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**Sir James Dunn Animal Welfare Centre,  
Atlantic Veterinary College  
16 October 2017**

***Awareness and survival-critical behaviours  
of newborn and young mammals***

***Professor David J Mellor***  
***BSc(Hons), PhD, HonAssocRCVS, ONZM***

[\*D.J.Mellor@massey.ac.nz\*](mailto:D.J.Mellor@massey.ac.nz)



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### 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 Sandoe, 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. DOI: 10.1080/00480169.2014.969349**



## 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 to *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:**

<i>Very Immature</i>	<i>Moderately Immature</i>	<i>Mature</i>
	<u>Species</u>	
<b>Marsupial joeys:</b> wallaby kangaroo opossum	<b>Newborn:</b> cats, dogs, ferrets hamsters, mice rats, rabbits	<b>Newborn:</b> cattle, deer goats, sheep horses, pigs* guinea-pigs
		<i>*Piglets intermediate:</i> neurologically mature; thermogenically suboptimal

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<b>Day 6</b>	<b>Day 3</b>	<b>10-15 min</b>
		<i>*Piglets intermediate</i>

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Marsupial joeys: wallaby kangaroo opossum	Newborn: cat, dogs, ferrets hamsters, mice rats, rabbits	Newborn: cattle, deer goats, sheep horses, pigs* guinea-pigs
	<u><i>Birth site and postnatal location</i></u>	
Rapid entry into pouch	Born in burrows, dens, nests or other shelters	Born outdoors with or without shelter*
		<i>*Piglets in nests</i>
		

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	<u><i>Birth site and postnatal location</i></u>	
Rapid entry into pouch	Born in burrows dens, nests or other shelters	Born on outdoors with or without shelter
	<u><i>Maternal nurturing &amp; protection</i></u>	
<i>In-pouch milk, care &amp; protection for several months</i>	<i>At secluded birth site, milk, care &amp; protection for several weeks*</i>	<i>Rapid bonding needed to get milk care &amp; protection from mobile dam</i>
	<i>*Piglets ~10 days</i>	
		

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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

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- Vestibular system
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- 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    *Hearing:* approaches adult values by 180 days
- ~140 days        *Sight:* can see well by 180 days
- 160 days         *Proprioception:* 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        *Pre-existent capacities* progressively mature
- Days 4-18        *Proprioception:* Improving postural & movement control
- Days 3-14        *Thermally-induced* isolation calls – dam retrieves pups
- Days 8-42        *Exploration:* excursions away from the dam and nest
- Day 11            *Olfaction:* sniffing directed at objects
- Day 13            *Hearing:* sound-induced startle reaction
- Days 14-18      *Sight:* partially to fully open eyes; responds to visual cues
- Days >13-14    *Isolation calls* and *dam retrieval* decline rapidly
- Days 18-42      *Autonomous volitional behaviour* increases



**Postnatal developmental milestones:**

*Moderately Immature at Birth*

*Rat pups Days 1 to 42*

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Newborn



Day 7



Day 14



Day 21



Day 28



Day 35



Day 42



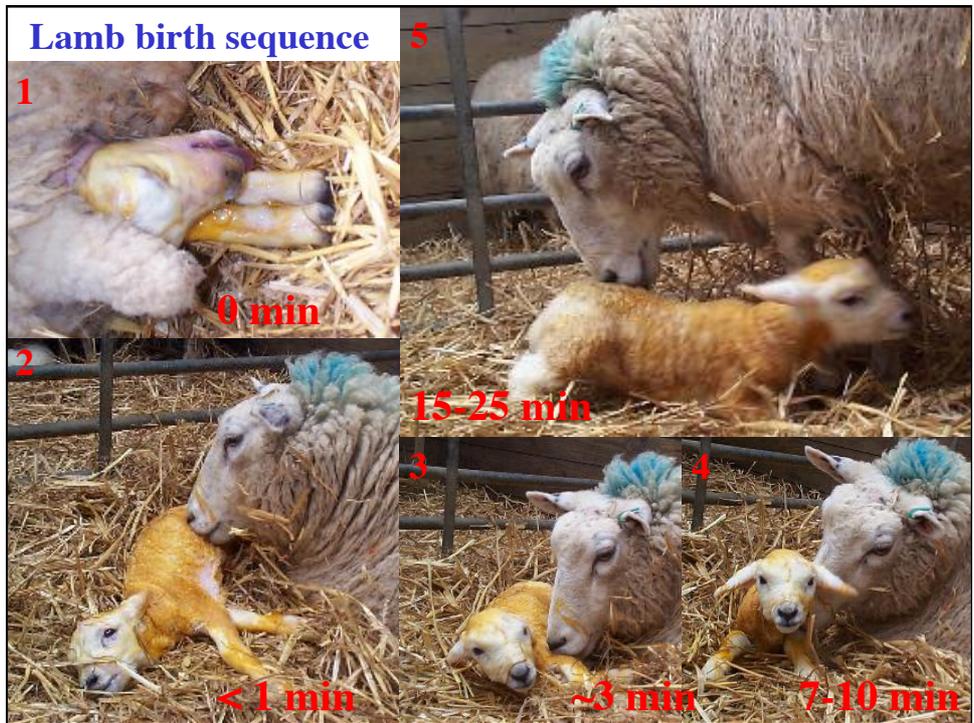
**Postnatal developmental milestones:**

*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)</i> |
|                | <i>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</i>     |
|                | <i>Autonomous volitional behaviour increases progressively</i>   |
| 12-24 h        | <i>Lamb recognises ewe via hearing and sight</i>                 |
|                | <i>Lamb follows ewe</i>  |





**Postnatal developmental milestones – Summary:**

<u><i>Birth status</i></u>	<u><i>All senses in place</i></u>	<u><i>Volitional behaviour</i></u>
<u><i>Very immature</i></u> 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
<u><i>Moderately immature</i></u> e.g. Rat pups	By 16-18 days	Explore actively well beyond nest Depart and return at will
<u><i>Mature</i></u> 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:

<b><u>Very immature</u></b>	e.g. Tammar joey
- <i>At birth:</i>	brain regions rudimentary; <u>only 2 cortical cell layers</u>
- <i>After birth:</i>	brain growth rate slow
- <i>Cortico-thalamic connections:</i>	none at birth; <u>established &amp; operating after 4-5 months</u>
<b><u>Moderately immature</u></b>	e.g. Rat pups
- <i>At birth:</i>	brain regions differentiated; <u>cortical neurons immature</u>
- <i>After birth:</i>	brain growth rate rises rapidly after birth
- <i>Cortico-thalamic connections:</i>	none or ineffective at birth; <u>established &amp; operating after 2-3 weeks</u>
<b><u>Mature</u></b>	e.g. Lamb
- <i>At birth:</i>	brain regions well differentiated; <u>cortical neurons are nearing maturity some weeks BEFORE birth</u>
- <i>BEFORE birth:</i>	brain growth rate rapid
- <i>Cortico-thalamic connections:</i>	<u>established &amp; operating some weeks BEFORE birth</u>

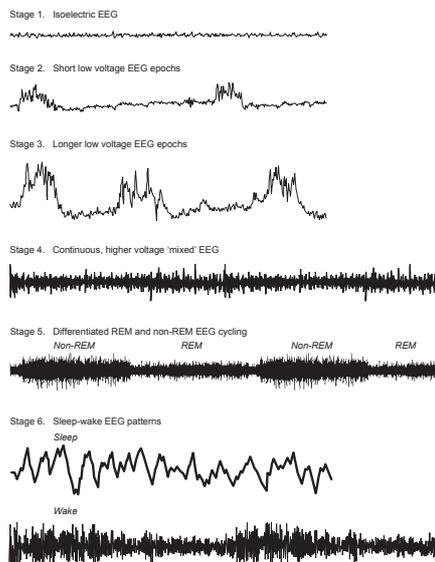
## Onset of cognitive capacity to modulate behaviour

**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*



## 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.

