

When Does Consciousness Arise?

In the womb, at birth or during early childhood?

BY CHRISTOF KOCH



MOTHERS will want to crucify me for this seemingly cruel question, but it needs to be posed: How do we know that a newly born and healthy infant is conscious? There is no question that the baby is awake. Its eyes are wide open, it wriggles and grimaces, and, most important, it cries. But all that is not the same as being conscious, of experiencing pain, seeing red or smelling Mom's milk.

It is well recognized that infants have no awareness of their own state, emotions and motivations. Even older children who can speak have very limited insight into their own actions. Anybody who has raised a boy is familiar with the blank look on your teenager's face when you ask him why he did something particularly rash. A shrug and "I dunno—it seemed like a good idea at the time" is the most you'll hear.

Although a newborn lacks self-awareness, the baby processes complex visual stimuli and attends to sounds and sights in its world, preferentially looking at faces. The infant's visual acuity permits it to see only blobs, but the basic thalamo-cortical circuitry necessary to support simple visual and other conscious percepts is in place. And linguistic capacities in babies are shaped by the environment they grow up in. Exposure to maternal speech sounds in the muffled confines of the womb enables the fetus to pick up statistical regularities so that the newborn can distinguish its mother's voice and even her language from others. A more complex behavior is imitation: if Dad sticks out his tongue and waggles it, the infant mimics his gesture by combining visual information with proprioceptive feedback from its own movements. It is therefore likely that the baby has some basic level of unreflective, present-oriented consciousness.

When did that newborn become consciously aware?



The Road to Awareness

But when does the magical journey of consciousness begin? Consciousness requires a sophisticated network of highly interconnected components, nerve cells. Its physical substrate, the thalamo-cortical complex that provides consciousness with its highly elaborate content, begins to be in place between the 24th and 28th week of gestation. Roughly two months later synchrony of the electroencephalographic (EEG) rhythm

across both cortical hemispheres signals the onset of global neuronal integration. Thus, many of the circuit elements necessary for consciousness are in place by the third trimester. By this time, preterm infants can survive outside the womb under proper medical care. And as it is so much easier to observe and interact with a preterm baby than with a fetus of the same gestational age in the womb, the fetus is often considered to be like a preterm baby, like an unborn newborn.

CORBIS

(Suspended in a **warm and dark cave**, connected to the placenta, the fetus is asleep.)

But this notion disregards the unique uterine environment: suspended in a warm and dark cave, connected to the placenta that pumps blood, nutrients and hormones into its growing body and brain, the fetus is asleep.

Invasive experiments in rat and lamb pups and observational studies using ultrasound and electrical recordings in humans show that the third-trimester fetus is almost always in one of two sleep states. Called active and quiet sleep, these states can be distinguished using electroencephalography. Their different EEG signatures go hand in hand with distinct behaviors: breathing, swallowing, licking, and moving the eyes but no large-scale body movements in active

and cushioned uterine environment and a range of neuroinhibitory and sleep-inducing substances produced by the placenta and the fetus itself: adenosine; two steroidal anesthetics, allopregnanolone and pregnanolone; one potent hormone, prostaglandin D₂; and others. The role of the placenta in maintaining sedation is revealed when the umbilical cord is closed off while keeping the fetus adequately supplied with oxygen. The lamb embryo now moves and breathes continuously. From all this evidence, neonatologists conclude that the fetus is asleep while its brain matures.

Dreamless Sleep?

One complication ensues. When people awaken during REM sleep, they often report vivid dreams with extensive narratives. Although consciousness during dreams is not the same as during wakefulness—most noticeably insight and self-reflection are absent—dreams are consciously experienced and felt. So does the fetus dream when in REM sleep? This is not known. But what would it dream of?

After birth, dream content is informed by recent and more remote memories. Longitudinal studies of dreaming in children by retired American psychologist David Foulkes suggest that dreaming is a gradual cognitive development that is tightly linked to the capacity to imagine things visually and to

visuospatial skills. Thus, preschoolers' dreams are often static and plain, with no characters that move or act, hardly any feelings and no memories. What would dreaming be like for an organism that spends its time suspended in a sort of isolation tank, with no memories, and no way to imagine anything at all? I wager that the fetus experiences nothing in utero; that it feels the way we do when we are in a deep, dreamless sleep.

The dramatic events attending delivery by natural (vaginal) means cause the brain to abruptly wake up, however. The fetus is forced from its paradisiac existence in the protected, aqueous and warm womb into a hostile, aerial and cold world that assaults its senses with utterly foreign sounds, smells and sights, a highly stressful event.

As Hugo Lagercrantz, a pediatrician at the Karolinska Institute in Stockholm, discovered two decades ago, a massive surge of norepinephrine—more powerful than during any skydive or exposed climb the fetus may undertake in its adult life—as well as the release from anesthesia and sedation that occurs when the fetus disconnects from the maternal placenta, arouses the baby so that it can deal with its new circumstances. It draws its first breath, wakes up and begins to experience life. **M**

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A two-week-old preterm infant born in the 25th gestational week. Although the newborn may already have some conscious experiences, a fetus of the same gestational age is kept actively sedated by the intrauterine environment.

sleep; no breathing, no eye movements and tonic muscle activity in quiet sleep. These stages correspond to rapid-eye-movement (REM) and slow-wave sleep common to all mammals. In late gestation the fetus is in one of these two sleep states 95 percent of the time, separated by brief transitions.

What is fascinating is the discovery that the fetus is actively sedated by the low oxygen pressure (equivalent to that at the top of Mount Everest), the warm

(Further Reading)

- ◆ **The “Stress” of Being Born.** Hugo Lagercrantz and Theodore A. Slotkin in *Scientific American*, Vol. 254, No. 4, pages 100–107 (92–102); April 1986.
- ◆ **The Importance of “Awareness” for Understanding Fetal Pain.** David J. Mellor, Tamara J. Diesch, Alistair J. Gunn and Laura Bennet in *Brain Research Reviews*, Vol. 49, No. 3, pages 455–471; November 2005.
- ◆ **The Emergence of Human Consciousness: From Fetal to Neonatal Life.** Hugo Lagercrantz and Jean-Pierre Changeux in *Pediatric Research*, Vol. 65, No. 3, pages 255–260; March 2009.