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AWSC Melbourne University Seminar
Cognitive awareness and survival-critical
behaviours of newborn and young mammals

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Introduction: present talk based on the following papers:

Mellor DJ & Gregory NG (2003). Responsiveness, behavioural arousal and awareness in fetal and newborn lambs: experimental, practical and therapeutic implications. *New Zealand Veterinary Journal* 51, 2-13.

Mellor DJ, Diesch TJ, Gunn AJ & Bennet L (2005). The importance of “awareness” in understanding fetal pain. *Brain Research Reviews* 48, 455-471.

Mellor DJ & Diesch TJ (2006). Onset of sentience: potential for suffering in fetal and neonatal farm animals. *Applied Animal Behaviour Science* 100, 45-57.

Mellor DJ & Diesch TJ (2007). Birth and hatching: key events in the onset of awareness in lambs and chickens. *New Zealand Veterinary Journal* 55, 51-60.

Diesch, T.J., Mellor, D.J., Johnson, C.B. and Lentle, R.G. (2008). Responsiveness to painful stimuli in anaesthetised newborn and young animals of varying neurological maturity (wallaby joeys, rat pups and lambs). *AATEX Journal* 14, Special Issue, 549-552.

Mellor, D.J., Patterson-Kane, E. and Stafford, K.J. (2009) Integrated perspectives: sleep, developmental stage and animal welfare. In *The Sciences of Animal Welfare*. Oxford: Wiley-Blackwell, pp 161-185.

Diesch, T.J. and Mellor, D.J. (2013). Birth transitions: pathophysiology, the onset of consciousness and possible implications for the neonatal maladjustment syndrome in the foal. *Equine Veterinary Journal* 45, 656-660.

Campbell, M.L.H., Mellor, D.J. and Sandøe, P. (2014). How should the welfare of fetal and neurologically immature postnatal animals be protected? *Animal Welfare* 23 (4) 369-379. doi: 10.7120/09627286.23.4.369.

Mellor, D.J. and Lentle, R.G. (2015). Survival implications of the development of behavioural responsiveness and awareness in different groups of mammalian young. *New Zealand Veterinary Journal* 63 (3), 131-140

Major Points

- **Life-threatening hazards for mammalian young:**
 - **Birth itself**
 - **Birth environment**
- **General developmental stage at birth:**
 - **Species-specific maturity categories**
 - **Birth site, milk, care and protection**
- **Development of sensory modalities:**
 - **The developmental sequence**
 - **Sensory modalities present at birth**
- **Postnatal developmental milestones:**
 - **Behaviour**
 - **Onset of sensory modalities absent at birth**
- **Onset of cognitive capacity to modulate behaviour**
 - **Key CNS developmental features**
 - **Timing in the three groups in relation to birth**
- **Conclusions**

Life-threatening hazards in mammalian young:

Birth itself – abrupt expulsion and adjustment:

- Tests neonate's *limits of physiological capacity*
- *Impaired neonates* usually die
- *Some strong neonates* are overwhelmed and die
- *Strong neonates* often survive

Birth environment – differs with ecological niches

- Unpredictable variability is a major hazard
- Usually *managed by the dam* to reduce variability
- *Young-dam behavioural interactions* are important
- These differ with the *species-specific ecological niche*

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General developmental stage at birth:

Very Immature

Marsupial joeys:

wallaby
kangaroo
opossum

Moderately Immature

Species

Newborn:

cats, dogs, ferrets
hamsters, mice
rats, rabbits

Mature

Newborn:

cattle, deer
goats, sheep
horses, pigs*
guinea-pigs

**Piglets intermediate:
neurologically mature;
thermogenically suboptimal*

General developmental stage at birth:

Very Immature

Marsupial joeys:

wallaby
kangaroo
opossum



Day 6

Moderately Immature

Species

Newborn:

cat, dogs, ferrets
hamsters, mice
rats, rabbits



Day 3

Mature

Newborn:

cattle, deer
goats, sheep
horses, pigs*
guinea-pigs



10-15 min

**Piglets intermediate*

General developmental stage at birth:

Very Immature

Marsupial joeys:

wallaby
kangaroo
opossum

**Rapidly entry
into pouch**

Moderately Immature

Species

Newborn:

cat, dogs, ferrets
hamsters, mice
rats, rabbits

Birth site and postnatal location

**Born in burrows, dens,
nests or other shelters**

Mature

Newborn:

cattle, deer
goats, sheep
horses, pigs*
guinea-pigs

**Born outdoors
with or without
shelter***

**Piglets in nests*

General developmental stage at birth:

Very Immature

Marsupial joeys:

wallaby
kangaroo
opossum

Moderately Immature

Species

Newborn:

cat, dogs, ferrets
hamsters, mice
rats, rabbits

Mature

Newborn:

cattle, deer
goats, sheep
horses, pigs*
guinea-pigs

Birth site and postnatal location

Rapidly entry
into pouch

Born in burrows dens,
nests or other shelters

Born on outdoors
with or without
shelter

Maternal nurturing & protection

In-pouch milk,
care & protection
for *several months*

At secluded birth site,
milk, care & protection
for *several weeks**

Rapid bonding
needed to get milk
care & protection
from *mobile dam*

**Piglets ~10 days*

Major Points

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Development of sensory modalities:

The developmental sequence is similar in each mammal studied to date:

- Somaesthetic system (touch, temperature, nociception)
- Chemosensory systems (olfaction, taste)
- Proprioceptive system
- Vestibular system
- Auditory system
- Visual system

Development of sensory modalities:

The developmental sequence is similar in each mammal studied to date:

- Somaesthetic system (touch, temperature, nociception)
- Chemosensory systems (olfaction, taste)
- Proprioceptive system
- Vestibular system
- Auditory system
- Visual system

Sensory modalities present at birth:

Very Immature

**Touch (muzzle/mouth),
temperature, taste,
smell, vestibular;
Not: nociception,
proprioception,
hearing or sight**

Moderately Immature

**Touch, temperature,
taste, smell, vestibular;
nociception;
Not: proprioception,
hearing or sight**

Mature

**Touch, temperature,
taste, smell, vestibular,
proprioception,
nociception, hearing,
sight**

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Postnatal developmental milestones:

Very Immature at Birth e.g. *Tammar wallaby joey*

Behavioural milestones:

1-100 days	Continuous teat attachment in pouch
100-180 days	Intermittent teat attachment; stays in pouch
180-250 days	Repeatedly leaves pouch and returns
250 days	Permanently leaves pouch; weaned 300-350 days

Postnatal onset of sensory capacities absent at birth:

125-130 days	<i>Hearing:</i> approaches adult values by 180 days
~140 days	<i>Sight:</i> can see well by 180 days
160 days	<i>Proprioception:</i> can stand unaided by 160 days



Day 6



Day 70



Day 185



Day 220

Postnatal developmental milestones:

Moderately Immature at Birth *e.g. Rat pup*

Behavioural milestones and onset of sensory capacities absent at birth

Days 1-18	<i>Pre-existent capacities progressively mature</i>
Days 4-18	<i>Proprioception: Improving postural & movement control</i>
Days 3-14	<i>Thermally-induced isolation calls – dam retrieves pups</i>
Days 8-42	<i>Exploration: excursions away from the dam and nest</i>
Day 11	<i>Olfaction: sniffing directed at objects</i>
Day 13	<i>Hearing: sound-induced startle reaction</i>
Days 14-18	<i>Sight: partially to fully open eyes; responds to visual cues</i>
Days >13-14	<i>Isolation calls and dam retrieval decline rapidly</i>
Days 18-42	<i>Autonomous volitional behaviour increases</i>

Postnatal developmental milestones:

Moderately Immature at Birth

Rat pups Days 1 to 42

(© Karen Robbins)



Newborn



Day 7



Day 14



Day 21



Day 28



Day 35



Day 42

Postnatal developmental milestones:

Mature at Birth e.g. Lambs

Postnatal behaviours and sensory capacities

1-5 min.	<i>Breathing starts</i>
1-20 min.	<i>Lies flat: then on sternum, legs tucked in with head up</i>
5-30 min.	<i>First tries to stand; unsteadily stands and walks</i>
15-60 min.	<i>Teat seeking starts; locates udder (smell, warmth, touch) First sucking bout occurs</i>
5-240 min.	<i>Vocal interactions with ewe; ewe-lamb bond established</i>
5 min. to 36 h	<i>Existing sensory capacities and discrimination mature Autonomous volitional behaviour increases progressively</i>
12-24 h	<i>Lamb recognises ewe via hearing and sight Lamb follows ewe</i>

Lamb birth sequence



Postnatal developmental milestones – Summary:

Birth status

All senses in place

Volitional behaviour

Very immature

e.g. Tammar joey
Virginia opossum

By 180 days
By 70-90 days

First leave dam's pouch
Leave pouch/ride on dam's back

Moderately immature

e.g. Rat pups

By 16-18 days

Explore actively well beyond nest
Depart and return at will

Mature

e.g. Lamb

By < 15 min after birth

Locate dam, suck on demand;
Stay with and follows dam

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Onset of cognitive capacity to modulate behaviour

Key CNS developmental features and timing in relation to birth:

Very immature

e.g. Tammar joey

- *At birth:* brain regions rudimentary; only 2 cortical cell layers
- *After birth:* brain growth rate slow
- *Cortico-thalamic connections:* none at birth; established & operating after 4-5 months

Moderately immature

e.g. Rat pups

- *At birth:* brain regions differentiated; cortical neurons immature
- *After birth:* brain growth rate rises rapidly after birth
- *Cortico-thalamic connections:* none or ineffective at birth; established & operating after 2-3 weeks

Mature

e.g. Lamb

- *At birth:* brain regions well differentiated; cortical neurons are nearing maturity some weeks BEFORE birth
- *BEFORE birth:* brain growth rate rapid
- *Cortico-thalamic connections:* established & operating some weeks BEFORE birth

Onset of cognitive capacity to modulate behaviour

Operational cortico-thalamic connections are required for cognitive modification of behaviour

How do we know when this occurs?

The EEG, generated in the cerebral cortex, provides evidence

Cortico-thalamic connections are in place when Stage 5 EEG patterns are present

Birth EEG status

Very immature

Moderately immature

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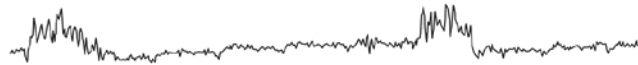
Moderately immature

Mature

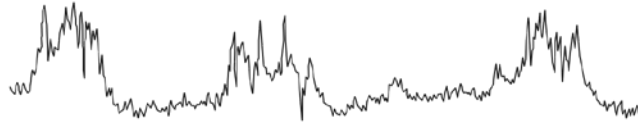
Stage 1. Isoelectric EEG



Stage 2. Short low voltage EEG epochs



Stage 3. Longer low voltage EEG epochs



Stage 4. Continuous, higher voltage 'mixed' EEG



Stage 5. Differentiated REM and non-REM EEG cycling



Stage 6. Sleep-wake EEG patterns



Onset of cognitive capacity to modulate behaviour

Operational cortico-thalamic connections are required for cognitive modification of behaviour

On the basis of EEG studies,
postnatal cognitive modulations of behaviour
would become apparent after:

2-3 months in Virginia opossum joeys

5-6 months in Tammar wallaby joeys

2-3 weeks in kittens, puppies, rat & mouse pups, & rabbit kits

Within 1-3 hours in calves, fawns, foals, kids, lambs & piglets

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CONCLUSIONS

- The onset of a capacity for behavioural flexibility and exposure to variable environments that require it coincide in these three groups.
- *Very immature* newborns are initially carried, nurtured and protected within the maternal pouch and *moderately immature* newborns are initially assiduously nurtured and protected in a nest or other secluded area by their dams.
- Assiduous maternal care meets otherwise fatal behavioural deficiencies of the young arising through their sensory immaturity.
- These newborns do not exhibit, nor do they require, a capacity for flexible behavioural responsiveness until they leave the pouch after several months or the nest after several days or weeks

CONCLUSIONS

The survival of *mature newborns* in their *highly variable and unpredictable birth environment* demands *a more prompt onset of behavioural flexibility*.

The *pre-existent capacity for cortical-subcortical interactivity AT BIRTH* makes this possible in these neonates.

The *consequent rapid onset of cognitive activity* in these neonates *extends their behavioural repertoire and capacity to respond to environmental challenges*.

