Mammalogy Lecture 5 -- Disparity in Diversity between Marsupials and Placentals

So, as we've seen over the last few lecture periods, Eutheria is much more diverse than Metatheria.

This is true in terms of the numbers of species; there are around 6111 eutherian species and ca. 379 metatherian species.

It's also true with regard to diversity in form. For example, there are no fully aquatic marsupials and there are no marsupials with powered flight.

It's likely that this lack of morphological diversity in metatherians is attributable to a constraint on the evolution of their front limb (Cooper and Steppan 2010 – pdf on course website). This paper compared the rate of evolution of metatherian vs. eutherian front limbs to quantify this constraint.

This difference in diversity is remarkable given that these two groups are sister taxa and exclusively share a common ancestor around 170 – 190 MYA.

So today, we'll discuss a long-hypothesized reason for this, and it focuses on reproduction, specifically, the **Trophoblast, Maternal Immune Response**, **& Reproductive Cycles** (Lillegraven et al. 1987. Biol. J. Linnean Soc., 32:281).

There is a difference in the trophoblasts; this is part of the embryonic contribution to the placenta that is well developed in eutherians, but less so in metatherians.

Eutherian Trophoblasts - The developing embryo, just ~ 5 days post fertilization, has reached a stage called the Blastocyst stage

- Early on, there is an outer protein coat called the *zona pellucida*, which is temporary. This is composed of proteins called zp-1, zp-2, & zp-3.

- The blastocyst differentiates strongly in eutherians into two layers, the embryoblast and the trophoblast.

- The trophoblast has many functions; we'll focus right now on immune response and maternal reproductive cycles.

- In eutherians, there is a complete encasement of the embryoblast (the layer that will develop into the embryo), by the trophoblast (the outer layer).

- Furthermore, the eutherian trophoblast implants into the uterine wall, and in many, it develops fingerlike projections into the uterine wall.

- All mammals reproduce sexually, and all are diploid (one hystricomorph from South America was thought to be tetraploid, but comparative genomics suggest it's diploid; Evans et al. 2017. https://academic.oup.com/gbe/article/9/6/1711/3954029?login=true), so half the genes are contributed by the father.

- Because of this, after the *zona pellucida* deteriorates, the developing embryo will be recognized as a foreign object by the immune system of the mother and potentially trigger an immune response, and attack by maternal T-lymphocytes, or T-cells.

- In eutherians, the trophoblast actually protects the embryonic tissues from the immune system of the mother, yet still allows for the passage of nutrients.

- At least two mechanisms contribute to this.

1) Production of **chorionic gonadotropins**, a class of hormones produced by the trophoblast, which maintain the trophoblast and *suppress maternal immune reaction*;

Chorionic gonadotropins have been suggested to repel maternal immune cells and also have been suggested to initiate cell death of the T-cells of the maternal immune system.

They also signal the Corpus Luteum (of the ovary) to halt the estrous cycle (by continued production of progesterone).

This is critical; in eutherians, pregnancy interrupts female reproductive cycles.

2) In many eutherians, some cells of the trophoblast fuse to form a **syncytio-trophobalst**. The cell membranes become continuous and the trophoblast behaves as a single cell. Maternal T-cell lymphocytes can't move past the trophoblast.

Syncytin genes have been captured (repeatedly) by eutherians and are endogenous retroviruses (Laviale et al. 2013. Philos Trans R Soc Lond B Biol Sci 368:1626.). There is evidence for this in *Monodelphis*, but not most metatherians (Cornelis et al. 2015. PNAS 112:E487.).

An excellent recent review of this is presented by Imakawa et al. (2022; pdf on course website), and this has happened repeatedly in eutherian evolution, along with endogenization of other retroviral genes that are likely important.

- Therefore, the developing eutherian embryo can escape from the mother's immune system and does not have to complete development in a short period of time. This allows for relatively **long intra-uterine development in eutherians** (long gestation times).

- These long gestation times permit eutherians to give birth to rather well developed (precocial) young.

- Metatherian trophobalst

- There is a shell membrane that is actually maternal tissue as it is formed by the maternal shell gland. The shell membrane breaks down after about 7 days.

- There is more yolk than in eutherians

- There is less differentiation between the trophoblast and the embryoblast.

- The trophoblast doesn't completely surround the embryonic tissues.

- There is less fusing of trophoblastic cells into the syncytio-trophoblast (fewer syncytins) so there is a less effective barrier between the developing embryo and the mother's immune system once the shell membrane deteriorates.

- Metatherians therefore lack the ability for the embryo to "hide" from maternal immune attack.

- In addition, there appears to be no signaling by chorionic gonadotropins to the Corpus Luteum, and the estrous cycle is not halted. Pregnancy must be completed within a cycle and metatherians have a very short gestation.

- As a result, metatherians have a very short gestation period and bear altricial young.

For example, *Macropus* typically has a gestation period of around 30 days and *Didelphis* has a gestation period of around 12 days (a similar-sized cat has a gestation period 5X longer, at ~60 days). Wombats (*Vombatus*) and Tasmanian devils (*Sarcophilus*) gestation periods are ~21 days, and a koala's (*Phasolarctus*) is ~32 days.

- Metatherians give birth to altricial, very poorly developed young; neonates attach to nipples and complete development.

Gazella & *Macropus* each are ~120 pounds and are plains grazers.

	Gestation	Lactation	Conception to Weaning
Gazella	165 days	55 days	~220 days
Macropus	30 days	~422 days	~452 days

- This has two effects on energetics of reproduction:
    1) Metatherians have a much longer overall period from conception to weaning.
    2) In metatherians, a higher percentage of time is spent lactating. Lactation is about twice as energetically costly than gestation.

- Therefore, eutherians experience a lower overall energy cost of reproduction and have a competitive advantage over metatherians.

- This advantage may explain the difference in species diversity between metatherians and eutherians, under the assumption that lower cost of eutherian reproduction leads to higher diversification rates.

Diversification Rate = Speciation Rate – Extinction Rate. There's evidence of a eutheria-specific acceleration of speciation after the Cretaceous and there's evidence of a higher extinction rate in metatherians.

- Also, this longer gestation in eutherians allows for increased diversity in morphology, especially with regard to the front limb.

- When metatherians are first born, because of such short gestation times, they are remarkably poorly developed. Hind limbs are simply limb buds & organogenesis has only just begun.

- In spite of this, they neonates of almost all marsupials actually have to crawl from the birth canal to the mammae, which may or may not be inside a pouch, where they attach and complete development during the extended period of lactation.

- Almost no assistance in offered by the mother. The most she may do is lay a saliva trail from birth canal to marsupium.

- Because of this, the front limbs of marsupials are rather constrained. That is, the front limbs are not free to evolve into such things as the wings of bats or the flippers of marine mammals (as measured by Cooper & Steppan, 2010).

- Summary: The much longer gestation times seen in eutherians, permitted by immune-response protection and the effects of chorionic gonadotropins on ovarian cycles, reduces overall cost of reproduction relative to metatherians and allows for greater diversity in morphology especially of the forelimb.