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Foreword

Lactation biology

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The single most important unifying characteristic of all mammals, whether they are marsupials, monotremes or eutherians, is their ability to lactate and produce milk as the sole food for their offspring. Neonates are unable to collect, chew and digest solid food and, as such, rely on milk as a complete diet. In addition, milk, and in particular the first milk or colostrum, provides immune protection that is critical to the survival of the neonate. In fact, the immune function of the mammary gland most likely evolved before its role in providing nutrition (Vorbach *et al.*, 2006; Oftedal, 2012). In our ruminant farm species, where there is no exchange of immune factors between the mother and the foetus *in utero*, timely conveyance of immune protection immediately after birth is of utmost importance. In the modern dairy cow, the metabolic priority towards milk secretion is so strongly developed that, even during the first weeks of lactation, when the animal is in a severely negative energy balance, changes in the endocrine milieu enable copious milk secretion to occur (Gross *et al.*, 2011). Indeed, the dairy cow now produces milk far in excess of the immediate requirements of its offspring, and milk has become an important commercial commodity, which is processed into a wide range of food ingredients and food products consumed by humans all over the world. Increasingly, milk is not only recognized for its nutritional properties but also for its bioactive, that is, health- and immune-stimulating properties (Stelwagen *et al.*, 2009).

This special issue of ANIMAL brings together a number of papers that address many aspects of lactation biology, from the evolution of the mammary gland, milk and its composition to current views on the regulation and management of milk production and mammary function in the modern dairy cow, as well exploring the bioactive properties of milk. The papers included in this issue are based on invited talks presented in two symposia held at the 61st Annual Meeting of the European Association of Animal Production (EAAP) that was held on the Isle of Crete, Greece, in 2010. The two papers on the evolution of milk and its composition are derived from the '*Evolution of Mammary Gland and Milk Secretion: Consequences for Lactation in Farm Animals*' symposium, chaired by Rupert Bruckmaier, whereas the remaining papers were presented at the 10th International Symposium on the Biology of Lactation in Farm Animals (BOLFA), chaired by Kerst Stelwagen. The BOLFA symposium is held every 2 years, mostly in conjunction with the annual meetings of either EAAP or ASAS (American Association of Animal Science). The first paper gives a very informative and comprehensive overview of the current state of knowledge about the origins and evolution of the mammary gland, its secretions and milk composition (Oftedal, 2012). The mammary gland may have evolved from a skin gland in synapsids, as many as 300 million years ago, well before mammals appeared as a branch on the evolutionary tree. The initial secretion appeared to have a protective, antimicrobial role, with the nutritive value of these secretions developing much later. The carbohydrate fraction of milk consists of lactose – a unique disaccharide – and a range of oligosaccharides, with lactose usually being by far the most prominent carbohydrate in milk and also the primary source of energy for the neonate. Oligosaccharides on the other hand seem to play more of a protective role and serve as prebiotics. Urashima *et al.* (2012) proposed that the importance of lactose in milk is a more a 'recent' evolutionary phenomenon, as α-lactalbumin, essential for lactose synthesis, was initially absent in milk. Instead, oligosaccharides were likely the key carbohydrates in primitive milk, playing an anti-infection role in the gastrointestinal tract of the milk-fed offspring. When lysozyme – the evolutionary precursor of α-lactalbumin – appeared, lactose was only produced in tiny amounts and its importance as an energy source gradually increased, because the neonates increasingly relied on milk to meet their nutritional demands.

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Because milk nowadays is a very important commercial commodity, there has been a concerted and ongoing effort to increase the milk production of dairy cows, through better nutrition, management and improved genetics. The huge difference in production between individual cows demonstrates that there is still room to optimize milk production further. Approximately 30% of the observed phenotypic difference in milk yield can currently be accounted for by genetics. Epigenetics, leading to changes in chromatin structure as a result of DNA methylation or acetylation events, rather than changes at the gene level, may result in acute (i.e. within the same animal) or permanent (i.e. passed on to the offspring) changes in the regulation of biological processes and may help to explain part of the remaining 70% phenotypic variability. Singh *et al*. (2012) discussed a role of DNA methylation in the regulation of α-casein expression in dairy cows and how epigenetics may play a role in transgenerational inheritance with regard to milk production, although the latter is difficult to substantiate in animals with large generation intervals. Stem cell research has been an active, albeit sometimes politically controversial area of research. The mammary gland, going repeatedly through cycles of lactation, regression and redevelopment, is a prime tissue to study the presence and role of stem cells. Capuco presented an overview of their work on identifying mammary stem cells in the bovine mammary gland and how they may be upregulated by endocrine interactions (Capuco *et al*., 2012). They also have shown for the first time that the mammary stem cell population can be manipulated *in vivo*, by infusing xanthosine into the mammary glands of prepubertal heifers. This approach potentially could lead to an increase in milk production.

It has been known for a long time that cows are susceptible to photoperiod, and that the amount of day light or darkness the animals experience may affect mammogenesis and also their milk yield and composition. Little is known about the underlying mechanisms by which photoperiod exerts its biological effects, other than that the pineal gland and associated endocrine changes (in particular melatonin and prolactin) seem to be involved. Plaut provided a comprehensive overview of the roles circadian clocks play (Plaut and Casey, 2012). Not only are daily and seasonal circadian rhythms coordinated by a master clock in the hypothalamus, but also it appears that there are peripheral circadian clocks in all organs of the body, including the mammary gland, which help to coordinate the signals from the master clock. How these clocks work at the molecular level is only now beginning to be unravelled. Proper management of dairy cows is particularly important during the dry period. It is generally accepted that to prepare the mammary gland for the next lactation cycle, milking must be ceased (i.e. the cow is 'dried off') for a period of up to 2 months. However, at the time of cessation of milking and during the subsequent onset of the next lactation, the mammary gland is extremely susceptible to mastitis. For this reason, and because of the high production levels during late lactation of the modern dairy cow, some have suggested to continue milking cows, without allowing a dry period. Collier discussed the concept of extended lactation and showed that there is a clear parity effect, with first parity dairy cows requiring a 60-day dry period for optimal performance, whereas in older cows a much shorter dry period or even eliminating the dry period may be a viable management option (Collier *et al*., 2012).

Dairy products and dairy ingredients form an important part of the human diet throughout the Western world, and increasingly so in other parts of the world. However, in addition to its nutritional role, milk is also recognized for its bioactive or health promoting properties. Milk is particularly rich in immune-enhancing and immune-stimulating factors and Wheeler discussed a number of minor milk components that may play a role in host defence (Wheeler *et al*., 2012). The commercial potential is promising; however, it is important that any claims based on milk-derived bioactives can be substantiated by showing efficacy in scientifically credible model systems. In the final paper of this series, Purup discussed a number of cell-based models to study the efficacy of milk-derived bioactives (Purup and Nielson, 2012). Such models, combined with *in vivo* model systems will be instrumental in substantiating credible health claims.

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