

early feeding with milk by gastric tube, regardless of the baby's clinical condition, as recommended by Smallpeice & Davies (1964); but others prefer to give the calories intravenously, fearing that regurgitation may be followed by inhalation, and influenced by the results of the controlled trials carried out by Wharton & Bower (1965), and by Cornblath, Forbes, Pildes, Luebben & Greengard (1966).

Recognition of the dangers of hypoglycaemia in the newborn and of the aetiological factors concerned, preventive administration of calories starting within a few hours of birth, early diagnosis and treatment where prevention has failed, are already combining to eliminate one of the avoidable causes of death and permanent handicap, which is essentially an acute nutritional problem.

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Nutrition and thermoregulation in the newborn pig

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At birth the farm pig weighs rather more than 1 kg; it is one of a litter usually six to twelve in number, and it grows rapidly to double its birth weight in 1 week. Milk is available from the sow at parturition, and normally the pig feeds shortly

after birth. The mean interval between successive sucklings is 1-1.25 h (Barber, Braude & Mitchell, 1955); each piglet obtains about 12 g of milk at each feed in the newborn period, rising to about 30 g at 2 weeks of age (Braude, 1954).

The newborn pig displays a characteristically homoeothermic type of response to cold by raising its metabolic rate to an upper limit of three to four times the resting minimal value. The animal can shiver from birth, and shows evidence of being able to control its skin circulation; measurement of the thermal circulation index suggests that peripheral vasoconstriction occurs in cool conditions (Mount, 1964, 1968).

The consequence of these responses is that thermoregulation is well established in the newborn pig in spite of the animal's lack of thermal insulation and correspondingly weak powers of heat conservation. The ability to regulate body temperature depends on the level of heat production, and the most direct way in which the effect of nutrition can be considered is to compare the pig fasted from birth with the normally fed pig.

Rectal temperature. Immediately following birth, rectal temperature falls sharply, usually by about 2° or rather more, although the extent of the fall, and the rate of the subsequent recovery towards the mature level of about 39°, are influenced by the environmental temperature (Newland, McMillen & Reineke, 1952; Mount, 1959). The fall occurs during the first 20-30 min, and the rise occupies the next 12-24 h. The result is that the mean rectal temperature of a number of pigs up to about 12 h old is in the region of 38°, while in the 2-day-old pig it is close to 39°.

These findings apply to pigs fed normally by the sow. When the animal is fasted from birth, however, the rectal temperature remains low, and is still at 37-38° by 16-24 h of age, that is 1-2° lower than in the fed pigs.

Metabolic rate. The rise in body temperature is accompanied by a rise in metabolic rate, whether this is measured in the warm or in the cold, but with a proportionately greater rise in the warm. Thermal neutrality may be defined as the range of environmental temperature over which metabolic rate is at a minimum; the lower end of the range is marked by the critical temperature; at temperatures below this level, the organism has to increase its metabolic rate if body temperature is to be maintained. The critical temperature for the newborn pig is close to 34°. When measured at thermal neutrality, metabolic rate determined as oxygen consumption is in the region of 8-10 ml/kg min in the first few hours after birth; by the 2nd day, it has risen to a mean value of about 15 ml/kg min in the normally fed animal. In the fasted pig, however, the rate remains low, although food reserves are not depleted by that time at that temperature (Morrill, 1952c).

When exposed acutely to cooler conditions, however, at 15-19°, metabolic rate rises to about 30 ml/kg min, whether the animals are fed or not. This suggests that under cold conditions it is the degree of environmental thermal demand which determines the rate of heat production, while in or near thermal neutrality the nutritional status of the animal is the principal factor.

Thermoregulatory capacity. In order to investigate the effects of age and body-weight on thermoregulatory capacity, a number of newborn pigs, some fed and

some unfed, were exposed individually to an environmental temperature of 5°, and their rectal temperatures and rates of oxygen consumption were studied for some hours (Mount, 1961). About half of the animals so exposed showed a steep decline in body temperature, and had to be removed from the test chamber in order to avoid death in hypothermia. The remaining pigs maintained their temperature with a relatively small decrease when placed in the cold. Analysis showed that age and body-weight by no means accounted for all the variation in cold resistance; it was found that cold resistance depended to a large degree on the maximum rate of heat production which could be achieved by the animal, a quantity termed the 'metabolic capability'. It was apparent too that whether the animal was fed or not was also not significant in determining the response, since the mean rates of fall of rectal temperature in the fed and unfed pigs were similar (see Table 1). Pomeroy (1953), however, obtained evidence under his conditions that a pig 12 h after birth could withstand cold exposure more successfully if it had recently been suckled; if the pig had not recently fed, its ability to withstand cold even at 48 h of age was not good.

Table 1. *Mean values and their standard errors for age, body-weight and rates of fall in rectal temperature of fed and fasted pigs, under 1 day old, exposed to 5° ambient temperature*

	Fed	Fasted
No. of pigs	6	5
Age (h)	13.5 ± 1.6	9.2 ± 3.8
Body-weight (kg)	1.26 ± 0.13	1.19 ± 0.09
Rate of fall in rectal temperature (°C/h)	2.37 ± 1.2	2.84 ± 0.62

The newborn pig's homoeothermic type of response to cold thus takes place whether the animal has fed or not, although the degree of response may be partly determined by feeding. The postnatal rise in body temperature and metabolic rate, however, which is determined primarily by time since birth and not mainly by the level of environmental thermal demand, does not take place if the animal is fasted from birth.

Energy stores. The newborn pig's carcass contains very little fat, only about 1% (Widdowson, 1950). Its skeletal muscle contains particularly large quantities of glycogen, however, at 20.9 g/kg body-weight, compared with 8.8 for the lamb and 2.3 for the rabbit (Dawes & Shelley, 1968). The fasted newborn pig therefore relies primarily on its glycogen stores for energy purposes.

McCance & Widdowson (1959) kept fasted newborn pigs at 12 and 31° environmental temperature, and investigated the pattern of metabolism. The pattern was similar in both cold and warm conditions, although intensified in the cold. The small amount of fat could make only a small contribution, and it was calculated that the glycogen which was used constituted 69 and 67% of the total solids metabolized in cold and warm conditions respectively: 24.0 g glycogen/kg per 24 h at 12°, and 11.2 g at 31°. Carbohydrate provided the main source of energy for the fasted newborn pig, although the 12° animals catabolized more tissue protein than the 31° pigs.

Glucose metabolism. The importance of carbohydrate to the newborn pig was made evident by the description by Graham, Sampson & Hester (1941) of a syndrome involving coma and death in newborn pigs. The only unusual finding in these animals was a very low level of blood sugar. It was found that, if food intake was restricted, the pigs were highly susceptible to spontaneous hypoglycaemia in the first few days following birth, but were increasingly resistant from about 1 week of age (Hanawalt & Sampson, 1947). Some animals could be resuscitated by the injection of glucose.

Morrill (1952*a,b,c,d*) subsequently showed that the rate of development of hypoglycaemia depended on environmental temperature; at 15° the animals were moribund at 28 h, but at 31° the same state was not reached for 84 h, suggesting that the higher temperature conserved the reserves by reducing metabolism. The warm pigs also lost a higher percentage (31%) of their initial body-weight than the cold pigs (12%), suggesting that metabolizable reserves which were available in the warm pigs could not be used in the cold animals. Goodwin (1957) later concluded from his observations that the metabolism of the newborn pig is dependent on the concentration of circulating glucose, so that when this is lowered heart and respiratory rates, and body temperature, also decline.

Respiratory quotient. In spite of the apparent dependence of the newborn pig on glucose, the respiratory quotient is not unity, although during the first 4 hours following birth it has a mean value between 0.90 and 0.95. Between 12 and 24 h the RQ falls to below 0.9, whether the pig has fed since birth or not. This is a clear indication that the animal is metabolizing material other than carbohydrate. During the remainder of the 1st week following birth the RQ lies mainly between 0.75 and 0.85. This is in keeping with the probability that fat metabolism increases markedly when the pig first begins to feed, since the fat content of the carcass rises from 1% to about 10% in the 1st week (Brooks, Fontenot, Vipperman, Thomas & Graham, 1964).

Summary. The increases in body temperature and in metabolic rate which occur in the first postnatal day in the pig do not take place if the animal is fasted from birth. Such complete dependency on food intake is not seen, however, either in the pig's acute metabolic response to cold, or in the fall in respiratory quotient from values often above 0.9 during the first 4 h following birth to below 0.9 during the 1st day. In spite of the newborn pig's apparent dependence on carbohydrate metabolism, the respiratory quotient is not unity.

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Nutrition and temperature control in the newborn baby

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At birth the constant supply of oxygen and food which the developing foetus enjoys in the uterus suddenly stops. The newborn infant quickly establishes an alternative source of oxygen when he expands his lungs and begins to breathe, but an alternative supply of nutrients is not obtained so quickly. Even if he is allowed to suckle at birth there is inevitably some delay before intestinal absorption of milk is sufficient to meet his metabolic needs. Thus he mobilizes his own food reserves and this leads to a change which is as fundamental, although not as dramatic, as the commencement of breathing, for in the uterus, glucose is probably the main source of cellular energy whereas after birth fatty acids play the major part.

After birth the resting rate of oxygen consumption increases over the first few hours or days of life. This is not surprising because the newborn infant moves his limbs more than the foetus and begins to breathe, suckle, digest and excrete for himself. Furthermore, he must vary his metabolic rate to maintain a constant internal thermal environment. This puts added demands on his limited food stores. Recent investigations have shown that the human infant like many newborn mammals has a supply of fat tucked away for the sole purpose of heat production in a special tissue called brown adipose tissue. Brown adipose tissue is a fat-storing tissue and therefore it must also be considered as a possible source of circulating free fatty acids. Indeed Shattock (1909), noting its rich blood supply, suggested that the special function of brown adipose tissue was the rapid supply of fat in an emergency.

Circulating free fatty acid (FFA) levels in newborn infants

A rise in plasma FFA from a cord level below 0.4 m-equiv./l. to values ranging between 0.8 and 1.2 m-equiv./l. within 24 h of birth have been observed in full-term human infants (Van Duyne & Havel, 1959; Novak, Hahn, Koldovsky &