1. Introduction

Over the past century, the world's population has experienced a rapid increase (Lee, 2011), resulting in a significant rise in the demand for dairy products (Hennessy et al., 2020). Dairy cows are crucial in global dairy production (Jacobs and Siegford, 2012). Currently, concentrated production has become predominant in animal husbandry (Cao and Li, 2013), yet it has introduced numerous challenges (Coleman, 2018), particularly concerning animal welfare (Lebacq et al., 2013). In modern animal husbandry, it is imperative to prioritise animal welfare alongside high yields (Edwardes et al., 2024), and good welfare not only enhances animal production efficiency and product quality (Dawkins, 2016) but also contributes to farm sustainability and public trust (Crossley et al., 2021). Given the complexity of animal welfare (Lutz et al., 2021), assessing the welfare status of dairy cows necessitates considering multiple indicators (Matthews et al., 2012).

This article explains how animal welfare is defined, measured, and improved.

2. Welfare definition

Animal welfare means the ability of animals to live in conditions that are healthy and comfortable and allow them to meet their basic needs while expressing their natural behaviours without enduring unnecessary suffering (Lundmark et al., 2018). This concept spans various dimensions, including biological functions, emotional states, and the opportunity to live naturally (Thomsen and Houe, 2018).

Animal welfare is a complex and multifaceted concept that can be quantified (Broom, 1991). There is no single measurement standard of welfare (Dawkins, 2006); instead, an overall

assessment using a range of indicators is required (Lutz et al., 2021). Methods for measuring animal welfare encompass aspects such as behavioural performance, environmental conditions, nutrition, health status, and emotional well-being of the animals (Dawkins, 2006; Matthews et al., 2012). Formulating pertinent regulations can play a crucial role in enhancing the welfare of dairy cows (Esslemont, 2011).

3. Potential welfare issues

Various factors, including the requirements of the cow, the surrounding environment, and human interaction, influence cow welfare. Ensuring optimal comfort for cows is essential for their welfare (Noordhuizen and Lievaart, 2005).

3.1 House

There are two types of grazing methods: the pasture(Figure 1) and indoor cowshed (Figure 2). Pasture grazing means allowing livestock to move freely and forage outdoors in open fields with plenty of space to roam. Indoor grazing is raising livestock indoors, usually in a barn, which is cheap and requires less space. But no matter which method to use, we need a cow house. The housing conditions significantly influence the welfare of dairy cows. The design and management of cowsheds play a crucial role in determining the welfare of the cows. Proper barn design and management practices can mitigate the risk of diseases in dairy cows while enhancing their comfort (Aubé et al., 2022). However, intensive housing and confined spaces can restrict the natural behavioural expressions of cows, limiting their ability to move, lie down, or socialise freely. This restriction can increase the cows' stress and discomfort (Noordhuizen and Lievaart, 2005).

Figure 1. Cow at pasture (Hein, 2023).

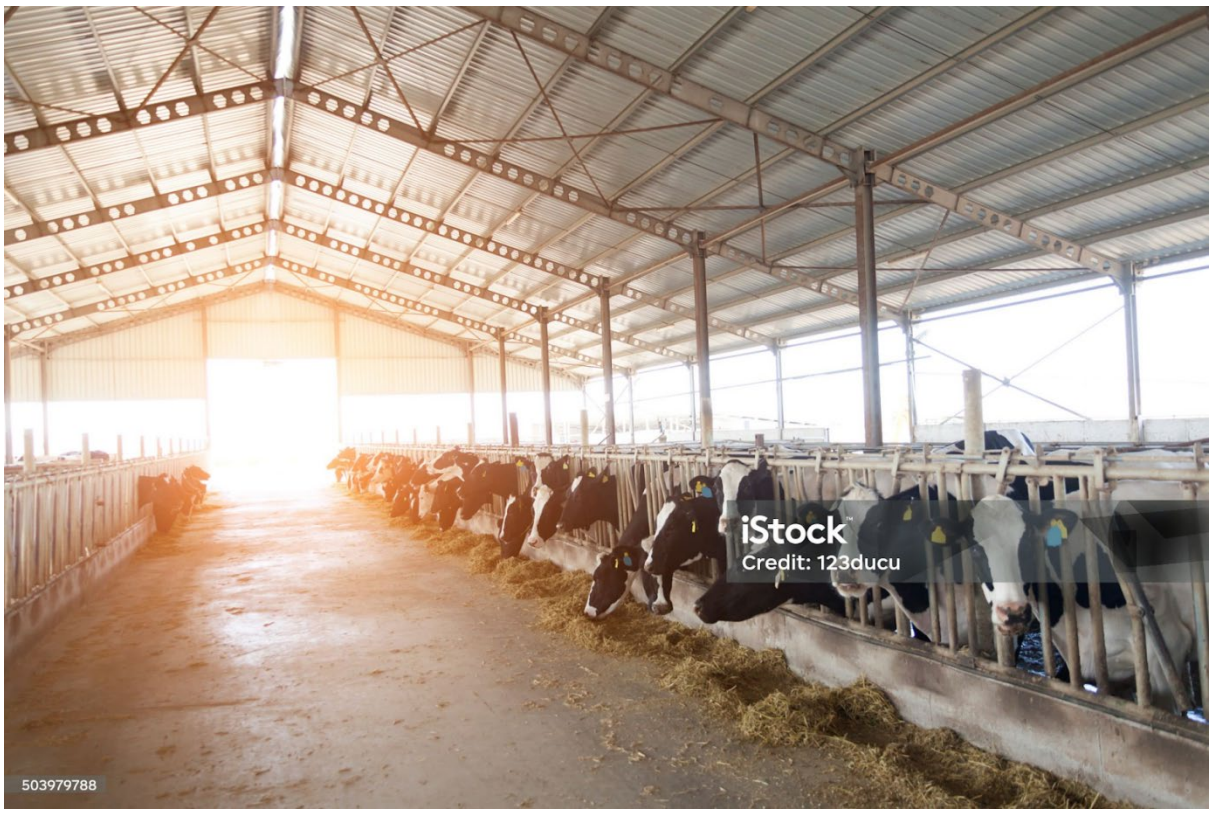


Figure 2. Indoor cowshed (123 ducu, 2016).

3.2 Feed

The quality and availability of feed influence dairy cows' nutritional intake and physiological health (Garamu, 2019). By optimising feed and feeding management practices, including providing good nutrition, regulating the frequency of feed supply, and ensuring cleanliness and proper drying of feed, dairy cows' feed intake and utilisation can be enhanced. This improvement contributes to maintaining healthy body conditions and productivity among dairy cows (Noordhuizen and Lievaart, 2005).

3.3 Disease

Diseases play bad roles in determining the welfare of dairy cows; they can directly impact their production performance and overall quality of life (Arnott et al., 2017). While grazing can help mitigate the risk of mastitis and hoof diseases, it also exposes cows to potential hazards such as parasites, ingestion of toxic plants, and metabolic disorders (Aubé et al., 2022).

3.4 Weather

Pasture environments are more comfortable for cow grazing. However, the comfort level of the pasture is subject to variations in weather and pasture conditions (Aubé et al., 2022). In the pasture, welfare challenges arise from adapting and mitigating cattle to cope with extreme weather conditions. These impacts, which include heat or cold stress, may adversely affect the cattle's health, performance, and overall welfare (Lyles and Calvo-Lorenzo, 2014).

3.5 Animal transportation

Live animal transportation, including animal export and import, is conducted in many countries. However, this practice exposes cows to extreme temperatures, exceeding the cow-

satisfied temperature between 0°C and 35°C (Fiore et al., 2012). Additionally, during transportation, cows may experience discomfort or pain caused by the actions of transport workers, which can significantly harm the welfare of the animals (Coleman, 2018).

3.6 Cow behaviour

Behavioural indicators such as standing time, lying time, and walking activity are significant focal points for assessing the welfare of cows (Noordhuizen and Lievaart, 2005). Reduced milk production often correlates with impaired welfare (Simitzis et al., 2021). While grazing allows cows greater freedom of movement, prolonged walking distances may adversely affect their welfare, mainly if the paths are unsuitable for walking (Aubé et al., 2022). Furthermore, reducing the time spent lying down can impact the physiology of cows, potentially leading to stress. Additionally, lying time serves as an indicator of lameness (Figure 3) in cows (Vasseur, 2017).

Figure 3. Cow lameness (Cara, 2022).

3.7 Human impact

Improper handling of cattle is cruelty, posing risks not only to the well-being of the cattle but also to the safety of the human handlers involved. Farm managers are pivotal (Simitzis et al., 2021), as effective management practices are crucial in enhancing dairy cow welfare (Noordhuizen and Lievaart, 2005).

4. Cow welfare: assessment criteria and how to measure it

When evaluating dairy cows' welfare status, considering multiple factors and employing various assessment methods to ensure thoroughness, reproducibility, and accuracy is important (Aubé et al., 2022). Quantifying welfare is necessary (Calamari and Bertoni, 2009) to consider the complex factors influencing welfare (Calamari and Bertoni, 2009). Continuous improvement in animal welfare should be promoted (Lundmark et al., 2018). To ensure the credibility and applicability of assessment techniques, we must directly relate the chosen indicators with animal welfare (Leliveld and Provolo, 2020), facilitate data accessibility (Napolitano et al., 2005), and maintain assessor consistency (Dawkins, 2006).

4.1 Emotions

Animals possess self-awareness and are capable of experiencing both pleasure and pain (Dawkins, 2006). Utilising "what animals want" as a reference standard can enhance welfare (Mellor, 2015). Emotion welfare is when animals undergo positive emotional experiences without prolonged negative emotional states (Keeling et al., 2021). Cow emotions can be inferred from their facial expressions (Figure 4) and observable behaviours indicative of distress (Comstock, 2018). Presently, most quantifiable indicators of emotional well-being focus on negative aspects, such as elevated stress hormone levels, abnormal behaviours, aggression, fear, and illness, as these are more readily measurable (Simitzis et al., 2021).

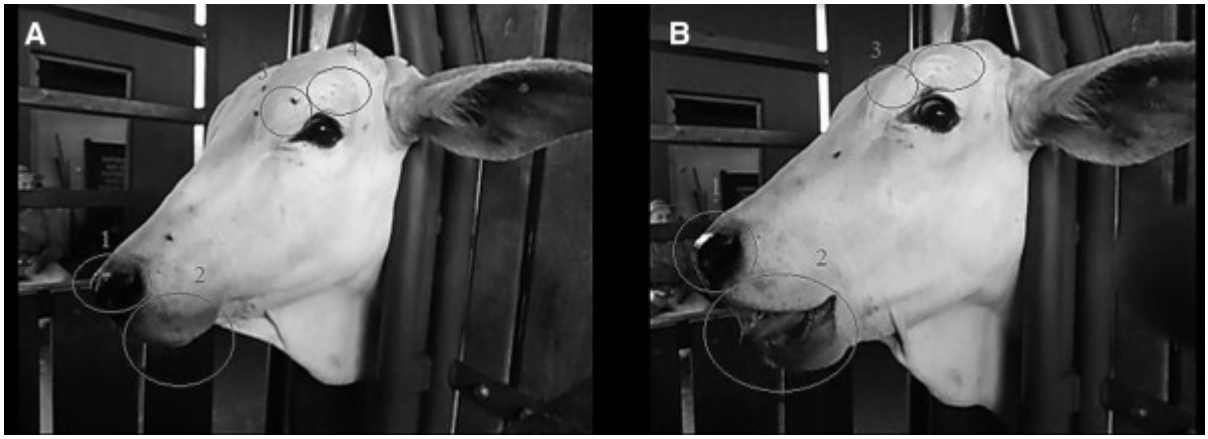


Figure 4. Dilated nostril, open mouth, and raised outer brow for cow face pain showing (Müller et al., 2019).

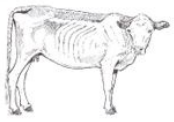
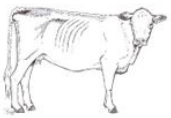
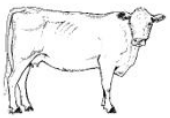
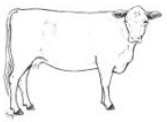
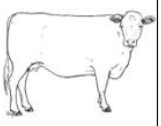
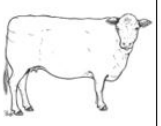
4.2 Biological functions

The health of dairy cows holds significant importance in pasture management and the design of feeding systems (Mee and Boyle, 2020). Monitoring various physiological indicators of dairy cows, including body weight, milk production, milk composition, blood composition, body temperature, and disease occurrences, allows for a comprehensive understanding of their production performance and health status (Vasseur, 2017; Leliveld and Provolo, 2020).

4.2.1 Body condition score

Body condition score (BCS), assessed through observing physical condition and behaviour, is a direct indicator of animal health and welfare (Matthews et al., 2012). There is a negative correlation between BCS and feed intake. Additionally, BCS is associated with indicators of illness, such as elevated body temperature and lameness (Leliveld and Provolo, 2020). A standardised scoring system can be employed, and we can point the BCS out of 5 points via visual observation of the animals(Table 1).

Table 1. BCS of cattle (Blackwood et al., 2018)

Mature cow body condition scores for Angus						
	BCS 0	**BCS 1**	**BCS 2**	**BCS 3**	**BCS 4**	**BCS 5**
						
Brief Description	• Weak, with no body reserves. At risk of death from cold, wet weather or other stressors • Recovery for transport dependent on high quality care but will be slow	• Healthy but with significant muscle wastage • Able to recover from transport if adequately fed	• Lean but strong and healthy with evident muscle wastage	• Moderate condition with rounding of skeletal features • Ideal condition for cows at weaning	• Healthy with significant fat reserves • Ideal condition for cows at joining	• Excessively fat animals with no skeletal features visible • A block shaped appearance and mobility only to walk.
Pin bones	• Inside of pin bones deeply sunken to the bone	• Inside of pin bones sunken	• Inside of pin bones slightly sunken	• Filled but not mounded	• Filled and mounded	• Not identifiable due to fat coverage
Hip and rump	• Hook bone prominent with rump deeply concave	• Hook bone prominent with rump concave	• Hook bone prominent with rump slightly concave	• Hook bone prominent	• Smoothly rounded	• Not identifiable due to fat coverage
Backbone	• Spines of backbone individually identifiable	• Spines of backbone identifiable	• Easily seen	• Not prominent	• Not prominent with rounded appearance	• Not identifiable due to fat coverage
Short ribs	• Very prominent and easy to see individually	• Prominent and very sharp to the touch	• Visible but not individually and fairly sharp to the touch	• Visible and are easily felt with firm pressure as 'rounded' rather than sharp	• Visible and are easily felt with firm pressure	• Cannot be seen or felt
Dewlap	• Dewlap is a skin fold with sternum identifiable	• Dewlap has no fat	• Dewlap has some fat	• A little fill in the brisket/sternum	• Full in the brisket /sternum	• Rounded fat deposit at the brisket/ sternum

4.2.2 Disease check

Disease significantly impacts the health and welfare of dairy cows, affecting various aspects such as milk production, reproductive capacity, and death rates while also causing pain and discomfort, which can compromise mobility and overall quality of life (Arnott et al., 2017).

Annual clinical examinations are a valuable tool for detecting the health status of dairy cows. Diseases can be detected through various methods, including blood tests, assessment of parasites, body lesions view, disease levels tests, adrenocortical activity tests, individual cell counts, heart rate, and metabolic levels (Broom, 1991; Regula et al., 2004; Nielsen et al., 2023).

Dairy cow mortality is related to animal welfare, although there is still limited research in this area. For instance, studies have indicated a relationship between the increase in dairy cow mortality and the number of lame cows (Thomsen and Houe, 2018; Lutz et al., 2021).

4.3 Assessment of Natural Cow Behavior

Assessing a cow's natural behaviour is crucial for evaluating its welfare level. Normal eating behaviours and positive social interactions typically signify that dairy cows are at a higher level of welfare (Beaver et al., 2020).

4.3.1 Animal Social Behavior

Providing cows with ample movement space can decrease stereotypic behaviours (Radkowska et al., 2020). Additionally, calves deprived of social contact may exhibit cognitive deficits and heightened fear responses to new stimuli, underscoring the significance of social interaction for the welfare of dairy cows (Beaver et al., 2020). Welfare assessments can also incorporate cows' social behaviours, such as mutual Grooming Behavior (Figure 5), to further gauge their well-being.

Figure 5. Cattle grooming behavior (Fawcett-Atkinson, 2021).

4.3.3 Vocalisation

Cattle vocalisations are closely linked to the expressed behaviour, with their frequency and volume varying across different behaviours. The sound differs significantly from other behaviours, mainly when lying (Meen et al., 2015). Vocal analysis can be a potential method for monitoring cattle welfare.

4.3.4 Feed assessment

Assessing the feeding status of dairy cows entails considering multiple indicators, with feed intake and milk production recognized as critical factors (Leliveld and Provolo, 2020). Decreased and excessive milk production harms welfare (Botheras, 2007). Additionally, feed intake serves as a reflection of the animal's health. Monitoring rumination time and lying frequency can help determine whether the feed supply is adequate (Leliveld and Provolo, 2020).

4.3.5 Sub-optimal mobility

Sub-optimal mobility (SOM) is a prevalent health disorder in dairy cow production, characterised by abnormal gait observed during exercise. Detecting abnormal movements in cows can aid in diagnosing SOM, which may result from health issues such as hoof problems and muscle or joint diseases (Edwardes et al., 2024).

4.4 Accommodation Environment Assessment

Both accommodation and grazing methods play significant roles in influencing cow welfare and behaviour. The accommodation environment encompasses tests such as cleanliness and accessibility of water sources, feed preparation, stall design and size, cow activity space, environmental changes, grazing season, lighting, ambient temperature, humidity, and floor

conditions (Nielsen et al., 2023; Simitzis et al., 2021; Simitzis et al., 2023). Maintaining the cows' health involves ensuring an accommodation environment that allows them to move freely or rest comfortably (Nielsen et al., 2023) and the ability to engage in exploration and social behaviours (Keeling et al., 2021).

5. Measures to improve dairy cow welfare

Improving dairy cow welfare necessitates thorough scientific evaluation, employing diverse methods (Esslemont, 2011), and improvements based on practical findings (Dawkins, 2006).

5.1 Feed

Improving feed formulation and supply is crucial to enhancing dairy cows' welfare, ensuring that cows receive adequate nutrition can optimise their performance and health. One approach is to adjust the ratio between concentrate and roughage because increasing this ratio is beneficial (Bruijnis et al., 2013). Different dietary options (Table 2) can provide cows with varied nutrients and support their overall welfare (Alqaisi and Schlecht, 2020).

Table 2. One type of cow feed (Arfuso et al., 2017).

Feed ingredients (%)	Period		
	Dry	Steaming-up	Early lactation
Alfalfa silage	54.0	23.0	32.5
Corn gluten feed	6.4	-	-
Corn	5.4	39.1	26.8
Straw	25.0	12.5	-
Corn silage	8.0	4.0	16.4
Soybean meal	-	9.8	6.8
Starch	-	10.0	6.5
Whole cottonseed	-	-	8.2
Mineral and vitamins*	1.2	1.6	2.8
Composition (%)			
Crude Protein	12.43	13.87	16.66
Ethereal Extract	4.18	4.55	5.32
Ash	7.55	7.83	7.34
Ndf	50.45	43.99	33.41
Nfc	25.49	33.56	38.27
Dry Metter Degradable	52.38	59.68	68.22
Adf	24.66	24.46	20.12
Starch	11.71	16.49	25.94
Calcium	0.39	0.41	0.98
Phosphorus	0.24	0.24	0.43
Magnesium	0.30	0.29	0.31
Sodium	0.10	0.11	0.62
Potassium	0.43	0.51	1.39
Chlorine	0.20	0.19	0.28
Sulfur	0.16	0.16	0.21

5.2 Living

Cows exhibit preferences. Natural environments promote increased social interaction (Beaver et al., 2020). Cows tend to spend more time lying or resting in pasture settings than indoors (Arnott et al., 2017). Therefore, if we can choose, pasture-based farming is considered more welfare-friendly. When designing and managing barns, it is essential to prioritise providing ample space for movement and comfort, which helps reduce stress and discomfort for cows.

Ample space ensures they have opportunities to rest naturally, have sufficient lying time, and maintain appropriate stocking densities to minimise disadvantages. Extreme climate also influences living conditions (Arnott et al., 2017; Rao et al., 2014), so we must consider that while designing. Additionally, selecting suitable flooring materials, improving floor surfaces, and maintaining cleanliness can help alleviate lameness issues and improve comfort and health for dairy cows (Winkler, 2014).

5.3 Diseases

Preventing and promptly treating diseases in dairy cows is crucial for enhancing their welfare (Esslemont, 2011). Improving floors and lying surfaces, controlling stocking density, and maintaining dry and clean floors can help reduce the incidence or prevalence of foot diseases (Crossley et al., 2021). Regular health checkups and vaccinations support cow health (Esslemont, 2011). Additionally, further steps can be taken to prevent and treat diseases in dairy cows, including additional pedicures and foot baths (Bruijnis et al., 2013).

5.4 Breeders: Technical improvements

Improving farmers' training and awareness levels, particularly in understanding natural cow behaviour, and utilising technology wisely are critical steps in enhancing dairy cow welfare (Trevisi et al., 2006). Effective management practices can mitigate adverse impacts on welfare (Regula et al., 2004), while technological advancements can improve overall welfare (Beaver et al., 2020). Positive human-cow interactions like brushing fur will enhanced cow welfare and reduced stress reactions (Simitzis et al., 2021). Also, proper equipment and handling techniques can help minimise pain and stress during dairy cow milking (Adamczyk, 2018).

5.4.1 Automatic feeding

As a modern technological application, automatic feeders (Figure 6) mimic the natural feeding requirements of cows, thereby better meeting their behavioural needs (Meen et al., 2015). This innovation enhances production efficiency and elevates animal welfare levels (Beaver et al., 2020).

Figure 6. Automatic cow feeding system (Calm, 2023)

5.4.2 Automatic milking system

Automatic milking systems (AMS) (Figure 7)are advanced milking technologies that enhance production efficiency and optimise cow management. By automating milking processes, AMS liberates labour and utilises automatic sensors to monitor cow conditions. Furthermore, AMS allows individual cows to adjust milking frequency themselves (Jacobs and Siegford, 2012). Reducing physiological stress due to decreased human-animal interaction contributes to enhanced dairy cows' welfare (Beaver et al., 2020).

Figure 7. Automatic milking systems(Fawcett, 2021).

5.4.3 Precision Livestock

Precision Livestock Farming (PLF)(Figure 8) is a digital, automated tool designed to measure and collect animal information efficiently. It automatically assesses welfare by detecting environmental and animal-based indicators through sensors. These indicators include sound detection, locomotor health, cold and heat stress, and social interaction (Kleen and Guatteo, 2023). PLF not only enhances farm management efficiency but also supports AMS by considering each animal's individual differences (Simitzis et al., 2021).

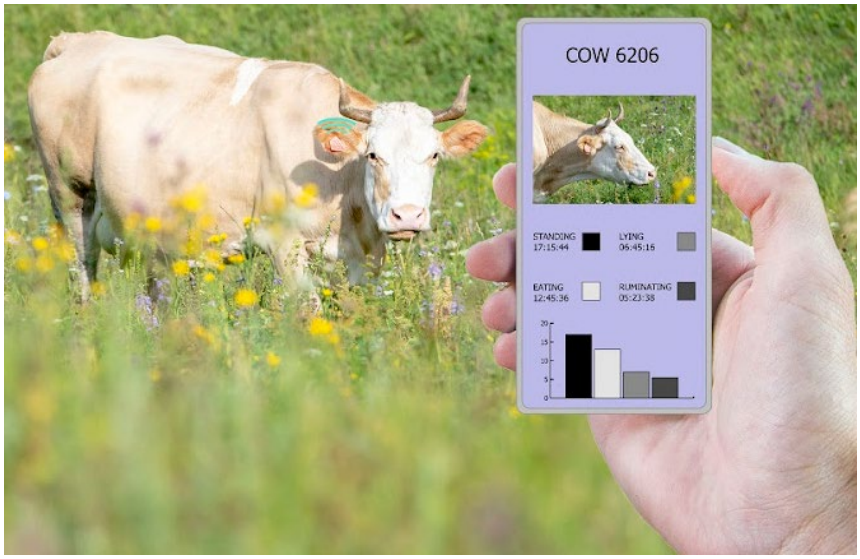


Figure 8. Precision Livestock Farming (Lu, 2021)

6. Conclusion

Assessing and enhancing dairy cow welfare are ongoing endeavours that necessitate careful consideration of various factors, including biological functions, natural behaviour, and breeding conditions. By employing scientific evaluation methods and implementing effective management measures, the welfare of dairy cows can be elevated, and it contributes to the sustainable development of the breeding industry and the enhancement of dairy product quality.

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