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
Present talk based on the following papers:


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

---

**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
<table>
<thead>
<tr>
<th>General developmental stage at birth:</th>
<th>Very Immature</th>
<th>Moderately Immature</th>
<th>Mature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
<td>Marsupial joeys:</td>
<td>Newborn:</td>
<td>Newborn:</td>
</tr>
<tr>
<td></td>
<td>wallaby</td>
<td>cats, dogs, ferrets</td>
<td>cattle, deer</td>
</tr>
<tr>
<td></td>
<td>kangaroo</td>
<td>hamsters, mice</td>
<td>goats, sheep</td>
</tr>
<tr>
<td></td>
<td>opossum</td>
<td>rats, rabbits</td>
<td>horses, pigs*</td>
</tr>
</tbody>
</table>

*Piglets intermediate: neurologically mature; thermogenically suboptimal

- Day 6: *Piglets intermediate*
- Day 3: 10-15 min
### General developmental stage at birth:

<table>
<thead>
<tr>
<th>Very Immature</th>
<th>Moderately Immature</th>
<th>Mature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marsupial joeys:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wallaby</td>
<td>Newborn:</td>
<td></td>
</tr>
<tr>
<td>kangaroo</td>
<td>cat, dogs, ferrets</td>
<td>cattle, deer</td>
</tr>
<tr>
<td>opossum</td>
<td>hamsters, mice</td>
<td>goats, sheep</td>
</tr>
<tr>
<td></td>
<td>rats, rabbits</td>
<td>horsed, pigs*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>guinea-pigs</td>
</tr>
</tbody>
</table>

#### Birth site and postnatal location

- **Rapid entry into pouch**
  - Born in burrows, dens, nests or other shelters
  - Born 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

• 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

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:**

<table>
<thead>
<tr>
<th>Very Immature</th>
<th>Moderately Immature</th>
<th>Mature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touch (muzzle/mouth),</td>
<td>Touch, temperature, temperature,</td>
<td>Touch, temperature,</td>
</tr>
<tr>
<td>temperature, taste,</td>
<td>taste, smell, vestibular;</td>
<td>taste, smell, vestibular,</td>
</tr>
<tr>
<td>smell, vestibular;</td>
<td>nociception;</td>
<td>proprioception,</td>
</tr>
<tr>
<td>Not: nociception,</td>
<td>Not: proprioception,</td>
<td>nociception, hearing,</td>
</tr>
<tr>
<td>proprioception,</td>
<td>hearing or sight</td>
<td>sight</td>
</tr>
<tr>
<td>hearing or sight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
### Postnatal Developmental Milestones:

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

#### Behavioural Milestones:

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Behavioural Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-100 days</td>
<td>Continuous teat attachment in pouch</td>
</tr>
<tr>
<td>100-180 days</td>
<td>Intermittent teat attachment; stays in pouch</td>
</tr>
<tr>
<td>180-250 days</td>
<td>Repeatedly leaves pouch and returns</td>
</tr>
<tr>
<td>250 days</td>
<td>Permanently leaves pouch; weaned 300-350 days</td>
</tr>
</tbody>
</table>

#### Postnatal Onset of Sensory Capacities Absent at Birth:

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Sensory Capacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>125-130 days</td>
<td><em>Hearing:</em> approaches adult values by 180 days</td>
</tr>
<tr>
<td>~140 days</td>
<td><em>Sight:</em> can see well by 180 days</td>
</tr>
<tr>
<td>160 days</td>
<td><em>Proprioception:</em> can stand unaided by 160 days</td>
</tr>
</tbody>
</table>

---

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

#### Behavioural Milestones and Onset of Sensory Capacities Absent at Birth:

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

**Mature at Birth** e.g. Lambs

**Postnatal behaviours and sensory capacities**

1-5 min.  
Breathing starts

1-20 min.  
Lies flat: then on sternum, legs tucked in with head up

5-30 min.  
First tries to stand; unsteadily stands and walks

15-60 min.  
Teat seeking starts; locates udder (smell, warmth, touch)  
First sucking bout occurs

5-240 min.  
Vocal interactions with ewe; ewe-lamb bond established

5 min. to 36 h  
Existing sensory capacities and discrimination mature  
Autonomous volitional behaviour increases progressively

12-24 h  
Lamb recognises ewe via hearing and sight

   Lamb follows ewe
Lamb birth sequence

1. 0 min
2. 15-25 min
3. < 1 min
4. 3 min
5. 7-10 min

Postnatal developmental milestones – Summary:

<table>
<thead>
<tr>
<th>Birth status</th>
<th>All senses in place</th>
<th>Volitional behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very immature</td>
<td>By 180 days</td>
<td>First leave dam’s pouch</td>
</tr>
<tr>
<td>e.g. Tammar joey</td>
<td>By 70-90 days</td>
<td>Leave pouch/ride on dam’s back</td>
</tr>
<tr>
<td>Virginia opossum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately immature</td>
<td>By 16-18 days</td>
<td>Explore actively well beyond nest</td>
</tr>
<tr>
<td>e.g. Rat pups</td>
<td></td>
<td>Depart and return at will</td>
</tr>
<tr>
<td>Mature</td>
<td>By &lt; 15 min after birth</td>
<td>Locate dam, suck on demand; Stay with and follows dam</td>
</tr>
<tr>
<td>e.g. Lamb</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**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**

### Onset of cognitive capacity to modulate behaviour

**Key CNS developmental features and timing in relation to birth:**

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

*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

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
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.