Animal Welfare Science and Bioethics Centre

Professor Kevin J Stafford – Co-Director
Professor Craig B Johnson – Co-Director
Dr Ngaio J Beausoleil – Deputy Director

Professor David J Mellor – Foundation Director

Collaborating Centre for Animal Welfare Science and Bioethical Analysis:
Founding Partner

http://animalwelfare.massey.ac.nz
AWSC Melbourne University Seminar
Cognitive 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
Introduction: 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
### 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><strong>Newborn:</strong></td>
<td><strong>Newborn:</strong></td>
</tr>
<tr>
<td>Marsupial joeys:</td>
<td>cats, dogs, ferrets</td>
<td>cattle, deer</td>
</tr>
<tr>
<td>wallaby</td>
<td>hamsters, mice</td>
<td>goats, sheep</td>
</tr>
<tr>
<td>kangaroo</td>
<td>rats, rabbits</td>
<td>horses, pigs*</td>
</tr>
<tr>
<td>opossum</td>
<td></td>
<td>guinea-pigs</td>
</tr>
</tbody>
</table>

*Piglets intermediate:*
- neurologically mature;
- thermogenically suboptimal
### 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><strong>Newborn:</strong></td>
<td><strong>Newborn:</strong></td>
</tr>
<tr>
<td>Marsupial joeys:</td>
<td>cat, dogs, ferrets</td>
<td>cattle, deer</td>
</tr>
<tr>
<td>wallaby</td>
<td>hamsters, mice</td>
<td>goats, sheep</td>
</tr>
<tr>
<td>kangaroo</td>
<td>rats, rabbits</td>
<td>horsed, pigs*</td>
</tr>
<tr>
<td>opossum</td>
<td></td>
<td>guinea-pigs</td>
</tr>
</tbody>
</table>

*Piglets intermediate*

**Day 6**

**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>Newborn:</td>
<td>Newborn:</td>
</tr>
<tr>
<td>wallaby</td>
<td>cat, dogs, ferrets</td>
<td>cattle, deer</td>
</tr>
<tr>
<td>kangaroo</td>
<td>hamsters, mice</td>
<td>goats, sheep</td>
</tr>
<tr>
<td>opossum</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**

- Rapidly entry into pouch
- Born in burrows, dens, nests or other shelters
- Born outdoors with or without shelter*
## General developmental stage at birth:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Species</th>
<th>Birth site and postnatal location</th>
<th>Maternal nurturing &amp; protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Immature</td>
<td>Marsupial joeys:</td>
<td>Born in burrows dens, nests or other shelters</td>
<td>In-pouch milk, care &amp; protection for several months</td>
</tr>
<tr>
<td></td>
<td>wallaby</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>kangaroo</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>opossum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately Immature</td>
<td>Newborn:</td>
<td>Born on outdoors with or without shelter</td>
<td>At secluded birth site, milk, care &amp; protection for several weeks*</td>
</tr>
<tr>
<td></td>
<td>cat, dogs, ferrets</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>hamsters, mice</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>rats, rabbits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mature</td>
<td>Newborn:</td>
<td></td>
<td>Rapid bonding needed to get milk care &amp; protection from mobile dam</td>
</tr>
<tr>
<td></td>
<td>cattle, deer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>goats, sheep</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>horsed, pigs*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>guinea-pigs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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), temperature, taste, smell, vestibular; Not: nociception, proprioception, hearing or sight</td>
<td>Touch, temperature, taste, smell, vestibular; nociception; Not: proprioception, hearing or sight</td>
<td>Touch, temperature, taste, smell, vestibular, proprioception, nociception, hearing, sight</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:**

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
Postnatal developmental milestones:

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

**Behavioural milestones and onset of sensory capacities absent at birth**

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

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

**Postnatal behaviours and sensory capacities**

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

1. 0 min
2. < 1 min
3. ~3 min
4. 7-10 min
5. 15-25 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><strong>Very immature</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. Tammar joey</td>
<td>By 180 days</td>
<td>First leave dam’s pouch</td>
</tr>
<tr>
<td>Virginia opossum</td>
<td>By 70-90 days</td>
<td>Leave pouch/ride on dam’s back</td>
</tr>
<tr>
<td><strong>Moderately immature</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. Rat pups</td>
<td>By 16-18 days</td>
<td>Explore actively well beyond nest</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depart and return at will</td>
</tr>
<tr>
<td><strong>Mature</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. Lamb</td>
<td>By &lt; 15 min after birth</td>
<td>Locate dam, suck on demand; Stay with and follows dam</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:

**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**

**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*. 