Tendency to slump while sitting, **poor muscle tone**, poor eye-hand coordination, inability to sit still and concentrate



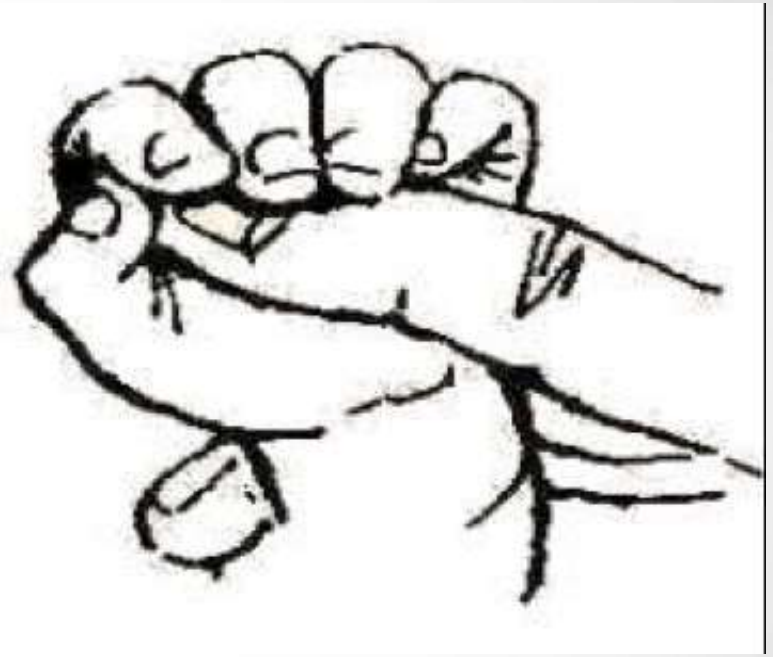
2.4.1.4 Rooting Reflex

- Method: When a newborn's cheek is stroked emerge
- Response: Turns to that side and opens its mouth
- Appears: Birth
- Should integrate by: 3 to 4 Months
- Purpose of reflex: automatic response to turn towards food
- Signs of retention: fussing eating, thumb sucking, dribbling, speech and articulation problems



2.4.1.5 Palmar Grasp

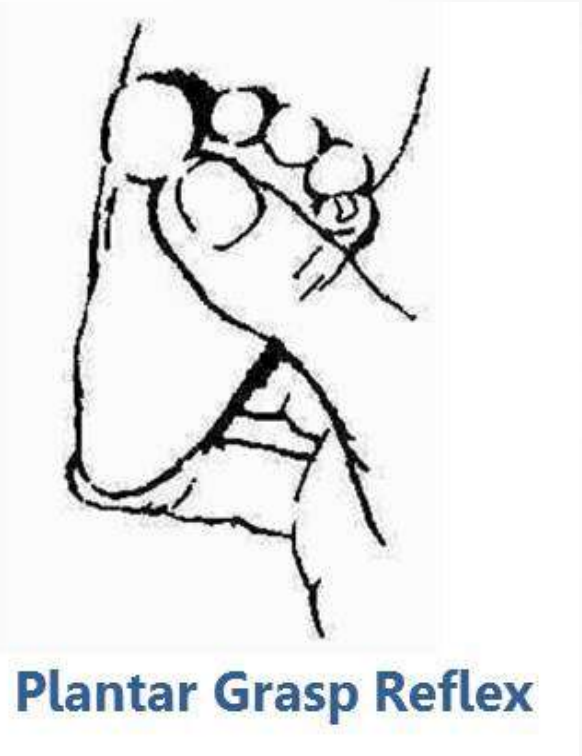
- Method: Placing the index finger in the palm of the infant.
- Response: Flexion of fingers, first making.
- Appears: Birth
- Should by integrate: 5 to 6 Months
- Present Palmar grasp after **4 months** is high accuracy predictive for **major neurological problem.**
- Signs of retention: difficult with fine motor skills, poor manual dexterity, messy handwriting



2.4.1.6 Plantar Grasp

- Method: Pressing a thumb against the sole just behind the toes in the foot.
- Response: Flexion of toes
- Appearance and disappearance:

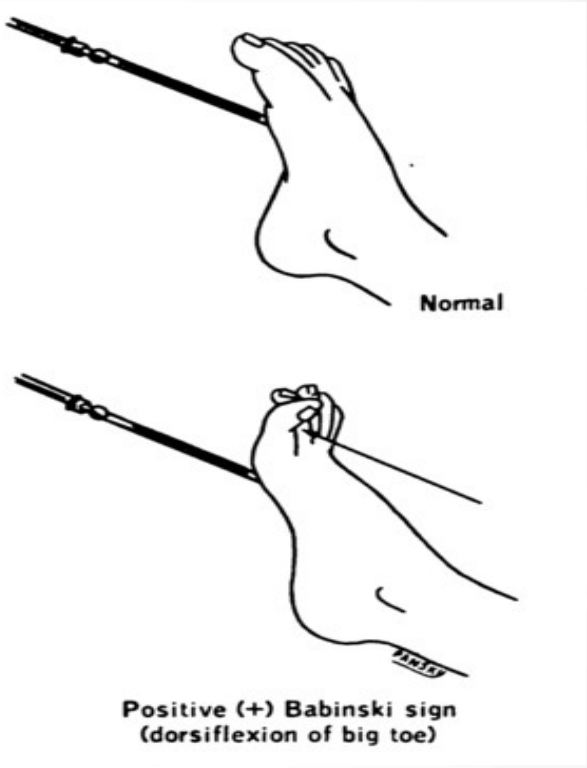
  4-12 Months
- Present Plantar grasp after **1 year** is high accuracy predictive for **cerebral palsy**.



Plantar Grasp Reflex

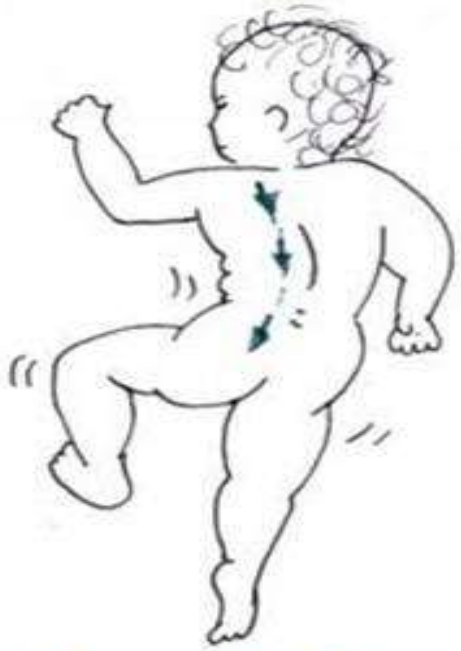
2.4.1.7 Babinski

- Method: Striking along the lateral aspect of the sole extending from the heel to the head of the fifth metatarsal.
- Combined extensor response: Simultaneous dorsiflexion of the great toe and fanning of the remaining toes.
- Appearance and disappearance: Birth-**Presence always abnormal**



2.4.1.8 Spinal Gallant Reflex

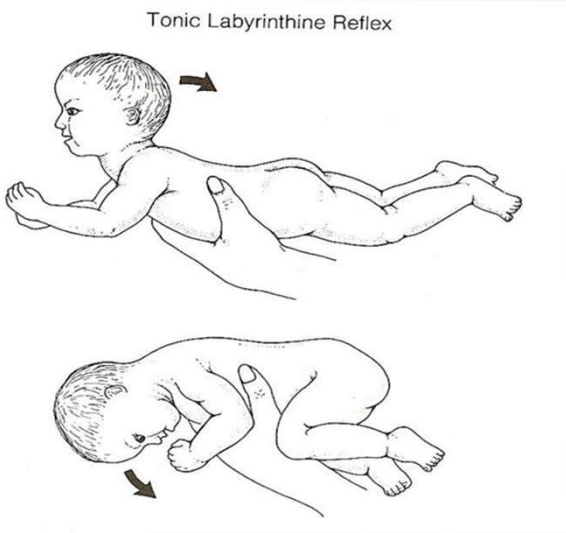
- Method: Scratching the skin of the infant's back from the shoulder downwards, 2-3 cm lateral to the spinous processes.
- Response: Incurvation of the trunk, with the concavity on the stimulated side.
- Appears: Birth
- Should integrate by: 3 to 9 Months
- Purpose of reflex: assist baby with birth process
- Signs of retention: unilateral or bilateral postural issues, bedwetting, poor concentration, poor short term memory



Galant Reflex

2.4.1.9 Tonic Labyrinthine Reflex

- Purpose of reflex: basis for head management and postural stability using major muscle groups
- Appears: in utero
- Should integrate by: 3 ½ years



- Signs of retention: **poor muscle tone**,
- Tendency to walk on toes, poor balance
- Motion sickness, spatial orientation issues
- (Piper 1994, Zitelli 2012, Stamer 2015).

Piper, M. C., & Darrah, J. Motor assessment of the developing infant. 1994. *Pennsylvania: WB Saunders Company*.

Stamer, M. H. (2015). *Posture and movement of the child with cerebral palsy*. PRO-ED, Incorporated.

Zitelli, B. J., McIntire, S. C., & Nowalk, A. J. (2012). *Zitelli and Davis' Atlas of Pediatric Physical Diagnosis E-Book: Expert Consult-Online and Print*. Elsevier Health Sciences.

2.4.2 General Movements

- Infants start to move 8 gestational weeks.
- There are two distinct patterns as a writhing and fidgety movements;
- Writhing Movements: Slow to moderate speed and amplitude of movements.
- Poor Repertoire: It is monotonously Movements, absence of complexity of normal general movements.
- Cramp Synchronized: It is rigid Movements with trunk and lower limbs contraction and relaxing simultaneously. If occurs consecutive weeks then high predictive power for cerebral palsy.
- All these patterns could be observed before 49 gestational weeks.

2.4.2 General Movements

- Fidgety Movements: Small amplitude and moderate speed of movements. Variable acceleration, fluent, and continual movements of neck, trunk, and limbs. It is a high predictive power for typical development.
- Absent Fidgety: Absence of fluent and continual fidgety movements.
- It is a high **predictive** power for **cerebral palsy**.
- Abnormal Fidgety: Movements like to fidgety but moderately and exaggeratedly amplitude, speed and jerkiness movements. It is correlate minor neurological dysfunction.
- All these patterns could be observed between 49 to 60 gestational weeks.

2.4.3 Voluntary Movements

- General movements start to decrease after 55 gestational weeks and voluntary movements start to increase gradually.
- General movements occur by Central Pattern Generator.
- Voluntary movements occur after increase to cortical inhibition and decrease primitive reflexes.
- Voluntary movements are initially simple and uncontrolled. With experience, variability and control of movements increase.

2.4.4 Development of Milestones 2 Months

- **Motor Development**
- Can hold head up and begins to push up when lying on tummy
- Makes smoother movements with arms and legs
- **Cognitive (learning, thinking, problem-solving)**
- Pays attention to faces
- Begins to follow things with eyes and recognize people at a distance
- Begins to act bored (cries, fussy) if activity doesn't change
- **Social and Emotional**
- Begins to smile at people
- Can briefly calm herself (may bring hands to mouth and suck on hand)
- Tries to look at parent
- **Language/Communication**
- Makes gurgling sounds
- Turns head toward sounds

2.4.4 Development of Milestones 4 Months

- **Motor Development**
- Holds head steady, unsupported
- Pushes down on legs when feet are on a hard surface
- May be able to roll over from tummy to back
- Can hold a toy and shake it and swing at dangling toys
- Brings hands to mouth
- When lying on stomach, pushes up to elbows

- **Cognitive (learning, thinking, problem-solving)**
- Reaches for toy with one hand
- Uses hands and eyes together, such as seeing a toy and reaching for it
- Follows moving things with eyes from side to side
- Watches faces closely
- Recognizes familiar people and things at a distance

2.4.4 Development of Milestones 4 Months

- **Social and Emotional**
- Smiles spontaneously, especially at people
- Likes to play with people and might cry when playing stops
- Copies some movements and facial expressions, like smiling or frowning

- **Language/Communication**
- Begins to babble
- Babbles with expression and copies sounds he hears
- Cries in different ways to show hunger, pain, or being tired

2.4.4 Development of Milestones 6 Months

- **Motor Development**
- Rolls over in both directions (front to back, back to front)
- Begins to sit without support
- When standing, supports weight on legs and might bounce
- Rocks back and forth, sometimes crawling backward before moving forward

- **Cognitive (learning, thinking, problem-solving)**
- Looks around at things nearby
- Brings things to mouth
- Shows curiosity about things and tries to get things that are out of reach
- Begins to pass things from one hand to the other

2.4.4 Development of Milestones 6 Months

- **Social and Emotional**
- Knows familiar faces and begins to know if someone is a stranger
- Likes to play with others, especially parents
- Responds to other people's emotions and often seems happy
- Likes to look at self in a mirror

- **Language/Communication**
- Responds to sounds by making sounds
- Strings vowels together when babbling ("ah," "eh," "oh") and likes taking turns with parent while making sounds
- Responds to own name
- Makes sounds to show joy and displeasure
- Begins to say consonant sounds (jabbering with "m," "b")

2.4.4 Development of Milestones 9 Months

- **Motor Development**
- Stands, holding on
- Can get into sitting position
- Sits without support
- Pulls to stand
- Crawls

- **Cognitive (learning, thinking, problem-solving)**
- Watches the path of something as it falls
- Looks for things she sees you hide
- Plays peek-a-boo
- Puts things in his mouth
- Moves things smoothly from one hand to the other
- Picks up things small things between thumb and index finger

2.4.4 Development of Milestones 9 Months

- **Social and Emotional**
- May be afraid of strangers
- May be clingy with familiar adults
- Has favorite toys

- **Language/Communication**
- Understands “no”
- Makes a lot of different sounds like “mamamama” and “babababababa”
- Copies sounds and gestures of others
- Uses fingers to point at things

2.4.4 Development of Milestones 12 Months

- **Movement/Physical Development**
- Gets to a sitting position without help
- Pulls up to stand, walks holding on to furniture (“cruising”)
- May take a few steps without holding on
- May stand alone

- **Cognitive (learning, thinking, problem-solving)**
- Explores things in different ways, like shaking, banging, throwing
- Finds hidden things easily
- Looks at the right picture or thing when it’s named
- Copies gestures
- Starts to use things correctly; for example, drinks from a cup, brushes hair
- Bangs two things together
- Puts things in a container, takes things out of a container
- Lets things go without help
- Pokes with index (pointer) finger
- Follows simple directions like “pick up the toy”

2.4.4 Development of Milestones 12 Months

- **Social and Emotional**
- Is shy or nervous with strangers
- Cries when mom or dad leaves
- Has favorite things and people
- Shows fear in some situations
- Hands you a book when he wants to hear a story
- Repeats sounds or actions to get attention
- Puts out arm or leg to help with dressing
- Plays games such as “peek-a-boo” and “pat-a-cake”

- **Language/Communication**
- Responds to simple spoken requests
- Uses simple gestures, like shaking head “no” or waving “bye-bye”
- Makes sounds with changes in tone (sounds more like speech)
- Says “mama” and “dada” and exclamations like “uh-oh!
- Tries to say words you say

2.4.4 Development of Milestones 18 Months

- **Motor Development**
- Walks alone
- May walk up steps and run
- Pulls toys while walking
- Can help undress herself
- Drinks from a cup
- Eats with a spoon

- **Cognitive (learning, thinking, problem-solving)**
- Knows what ordinary things are for; for example, telephone, brush, spoon
- Points to get the attention of others
- Shows interest in a doll or stuffed animal by pretending to feed
- Points to one body part
- Scribbles on his own
- Can follow 1-step verbal commands without any gestures; for example, sits when you say “sit down”

2.4.4 Development of Milestones 18 Months

- **Social and Emotional**
- Likes to hand things to others as play
- May have temper tantrums
- May be afraid of strangers
- Shows affection to familiar people
- Plays simple pretend, such as feeding a doll
- May cling to caregivers in new situations
- Points to show others something interesting
- Explores alone but with parent close by

- **Language/Communication**
- Says several single words
- Says and shakes head “no”
- Points to show someone what he wants

2.4.4 Development of Milestones 24 Months

- **Movement/Physical Development**
- Stands on tiptoe
- Kicks a ball
- Begins to run
- Climbs onto and down from furniture without help
- Walks up and down stairs holding on
- Throws ball overhand
- Makes or copies straight lines and circles

- **Cognitive (learning, thinking, problem-solving)**
- Finds things even when hidden under two or three covers
- Begins to sort shapes and colors
- Completes sentences and rhymes in familiar books
- Plays simple make-believe games
- Builds towers of 4 or more blocks
- Might use one hand more than the other
- Follows two-step instructions such as “Pick up your shoes and put them in the closet.”
- Names items in a picture book such as a cat, bird, or dog

2.4.4 Development of Milestones 24 Months

- **Social and Emotional**
- Copies others, especially adults and older children
- Gets excited when with other children No image available for this milestone
- Shows more and more independence
- Shows defiant behavior (doing what he has been told not to)
- Plays mainly beside other children, but is beginning to include other children, such as in chase games

https://www.cdc.gov/ncbddd/actearly/milestones/index.html

- **Language/Communication**
- Points to things or pictures when they are named
- Knows names of familiar people and body parts
- Says sentences with 2 to 4 words
- Follows simple instructions
- Repeats words overheard in conversation
- Points to things in a book

2.4.4 Development of Milestones

- All infant and young children don’t have to follow up these processes.
- Development pathway is unique and variability.
- The development of motor, cognitive, social, and linguistic can follow different pathways.
- While there is rapid skill learning in one area, it may slow down in other areas.

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Developmental Risk

2.5.1 Early childhood development

The early years of a child's life are very important for his or her health and development. Healthy development means that children of all abilities, including those with special health care and physical needs, are able to grow up where their social, emotional and educational needs are met. Having a safe and loving home and spending time with family—playing, singing, reading, and talking—are very important. Proper nutrition, exercise, and sleep also can make a big difference.

Examples of typical birth to five developmental timelines can be found here:

CDC milestones

Available in English and Spanish

2.5.1 Epigenetics and child development

"Epigenetics" is an emerging area of scientific research that shows how environmental influences—children's experiences—actually affect the expression of their genes. During development, the DNA that makes up our genes accumulates chemical marks that determine how much or little of the genes is expressed. This collection of chemical marks is known as the "epigenome." The different experiences children have rearrange those chemical marks. This explains why genetically identical twins can exhibit different behaviors, skills, health, and achievement. This means the old idea that genes are "set in stone" has been disproven.

Nature vs. Nurture is no longer a debate. It's nearly always both!

Source: Centre for the Developing Child, Harvard University

(resources on the CDC website are available in a number of languages, however not all resources are available in all languages - clicking on the resource tab enables you to identify which resources are available in your chosen language)

2.5.1 Epigenetics and child development

- Experiences very early in life, when the brain is developing most rapidly, cause epigenetic adaptations that influence whether, when, and how genes release their instructions for building future capacity for health, skills, and resilience.
- That's why it's crucial to provide supportive and nurturing experiences for young children in the earliest years.
- Services such as high-quality health care for all pregnant women, infants, and toddlers, as well as support for new parents and caregivers can—quite literally— affect the chemistry around children's genes. Supportive relationships and rich learning experiences generate positive epigenetic signatures that activate genetic potential.

Source: Centre for the Developing Child, Harvard University

2.5.1 Supportive caregiving environments

Learning how to cope with adversity is an important part of healthy child development. When we are threatened, our bodies prepare us to respond by increasing our heart rate, blood pressure, and stress hormones, such as cortisol. When a young child's stress response systems are activated within an environment of supportive relationships with adults, these physiological effects are buffered and brought back down to baseline. The result is the development of healthy stress response systems. However, if the stress response is extreme and long-lasting, and buffering relationships are unavailable to the child, the result can be damaged, weakened systems and brain architecture, with lifelong repercussions.

https://developingchild.harvard.edu/resources/experiences-build-brain-architecture/

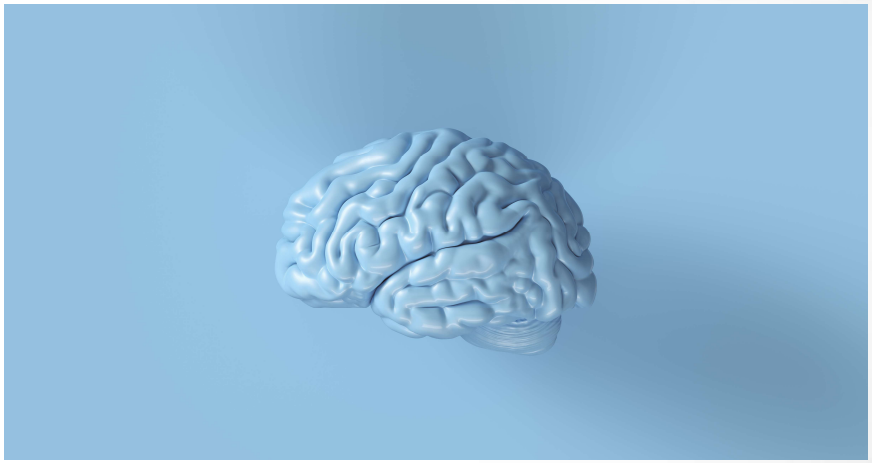
Source: Centre for the Developing Child,Harvard University

2.5.1 Family wellbeing and child development

The Harvard Centre for the Developing Child advocate for three core principles to improve outcomes for children and families. These are:

1. Support responsive relationships - When adults model responsive relationships, the benefits come full circle, ultimately helping children become healthy, responsive parents themselves.
2. Strengthen core life skills - Core life skills are crucial for learning, development, and making healthy choices for ourselves and our families
3. Reduce sources of stress - Constant stress depletes precious energy the brain needs for healthy development in childhood and adulthood

CDC: https://developingchild.harvard.edu/resources/three-early-childhood-development-principles-improve-child-family-outcomes/#reduce-stress

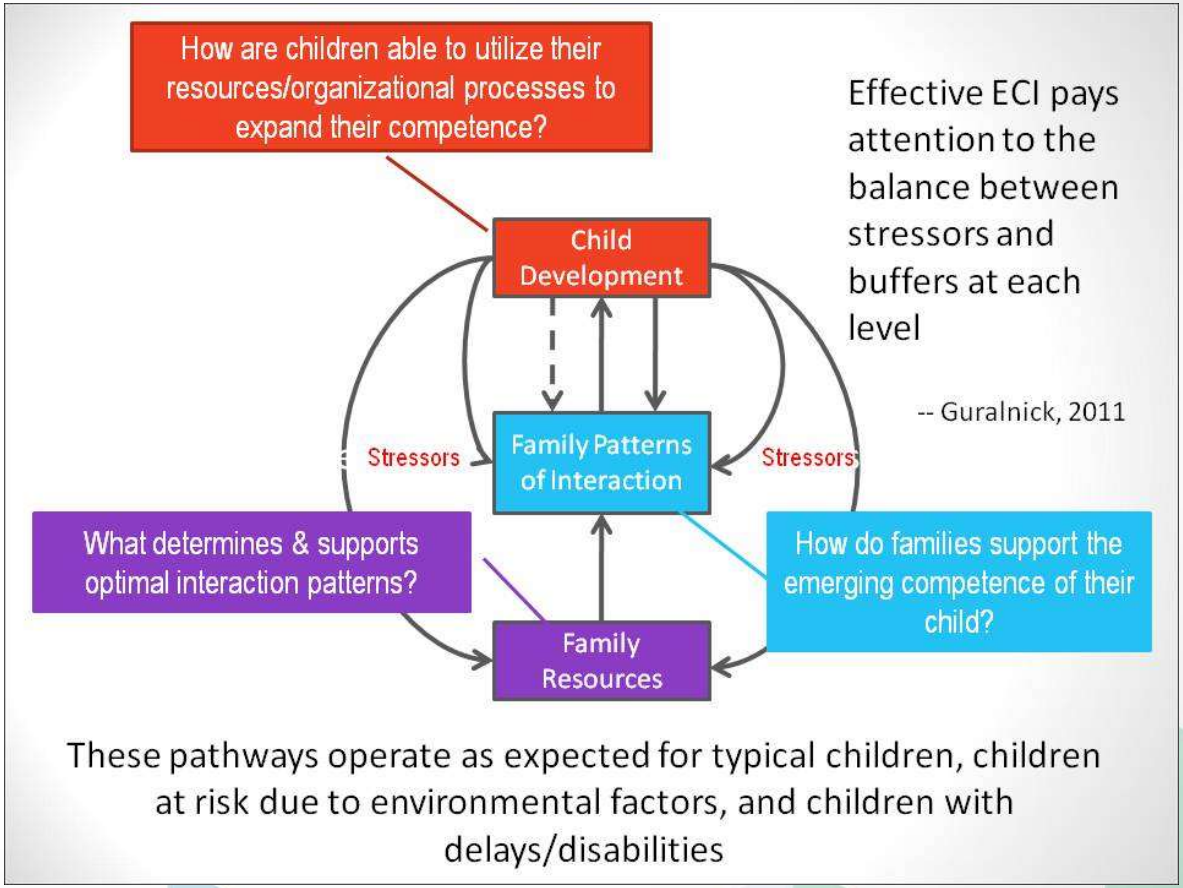


Source: Getty Images

2.5.1 Family wellbeing and child development

- When these three principles are enacted through policy and practice, research shows that healthy child development follows and children grow up to be positive and active participants in society as shown in this video and the diagram opposite:

- Brain architecture



2.5.1 The important role of serve and return

- Serve and return interactions shape brain architecture. When an infant or young child babbles, gestures, or cries, and an adult responds appropriately with eye contact, words, or a hug, neural connections are built and strengthened in the child's brain that support the development of communication and social skills. Much like a lively game of tennis, volleyball, or Ping-Pong, this back-and-forth is both fun and capacity-building. When caregivers are sensitive and responsive to a young child's signals and needs, they provide an environment rich in serve and return experiences.
- Because responsive relationships are both expected and essential, their absence is a serious threat to a child's development and well-being. Healthy brain architecture depends on a sturdy foundation built by appropriate input from a child's senses and stable, responsive relationships with caring adults. If an adult's responses to a child are unreliable, inappropriate, or simply absent, the developing architecture of the brain may be disrupted, and subsequent physical, mental, and emotional health may be impaired. The persistent absence of serve and return interaction acts as a "double whammy" for healthy development: not only does the brain not receive the positive stimulation it needs, but the body's stress response is activated, flooding the developing brain with potentially harmful stress hormones.
- Building the capabilities of adult caregivers can help strengthen the environment of relationships essential to children's lifelong learning, health, and behavior. A breakdown in reciprocal serve and return interactions between adult caregivers and young children can be the result of many factors. Adults might not engage in serve and return interactions with young children due to significant stresses brought on by financial problems, a lack of social connections, or chronic health issues. Caregivers who are at highest risk for providing inadequate care often experience several of these problems simultaneously. Policies and programs that address the needs of adult caregivers and help them to engage in serve and return interactions will in turn help support the healthy development of children
- https://developingchild.harvard.edu/science/key-concepts/serve-and-return/

Source: Centre for the Developing Child, Harvard University

2.5.2 What is developmental risk?

Source: Getty Images

In the absence of safe, warm and responsive, healthy conditions , children's development can be placed at risk. This means that the 'normal' sequence for developmental timelines may be delayed or disordered according to the nature and level of risk and the child's own genetic inheritance.

For some children, these delays may be transient but for others they may be long-term and persistent resulting in a diagnosis of a developmental disability such as Cerebral Palsy. This may co-exist with other conditions.

2.5.2 What is developmental risk?

- Developmental disabilities begin anytime during the developmental period and usually last throughout a person's lifetime. Most developmental disabilities begin before a baby is born, but some can happen after birth because of injury, infection, or other factors. Most developmental disabilities are thought to be caused by a complex mix of factors. These include socio-economic factor as poverty and other adverse experiences, genetic factors that are familial, and biological/environmental factors such as the home environment, maternal pregnancy experiences or natural disasters such as earthquakes.
- Therefore factors such as parental health and behaviors (such as smoking and drinking) during pregnancy; complications during birth; infections the mother might have during pregnancy or the baby might have very early in life; and exposure of the mother or child to high levels of environmental toxins, such as lead all have the potential to place an infant at risk.
- For some developmental disabilities, such as fetal alcohol spectrum disorders (FASD), which is caused by drinking alcohol during pregnancy, we know the cause. But for most, we do not.

Source: Centre for Disease Control (CDC) CDC

2.5.2 What is developmental risk?

The Centre for Disease Control (CDC) provide examples of what we know about specific developmental disabilities:

- At least 25% of hearing loss among babies is due to maternal infections during pregnancy, such as cytomegalovirus (CMV) infection; complications after birth; and head trauma.
- Some of the most common known causes of intellectual disability include fetal alcohol spectrum disoders (FASD); genetic and chromosomal conditions, such as Down syndrome and fragile X syndrome; and certain infections during pregnancy.
- Children who have a sibling with autism are at a higher risk of also having autism spectrum disorder.
- Low birthweight, premature birth, multiple birth, and infections during pregnancy are associated with an increased risk for many developmental disabilities.
- Untreated newborn jaundice (high levels of bilirubin in the blood during the first few days after birth) can cause a type of brain damage known as kernicterus. Children with kernicterus are more likely to have cerebral palsy, hearing and vision problems, and problems with their teeth. Early detection and treatment of newborn jaundice can prevent kernicterus.

Source: Centre for Disease Control and Infection (CDC) CDC

2.5.2 Red flags for developmental delay

Children can have developmental delay in one or more areas. Child's doctor should be consulted if there are any concerns. See CDC for more information on developmental milestones https://www.cdc.gov/ncbddd/actearly/milestones/index.html

2.5.2.1 Cerebral Palsy

Cerebral palsy is the name for a group of lifelong conditions that affect movement and co-ordination, caused by a problem with the brain that occurs before, during or soon after birth.

Symptoms of cerebral palsy

- The symptoms of cerebral palsy aren't usually obvious just after a baby is born. They normally become noticeable during the first two or three years of a child's life.
- Symptoms can include:
- delays in reaching development milestones – for example, not sitting by eight months or not walking by 18 months
- seeming too stiff or too floppy
- weak arms or legs
- fidgety, jerky or clumsy movements
- random, uncontrolled movements
- walking on tip-toes
- a range of other problems – swallowing difficulties speaking problems, vision problems and learning disabilities
- such as The severity of symptoms can vary significantly. Some people only have minor problems, while others may be severely disabled.
- Source: NHS https://www.nhs.uk/conditions/cerebral-palsy/ available in English

2.5.2.1 Major Risk Factors for Developing Cerebral Palsy

Some factors increase the chance that a child will have CP. These are called risk factors. It is important to remember that having a risk factor does not mean that a child will have CP.

According to NICE (2017), the following are **major** risk factors for developing cerebral palsy (therefore more likely to result in CP that those factors mentioned on the previous slides):

- birth before 28 weeks
- neonatal encephalopathy
- neonatal sepsis (particularly with a birth weight below 1.5 kg). (NICE, 2017)

2.5.2.1 Developmental risk for congenital cerebral palsy (1 of 2)

Some of the risk factors for congenital CP are:

- Low birthweight—Children who weigh less than 5 1/2 pounds (2,500 grams) at birth, and especially those who weigh less than 3 pounds, 5 ounces (1,500 grams) have a greater chance of having CP.
- Premature birth—Children who were born before the 37th week of pregnancy, especially if they were born before the 32nd week of pregnancy, have a greater chance of having CP. Intensive care for premature infants has improved a lot over the past several decades. Babies born very early are more likely to live now, but many have medical problems that can put them at risk for CP.
- Multiple births—Twins, triplets, and other multiple births have a higher risk for CP, especially if a baby's twin or triplet dies before birth or shortly after birth. Some, but not all of this increased risk is due to the fact that children born from multiple pregnancies often are born early or with low birthweight, or both.
- Assisted reproductive technology (ART) infertility treatments—Children born from pregnancies resulting from the use of some infertility treatments have a greater chance of having CP. Most of the increased risk is explained by preterm delivery or multiple births, or both; both preterm delivery and multiple births are increased among children conceived with ART infertility treatments.

Source: CDC available in English

2.5.2.1 Developmental risk for congenital cerebral palsy (2of 2)

Some of the risk factors for congenital CP are:

- **Infections during pregnancy**—Infections can lead to increases in certain proteins called cytokines that circulate in the brain and blood of the baby during pregnancy. Cytokines cause inflammation, which can lead to brain damage in the baby. Fever in the mother during pregnancy or delivery also can cause this problem. Some types of infection that have been linked with CP include viruses such as chickenpox, rubella (german measles), and cytomegalovirus (CMV), and bacterial infections such as infections of the placenta or fetal membranes, or maternal pelvic infections.

- **Jaundice and kernicterus**— Jaundice is the yellow color seen in the skin of many newborns. Jaundice happens when a chemical called bilirubin builds up in the baby's blood. When too much bilirubin builds up in a new baby's body, the skin and whites of the eyes might look yellow. This yellow coloring is called jaundice. When severe jaundice goes untreated for too long, it can cause a condition called kernicterus. This can cause CP and other conditions. Sometimes, kernicterus results from ABO or Rh blood type difference between the mother and baby. This causes the red blood cells in the baby to break down too fast, resulting in severe jaundice.

- **Maternal medical condictions**—Mothers with thyroid problems, intellectual disability, or seizures have a slightly higher risk of having a child with CP.

- **Birth complications**—Detachment of the placenta, uterine rupture, or problems with the umbilical cord during birth can disrupt oxygen supply to the baby and result in CP.

Source: CDC available in English

2.5.2.1 Developmental risk for acquired cerebral palsy

A small percentage of CP is caused by brain damage that occurs more than 28 days after birth. This is called acquired CP, and usually is associated with an infection (such as meningitis) or head injury.

Causes

Some causes of acquired CP are:

- Infection—Infections of the brain, for example, meningitis or encephalitis during infancy.
- Injury—Injuries to the brain, for example, head injuries caused by motor vehicle crashes or child abuse.
- Problem with blood flow to the brain—Cerebrovascular accidents, for example, stroke or bleeding in the brain associated with a blood clotting problem, blood vessels that didn't form properly, a heart defect that was present at birth, or sickle cell disease.

Risk Factors

Some things increase the chance that a child will have CP. These are called risk factors. It is important to remember that having a risk factor does not mean that a child will have CP. Some risk factors for acquired CP are:

- Infancy—Infants are at greater risk of a brain-damaging event than older children.
- Preterm or low birthweight—Children born preterm or at low birthweight are at greater risk for acquired CP.
- Brain infections—Not getting certain vaccinations increases the risk of brain infections that can result in CP.
- Injury—Inadequate safety measures or lack of adult supervision can increase the risk of injury that can result in CP.

Source: CDC available in English

2.5.2.1 Possible signs for cerebral palsy

Source: Getty Images

The following are the most common delayed motor milestones in children with cerebral palsy from birth to three years:

- not sitting by 8 months (corrected for gestational age)
- not walking by 18 months (corrected for gestational age)
- early asymmetry of hand function (hand preference) before 1 year (corrected for gestational age). (NICE 2017)

2.5.2.1 Case study of acquired CP

Toby was born full-term via a Cesearian birth. His Mother had Job Syndrome during pregnancy (Autosomal dominant hyper-IgE syndrome (AD-HIES), also known as Job syndrome, is a condition that affects several body systems, particularly the immune system. Recurrent infections are common in people with this condition).

Toby has nine siblings and none share the same set of parents.

He lives with his Father and three of his siblings in deprived urban area. His mother experienced severe post-natal depression and displayed/expressed thoughts of harmful behaviour towards Toby.

At four months old, he developed childhood bronchiolitis and was rushed to hospital. Shortly after being admitted he as diagnosed with severe spasticty, epilepsy and cerebral palsy. Prior to this he had a been a typical developing infant.

It can be seen that Toby's early experiences were less than optimal and although a single experience might explain his diagnosis, there are many factors that may have contributed.

2.5.2.2 Premature birth

The world health organisation defines preterm birth as babies born alive before 37 weeks of pregnancy are completed. There are sub-categories of preterm birth, based on gestational age:

- extremely preterm (less than 28 weeks)
- very preterm (28 to 32 weeks)
- moderate to late preterm (32 to 37 weeks).

Preterm birth is also sometimes defined in terms of birth weight:

- Low birthweight - Born weighing less than 2500g (5lbs)
- Very low birthweight - Born weighing less than 1500g (3lbs)
- Extremely low birthweight - Born weighing less than 1000g (2lbs)

2.5.2.2 Premature birth

Source: Getty Images

Globally, 15 million babies are born preterm each year, representing 11% of all live births. That is more than 1 in 10 babies. Approximately 1 million children die globally each year due to complications of preterm birth and many survivors face a lifetime of disability, including learning disabilities and visual and hearing problems (Liu, Oza, Hogan, Chu, Perin, Zhu J, et al. 2016).

Reaching developmental milestones may take longer for premature babies compared to babies born at full term because they are in fact younger and not always assessed according to their corrected age.

2.5.2.2 Premature birth

Developmental risk to the child

- Major impact on development in about 10% of cases; more subtle impact in 50% of cases
- Impacts are both short and long-term (physical and mental health), although many do better than the early days/months would suggest
- Greater risk at younger gestational ages
- Medical fragility (respiratory, brain damage, vision, hearing, etc.) Most Extremely Preterm children are readmitted to hospital before age 2
- Impact may not be apparent in infancy: learning, behaviour, social
- We have very few preventative tools because we don’t understand the basic biology of premature birth. (Foster-Cohen, 2016)

Source: Getty Images

2.5.2.2 Premature birth

Body: At 23 weeks

Fat stores not yet laid down:

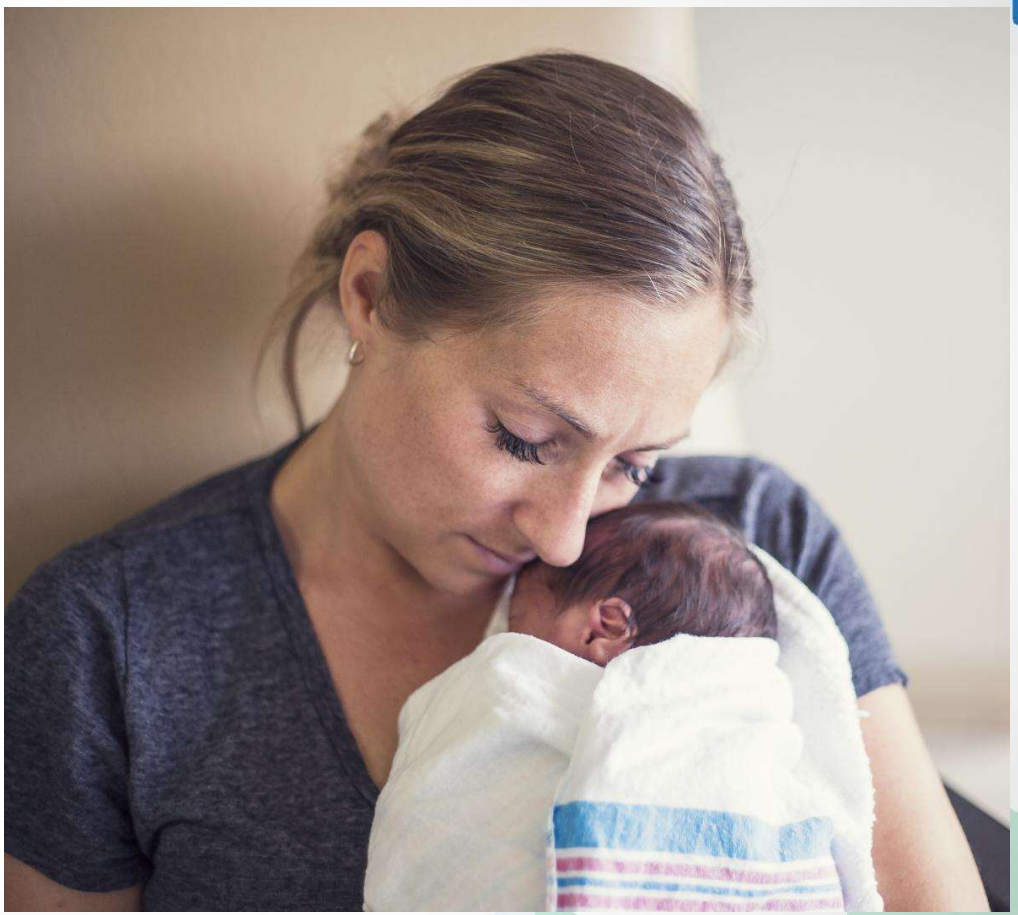
97-99% of children born VLBW or ELBW are <10th percentile for weight and height: don't put on fat; immature gut.

Eyes not fully developed:

Vision problems affect 10% of children born < 26 weeks GA; 2% < 32 weeks.

Lungs not fully developed:

Chronic lung disease affects 35% of children born <1,500 grams, Asthma is ongoing risk. (Foster-Cohen, 2016)



Source: Getty Images

2.5.2.2 Premature birth

- Immature neurological systems lead to difficulty interpreting signals/cues
- Cerebral Palsy: 6-9% of children born ≤ 32 Weeks; 16-28% of those born ≤ 26 weeks.
- Less myelination (i.e. less efficient connections between brain cells)
- Particularly fragile pre-frontal cortex.
  - associated with complex planning, decision-making, behavioural inhibition, working memory and judgement (Executive Function) (Foster-Cohen, 2016)

Source: Getty Images

2.5.2.2 Premature birth

The most common adverse outcomes following preterm birth are cognitive problems (e.g., lower IQ, poor executive function and working memory), learning difficulties, social difficulties (e.g., autism spectrum disorders, difficulties interacting and forming relationships with peers), behavioural problems (e.g., attention problems, attention deficit/hyperactivity disorders), emotional problems (e.g., anxiety disorders, phobias), and poor motor coordination (e.g., cerebral palsy and clumsiness).

These kinds of difficulties can impact a child's performance and integration at school. As a consequence, preterm children are at increased risk for poor academic attainment and special educational needs (SEN) compared with their term-born peers, and poor achievement in mathematics has been reported to be especially common among very preterm children.

Children's mathematics skills have been suggested to be important for their future health and wellbeing, employment prospects and income as an adult (Wolke et al., 2015)

2.5.3 Teratogens in pregnancy

Source: Getty Images

A teratogen is a substance that interferes with the normal development of the embryo or fetus. Examples include both illegal substances and those that we can buy over the counter or take for granted as a basic 'food stuff' such as alcohol. Examples include:

- Drugs (for example, prescribed penicillin, diet pills vitamin A);
- Tobacco;
- Illegal drugs (cocaine, heroin)
- Alcohol
- Lead, mercury, solvents and other environmental pollutants
- Maternal diseases (for example, cancer, toxoplasmosis, chicken pox, TB)
- Herbal medications;
- Extreme maternal stress.

2.5.3.1 Prenatal exposure to alcohol (PAE)

Source: Getty Images

Alcohol is known to present the most serious risk to a developing fetus (Institute of Medicine, 1996). The effects of alcohol on the behaviour a developing fetus can be measured in utero and have been shown to exert adverse consequences on normal neurobehavioural processes, contributing to the adverse consequences seen after birth. In addition prenatal exposure to alcohol (PAE) may prime the individual to prefer alcohol after birth (Hepper, 2013).

2.5.3.1 Fetal alcohol spectrum disorders

Educational or Diagnostic Term	Factors Required for Confirmation/Diagnosis
Fetal Alcohol Syndrome (FAS)	Confirmed exposure to maternal alcohol; Facial dysmorphology; Growth retardation; and Central nervous system dysfunction.
Partial FAS (pFAS)	Confirmed exposure to maternal alcohol; Facial dysmorphology; and either Growth retardation or central nervous system dysfunction.
Alcohol-related Neurodevelopmental Disorder (ARND)	Confirmed exposure to maternal alcohol; and Central nervous system dysfunction
Alcohol-Related Birth Defects (ARBD)	Presence of congenital anomalies e.g. cardiac, skeletal, renal ocular, auditory – known to be associated with prenatal alcohol exposure.

Collectively the range of effects of PEA has been termed Fetal Alcohol Spectrum Disorders (FASD).

2.5.3.1 Characteristics of children with FASD

Characteristics of children with FASD

- 35% are born pre term
- 65% are born with low birth weight
- Only 7% diagnosed at birth, the average age of diagnosis is 3.3 years
- 53% have microcephaly
- 24% have significant birth defects
- 85% have behavioural problems
- 40% lived with birth parent (which means that 60% do not)
- 51% have a sibling with FASD (which means that one child with FASD in the family should trigger more support for the family in future pregnancies).

Elliott, E. (2013) Australian Perspectives on FASD. In Carpenter, Blackburn and Egerton (2013) Interdisciplinary Approaches to FASD. London: Routledge.

Source: Getty Images

2.5.3.1 Webinar on FASD

Source: Getty Images

- Useful webinar on FASD for Occupational Therapists FASD webinar
- Available in English

2.5.4 Prognosis

Source: Getty Images

- As with all developmental delays and difficulties, early intervention has the potential to alter developmental trajectories significantly, so early identification, assessment and family-centred intervention is the key to improving both short term and long term prognosis.
- Because Cerebral Palsy is complicated it is not possible to determine a specific or exact prognosis for every individual. There are many ways in which the outlook can be improved, even with the most severe complications.
- The best outcomes for children and families are achieved through interdisciplinary co-ordinated early childhood intervention services where professionals work closely with families to develop family-centred programmes to fulfill the child's potential.

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