

Differences in body compositions, growth and food intakes between mice which have been selected for a small or large body size

Effect of plane of neonatal nutrition

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1. Q-strain mice selected for high-line (QLF) or low-line (QSC) body-weights at 6 weeks of age were culled to litters of two or eight (QLF-2, QLF-8, QSC-2, QSC-8) at birth and were suckled in these groups until 19 d of age.
2. Body-weights were measured daily for all groups and body compositions compared at birth and 19 and 42 d of age. Food intakes and urinary and faecal nitrogen were measured during metabolism trials between 19 and 42 d.
3. QLF-2 and QSC-2 mice grew faster than the corresponding groups of eight until 19 d of age. They also deposited more fat as a percentage of total gain.
4. In the period 19–42 d the influence of genetic selection reappeared and was manifest in a slowing of growth rates of QLF-2 and QSC-2 animals so that by 42 d of age there were no differences in body-weight between the groups within a line.
5. During the period 19–42 d the total food intakes of each group within a line did not differ although, on the basis of food intake per unit metabolic body-weight ($\text{g/kg body-weight}^{0.75}$ per d) QLF-2 and QSC-2 ate less food than QLF-8 and QSC-8 respectively.
6. The differences in body-weight at 19 d between groups were largely overcome by the increased contribution of protein and water to the weight gain of the groups of eight during the post-weaning period.

Q-strain mice have been genetically selected during sixteen generations on the basis of either a large (QLF) or a small (QSC) body-weight at 6 weeks of age (Falconer, 1973). These selection criteria have also produced the correlated responses of either a high (QLF mice) or low (QSC mice) rate of pre- and post-weaning growth (Rucklidge, 1981). QLF mice are larger than QSC at all ages and it might be argued that large (QLF) mothers can provide an improved level of nutrition both pre- and post-partum to their pups. The converse might apply to QSC mice.

Stanier & Mount (1972) showed that mice which had been selected for a large mature body-weight could be induced to increase their pre-weaning growth rates further by culling the litters to groups of four, but surprisingly there was no such increase when litters of small mice were similarly culled. They also reported that large mice cross-fostered on small mothers grew better than small mice suckled on their natural mothers, and concluded that the milk supply to small mice suckled on natural mothers was not normally the factor responsible for their low rate of growth.

The effects of under- and overnutrition of rats during different periods of post-partum development have been extensively reviewed by McCance & Widdowson (1974). They concluded that the subsequent rate of growth of an animal seems to be predetermined by its rate of growth – or possibly its size – during the critical period of development early in life when the regulating centres of the hypothalamus are being coordinated with that rate of growth. Rats undernourished from birth grew less well than animals over-nourished during the same period, and did not regain the body-weight of control animals when fed *ad lib.* in the post-weaning phase. Underfeeding in the post-weaning phase also reduced growth rate and body-weight but this was regained on the continuation of *ad lib.* feeding with an appropriate increase in food intake until body-weights were equated with controls.

The present paper presents an examination of the extent to which neonatal nutrition influences the subsequent appetite, growth rate, mature body size, energetic efficiency and body compositions of Q-strain mice and to what extent any such effects are overridden by genetic differences between the lines of mice.

MATERIALS AND METHODS

The experimental animals were obtained from the Unit of Animal Genetics, University of Edinburgh. The breeding stock of large mice was designated QLF (Q-strain, large line, L, replicate, F) and that of the small mice QSC (Q-strain, small line, S, replicate, C) (Falconer, 1973). The stocks were housed and fed as described previously (Rucklidge, 1981). The diet had an apparently digestible energy content of 17.18 MJ/kg dry matter and an apparently digestible nitrogen content of 28.20 g/kg dry matter.

Once the female was confirmed to be pregnant the male was removed to prevent post-partum mating which might adversely affect the milk output of the mother. At birth, the maternal weight and individual pup weights were recorded. Mean weights of individual pups were recorded (excluding pups which were obviously runted) and litters were culled to groups of two, four, six or eight, the individuals being chosen to have body-weights close to the mean value for that litter. The groups were designated QLF 2, QLF 4 etc. and QSC 2, QSC 4 etc. Between birth and 19 d of age the individual pups were weighed daily and from 10 d they had access to creep feed. At 19 d the pups were removed and housed in pairs in the metabolism cages described by Rucklidge & McKenzie (1980). Body-weights and food intakes of the mice were measured daily and N balance trials and comparative slaughter experiments performed as described by Rucklidge (1981).

RESULTS

All the experiments reported in this paper were performed using animals culled to groups of two, four, six or eight. Only the results obtained for groups of two and eight are formally presented being the two extremes within which the groups of four and six form a continuous series.

Body-weight measurements

The mean (\pm SE) body-weights (g) of the mothers of QLF and QSC mice were different immediately post partum (QLF 43.12 ± 0.61 , QSC 26.98 ± 0.50 ; $P < 0.001$) and the number of pups/litter born to the respective lines also differed (QLF 9.52 ± 0.37 , QSC 8.41 ± 0.33 ; $P < 0.001$). However the mean weight of pups produced per g maternal body-weight was higher for the QSC mice than the QLF mice (QLF 0.39, QSC 0.46).

Body-weights of QLF-2 and QLF-8 mice were measured from birth until 19 d (pre-weaning) and from 19 to 42 d (post-weaning) (Fig. 1 (*a* and *b* respectively)). QSC-2 and QSC-8 mice were similarly treated (Fig. 1 (*c* and *d* respectively)). Although there was an indication of a difference in body-weight between QLF-2 and QLF-8 within a few days post partum, the difference did not attain statistical significance until 10 d and remained different until 34 d after which the weights were similar (Table 1). The body-weights of QSC-2 and QSC-8 were not significantly different until 8 d but the difference remained until 39 d of age. No significant differences in body-weight were apparent between QLF-8 and QSC-2 between 1 and 8 d but by 10 d QSC-2 mice were significantly heavier ($P < 0.01$) and remained so until 24 d after which QLF-8 became heavier again ($P < 0.01$) until the end of the experimental period ($P < 0.001$) (Table 1).

Body compositions

There were no significant differences between the body compositions of QLF-2 and QLF-8 mice at 19 d but at 42 d post partum QLF-2 mice had more fat ($P < 0.05$) and less water

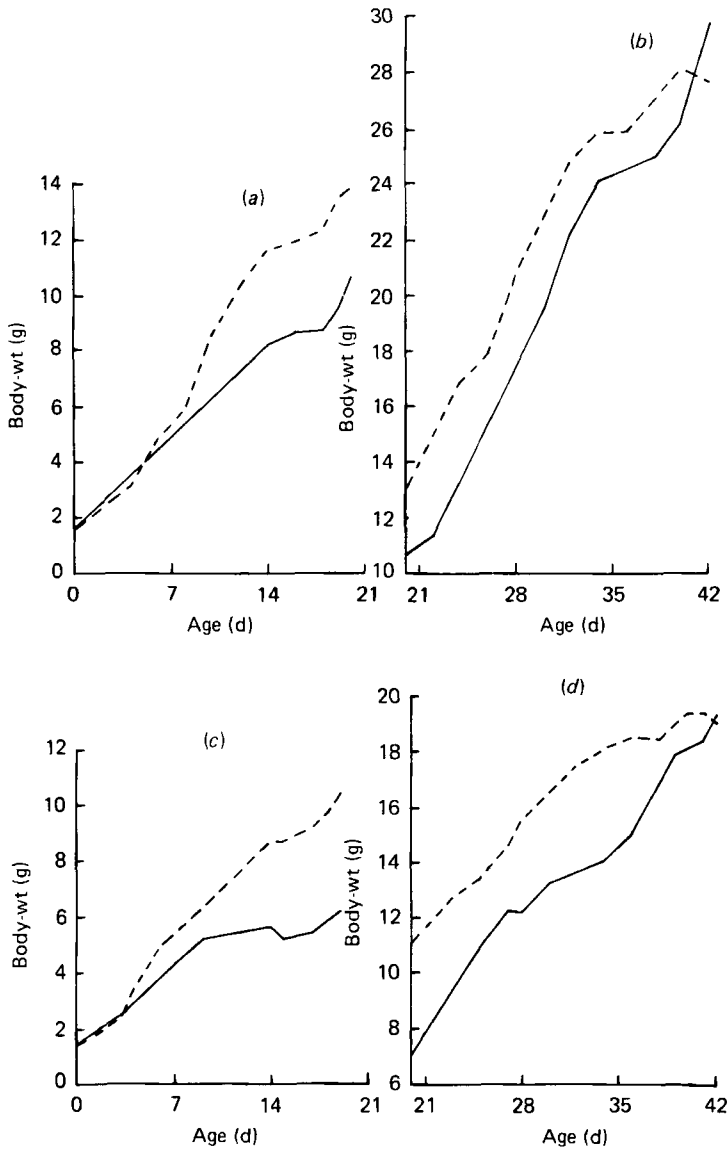


Fig. 1. Growth curves of selected mice from birth to 6 weeks of age (weaning at 19 d of age). (a, b), QLF-2 mice (—) selected for large body-weight at 6 weeks of age suckled in groups of two. QLF-8 mice (- -) selected for large body-weight at 6 weeks of age suckled in groups of eight. (c, d), QSC-2 mice (—) selected for small body-weight at 6 weeks of age suckled in groups of two. QSC-8 mice (- -) selected for small body-weight at 6 weeks of age suckled in groups of eight. Body-weight (g) at 19 d QLF-2 13.47, QLF-8 9.66, QSC-2 10.50, QSC-8 6.84; at 6 weeks QLF-2 27.67, QLF-2 29.94, QSC-2 19.35, QSC-8 19.39.

($P < 0.05$) than QLF-8 mice. Protein and ash concentrations were similar between these groups at the same age although the concentrations of protein and fat had increased in both groups between 19 and 42 d with a decrease in the concentration of body water (Table 2).

At 19 d QSC-2 mice had a higher concentration of fat ($P < 0.05$) and a lower concentration of water ($P < 0.05$) than QSC-8 mice but there were no differences in body

Table 1. A comparison of body-weights (g) of QLF-2, QLF-8, QSC-2 and QSC-8 group mice at different ages

(Values expressed as means with their standard errors)

Age (d)	QLF-2			QLF-8			QSC-2			QSC-8		
	<i>n</i>	Mean	SE	<i>n</i>	Mean	SE	<i>n</i>	Mean	SE	<i>n</i>	Mean	SE
Birth	64	1.78	0.02	64	1.78	0.02	32	1.49	0.03	32	1.49	0.03
8	6	5	0.25	32	5.49	0.15	8	5.45	0.17	32	4.46	0.10
10	6	8.59	0.41	32	6.31	0.07	10	6.87	0.10	24	4.93	0.20
24	12	16.96	0.61	6	14.18	0.34	4	12.92	0.29	18	10.26	0.35
34	10	25.85	0.58	8	24.84	0.60	6	18.10	0.87	12	14.08	0.64
39	12	26.87	0.79	6	27.84	0.41	6	18.80	0.93	8	17.83	1.13

Significance of differences				
	QLF-2 v. QLF-8	QSC-2 v. QSC-8	QLF-8 v. QSC-2	QLF-8 v. QSC-8
Birth	NS	NS	$P < 0.001$	$P < 0.001$
8	NS	$P < 0.001$	NS	$P < 0.001$
10	$P < 0.001$	$P < 0.001$	$P < 0.01$	$P < 0.001$
24	$P < 0.001$	$P < 0.001$	$P < 0.01$	$P < 0.001$
34	NS	$P < 0.001$	$P < 0.001$	$P < 0.001$
39	NS	NS	$P < 0.001$	$P < 0.001$

QLF-2, mice selected for large body size at 6 weeks of age culled to litter of two pups at birth; QLF-8, mice selected for large body size at 6 weeks of age culled to litter of four pups at birth; QSC-2, mice selected for small body size at 6 weeks of age culled to litter of two pups at birth; QSC-8, mice selected for small body size at 6 weeks of age culled to litter of eight pups at birth.

The statistical analysis employed a one-way analysis of variance and pairs of means were compared using a two tailed *t* test based on the pooled residual standard deviation. This standard deviation reflects the variability between values within the same group, each of these values being based upon a pair of litter mate mice.

NS, not significant.

compositions between these groups at 42 d. There was however a small increase in protein concentration between 19 and 42 d in each group. There was a large increase in the concentration of fat between 19 and 42 d in the QSC-8 mice and this was accompanied by a decrease in body water (Table 2). QSC-2 and QLF-8 mice had similar body compositions at 19 and 42 d despite the difference in body-weights at 42 d. QLF-8 mice were fatter than QSC-2 mice at 19 d but there were no differences in body composition at 42 d.

The contributions of the different body components (protein, fat, water and ash) to the overall weight gains are shown in Table 3. Between birth and 19 d, QLF-2 and QLF-8 mice grew with a similar composition of weight gain (although QLF-2 grew more in absolute terms). During the period 19–42 d QLF-2 mice had a large proportion of fat contributing to weight gain and a decreased contribution of water compared with QLF-8 mice. The contribution of protein to weight gain in this period was similar between groups.

QSC-2 mice had a larger contribution of fat to the weight gain between birth and 19 d compared with QSC-8 but this does not fully account for the increase in over-all body-weight by 19 d. The contribution of protein and water to weight gain was not different between these groups in the pre-weaning period. Between 19 and 42 d the desposition of fat contributed more to weight gain in the QSC-8 group than QSC-2 such that the body compositions were similar at 42 d. A comparison of QLF-8 with QSC-2 (which grew at the same absolute rates between 1 and 23 d) indicates that the composition of growth between birth and 42 d was similar despite the large difference in body-weight at 42 d.

Table 2. The composition (g/kg) of digesta-free carcass of QLF-2, QLF-8, QSC-2 and QSC-8 mice at birth and 19 and 42 d of age (Values expressed as means with their standard errors)

	QLF			QSC						
	<i>n</i>	Mean	SE	<i>n</i>	Mean	SE				
Body composition at birth (g/kg)										
Water	Pooled sample of 14	826	—	Pooled sample of 7	818	—				
Fat	8	64	8	9	44	4				
Protein	8	183	5	9	180	2				
Ash	Pooled sample of 14	20	—	—	ND	—				
		QLF-2		QLF-8		QSC-2		QSC-8		
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Composition at 19 d (g/kg)										
(No. of values)...	(7)	(8)				(7)	(9)			
Water	697	7	716	10	714	11	740	4		
Fat	86	12	64	8	79	15	44	4		
Protein	184	7	183	5	170	4	180	2		
Ash	31	4	32	1	29	1	31	2		
Composition at 42 d (g/kg)										
(No. of values)...	(6)	(6)				(5)	(14)			
Water	649	5	680	9	664	12	661	7		
Fat	117	7	74	14	79	22	99	8		
Protein	195	3	194	5	196	3	195	3		
Ash	33	2	32	1	33	1	33	1		
Significance of differences										
		QLF-2 v. QLF-8		QSC-2 v. QSC-8		QLF-8 v. QSC-2		QLF-8 v. QSC-8		
Age (d)...	(19)	(19)				(19)	(19)			
Water	NS	<i>P</i> < 0.05				NS	NS			
Fat	NS	<i>P</i> < 0.05				NS	<i>P</i> < 0.05			
Protein	NS	NS				NS	NS			
Ash	NS	NS				NS	NS			
Age (d)...	(42)	(42)				(42)	(42)			
Water	<i>P</i> < 0.05	NS				NS	NS			
Fat	<i>P</i> < 0.05	NS				NS	NS			
Protein	NS	NS				NS	NS			
Ash	NS	NS				NS	NS			

QLF-2, mice selected for large body size at 6 weeks of age culled to litter of two pups at birth; QLF-8, mice selected for large body size at 6 weeks of age culled to litter of eight pups at birth; QSC-2, mice selected for small body size at 6 weeks of age culled to two pups at birth; QSC-8, mice selected for small body size at 6 weeks of age culled to eight pups at birth.

The statistical analysis employed a one-way analysis of variance and pairs of means were compared using a two tailed *t* test based upon the pooled residual standard deviation. This standard deviation reflects the variability between values within the same group, each of these values being based upon a pair of litter-mate mice.

ND, not determined; NS, not significant.

Table 3. *The composition of weight gains (protein, fat, water, ash) between birth and 19 d and between 19 and 42 d for QLF-2, QLF-8, QSC-2 and QSC-8 mice*

	QLF-2				QLF-8			
	Gain from birth to 19 d		Gain from 19 to 42 d		Gain from birth to 19 d		Gain from 19 to 42 d	
	Absolute gain (g)	% of gain	Absolute gain (g)	% of gain	Absolute gain (g)	% of gain	Absolute gain (g)	% of gain
Body-wt	11.69	—	14.20	—	7.88	—	20.28	—
Protein	2.22	18.99	2.88	19.99	1.55	19.63	4.01	19.80
Fat	1.09	9.29	2.06	14.51	0.56	7.11	1.60	7.89
Water	7.90	67.57	8.45	59.52	5.44	69.10	13.45	66.33
Ash	0.38	3.27	0.50	3.52	0.28	3.52	0.65	3.21
	QSC-2				QSC-8			
Body-wt	9.01	100	8.85	100	5.35	100	12.55	100
Protein	1.72	19.14	1.97	22.26	1.00	18.69	2.59	20.66
Fat	0.84	9.32	0.77	8.70	0.26	4.82	1.61	12.79
Water	6.29	69.78	5.34	60.34	3.84	71.78	7.75	61.78
Ash	ND		0.33	3.75	ND		0.43	3.41

QLF-2, mice selected for large body size at 6 weeks of age culled to litter of two pups at birth; QLF-8, mice selected for large body size at 6 weeks of age culled to litter of eight pups at birth; QSC-2, mice selected for small body size at 6 weeks of age culled to litter of two pups at birth; QSC-8, mice selected for small body size at 6 weeks of age culled to litter of eight pups at birth.

ND, not determined.

Food intakes

The food intakes of QLF-2, QLF-8, QSC-2 and QSC-8 mice were measured daily from 19 to 42 d (Table 4). The QLF groups ate more food than their respective QSC groups ($P < 0.001$) but there were no differences in food intake between the groups within a particular line (Table 4). The QLF-8 mice did eat more food per unit metabolic body-weight ($\text{g/kg } W^{0.75}$ per d) than QSC-2 mice ($P < 0.05$). There were no differences in food intakes per unit metabolic body-weight between groups QLF-2 and QSC-2, groups QSC-2 and QSC-8 or groups QLF-8 and QSC-8. The gross food efficiency (g food intake/g body-weight gain) for QLF-2 was less than that of QLF-8 ($P < 0.05$). A similar difference exists between QSC-2 and QSC-8 and between QSC-8 and QLF-2. QLF-8 mice were more efficient ($P < 0.001$) than QSC-2 mice (Table 4).

The partitioning of dietary energy and dietary N

Between 19 and 42 d, QLF-2 and QLF-8 mice deposited the same proportion of their apparently digestible energy intakes (Table 5), but QLF-2 mice deposited more of their energy intake as fat while QLF-8 deposited more as protein ($P < 0.05$). QSC-8 animals deposited more of their apparently digestible energy than QSC-2 animals between 19 and 42 d ($P < 0.001$). Both groups deposited similar proportions of their energy intakes as protein but the QSC-8 animals deposited almost seven times as much energy as fat compared with QSC-2.

QSC-8 mice deposited a similar proportion of energy intake to QLF-2 and QLF-8 (approximately 8%) while the QSC-2 deposited approximately half this amount, the short

Table 4. Food intake, food intake/unit metabolic weight, weight gains, gross food efficiencies and N excretion as urine and faeces of QLF-2, QLF-8, QSC-2 and QSC-8 mice between 19 and 42 d on feeding trial

(Values expressed as means with their standard errors; no. of pairs of mice shown in parentheses)

	QLF-2 (6)		QLF-8(6)		QSC-2 (5)		QSC-8 (4)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Gross food intake (g/mouse)	110.2	2.6	107.3	2.9	86.1	3.9	84.5	3.7
Mean metabolic body-wt (kg body-wt (W) ^{0.75})	0.0541		0.0505		0.0427		0.0398	
Food intake per unit metabolic body-wt (g/kg W ^{0.75} per d)	88.6	1.4	92.4	2.1	87.6	2.4	92.3	2.5
Body-wt gain (g/animal)	14.2	0.7	17.7	0.6	8.7	0.7	10.4	1.0
Gross food efficiency (g food intake/g body-wt gain)	7.9	0.4	6.1	0.1	10.1	0.8	8.2	0.6

	Significance of differences			
	QLF-2 v. QLF-8	QSC-2 v. QSC-8	QLF-8 v. QSC-2	QLF-8 v. QSC-8
Gross food intake	NS	NS	<i>P</i> < 0.001	<i>P</i> < 0.001
Food intake per unit metabolic body-wt	NS	NS	<i>P</i> < 0.05	NS
Body-wt gain	<i>P</i> < 0.001	<i>P</i> < 0.001	<i>P</i> < 0.001	<i>P</i> < 0.001
Gross food efficiency	<i>P</i> < 0.05	<i>P</i> < 0.05	<i>P</i> < 0.001	<i>P</i> < 0.05

QLF-2, mice selected for large body size at 6 weeks of age culled to litters of two pups at birth; QLF-8, mice selected for large body size at 6 weeks of age culled to litters of eight pups at birth; QSC-2, mice selected for small body size at 6 weeks of age culled to litters of two pups at birth; QSC-8, mice selected for small body size at 6 weeks of age culled to litters of eight pups at birth.

The statistical analysis employed a one-way analysis of variance and pairs of means were compared using a two tailed *t* test based upon the pooled residual standard deviation. This standard deviation reflects the variability between values within the same group, each of these values being based upon a pair of litter mate mice.

NS, not significant.

fall caused by the decrease in fat deposition by QSC-2 animals which had a higher body fat concentration at 19 d before the metabolic trial, compared to the QSC-8 mice.

There were no significant differences between the times or groups with respect to the percentage of N intake excreted in the urine (Table 5) and this is not surprising in view of the similar proportions of protein in the body compositions of the animals at all stages of development (see Table 2). QSC-8 mice excreted more faecal N than the QSC-2 mice (*P* < 0.05). The percentage of the apparently digestible N deposited by QSC-2 mice was less than QLF-8 mice (*P* < 0.01) and QLF-8 mice deposited more apparently digestible nitrogen as protein than QLF-2 mice (*P* < 0.05).

Table 5. *The deposition and partitioning of apparently digestible energy and apparently digestible nitrogen by QLF-2, QLF-8, QSC-2 and QSC-8 mice between fat and protein from 19 until 42 d of age*

(Values expressed as means with their standard errors)

No. of pairs of mice...	QLF-2 (6)		QLF-8 (6)		QSC-2 (5)		QSC-8 (4)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Apparently digestible energy intake (kJ)	3786	90	3688	99	2965	134	2903	127
Amount (%) apparently digestible energy deposited as:								
Protein and fat	7.76	0.54	7.27	0.74	3.86	0.35	8.31	0.54
Fat	4.25	0.45	2.79	0.73	0.71	0.41	4.86	0.33
Protein	3.53	0.27	4.42	0.27	3.15	0.25	3.44	0.32
Amount (%) apparently digestible N deposited as:								
Urinary N excretion	75.00	1.60	74.70	2.60	77.00	1.50	75.30	3.30
Faecal N excretion	9.10	0.80	8.80	0.30	8.10	0.30	10.40	0.70
Protein	14.65	0.99	18.09	1.15	12.92	0.90	14.08	1.30
	Significance of differences							
	QLF-2 v. QLF-8		QSC-2 v. QSC-8		QLF-8 v. QSC-2		QLF-2 v. QSC-2	
Apparently digestible energy intake	NS		NS		$P < 0.001$		$P < 0.001$	
Amount (%) apparently digestible energy deposited as:								
Protein and fat	NS		$P < 0.001$		$P < 0.01$		$P < 0.001$	
Fat	NS		$P < 0.001$		$P < 0.001$		$P < 0.001$	
Protein	$P < 0.05$		NS		$P < 0.001$		NS	
Amount of apparently digestible N deposited as:								
Urinary N excretion	NS		NS		NS		NS	
Faecal N excretion	NS		$P < 0.05$		NS		NS	
Protein	$P < 0.05$		NS		$P < 0.01$		NS	

QLF-2, mice selected for large body size at 6 weeks of age culled to litter of two pups at birth; QLF-8, mice selected for large body size at 6 weeks of age culled to litter of eight pups at birth; QSC-2, mice selected for small body size at 6 weeks of age culled to litter of two pups at birth; QSC-8, mice selected for small body size at 6 weeks of age culled to litter of eight pups at birth.

The statistical analysis employed a one-way analysis of variance and pairs of means were compared using a two-tailed *t* test based on the pooled residual standard deviation. This standard deviation reflects the variability between value within the same group, each of the SE values being based upon a pair of litter mate mice.

NS, not significant.

DISCUSSION

QLF and QSC mice have been selected for a high or low body-weight at 42 d of age (Falconer, 1973). This trait also produces the correlated responses of rapid or slow pre- and post-weaning growth rates and differences in body-weight at all ages (Rucklidge, 1981). The experiments reported in this paper were designed to investigate the effects of increasing the plane of neonatal nutrition of QLF and QSC mice upon: (a) growth rates and

composition of growth in the pre- and post-weaning periods of development, (b) appetite and the efficiency with which the food intake is deposited.

QLF mice gave birth to more pups of a larger body-weight than QSC mice. However, with respect to maternal body-weight, the weight of pups that QSC mice suckled was greater than that suckled by QLF. QLF-2 mice (over-nourished) grew better than those suckled in groups of four, six and eight in the order two, four, six, eight until 19 d. Although the contribution of fat to the weight gain before weaning was greater in the over-nourished animals there was also a substantial and significant increase in protein deposition. Regarding body-weight the present findings are similar to those of Stanier & Mount (1972) who reported an increase in growth rate and body-weight until 19 d for selected large-strain mice suckled in litters of four compared to litters of nine. However, contrary to their finding that selected small mice did not exhibit a similar response to their large line, in this experiment QSC-2 mice grew better than other QSC mice suckled in groups of four, six and eight. In a cross-fostering experiment (Stanier & Mount, 1972), small mice grew better when suckled by large dams but it was concluded that there was no restraint on growth by reduction in the milk supplied to small mice by their natural mothers. Large mice fostered by small dams grew less well than those suckled by natural mothers but they still had a greater weight gain than small mice suckled by small dams indicating continuing genetic influences on growth.

In the present work QSC-2 mice grew as well as the QLF-8 mice in the preweaning period, despite a difference in birth weight (Table 1, Fig. 1). There were however differences in the pattern of growth. QLF-8 and QSC-8 mice suffered a marked check in growth between 14 and 18 d (QLF) and between 9 and 17 d (QSC) post partum. This period may reflect a faltering in the milk supply before the pups are capable of eating solid food (which was freely available to them if needed). Neither QLF-2 nor QSC-2 mice exhibited this check in growth. These findings suggest that in natural litters of both QLF and QSC mice the maternal milk supply imposes a constraint on the maximum possible rate of growth. The fact that the total live body-weight of pups supported by the dam is greater for the groups of eight than for the groups of two for both lines at all ages indicates that there may be a greater production of milk by these animals. Thus there is probably more than a single factor to be considered with respect to food intake and supply during the suckling period and it is the interaction of these which ultimately governs the rate of growth of the animal in this period.

After 19 d the growth rates of the QLF-2 and QSC-2 mice were lower than those of the QLF-8 and QSC-8 groups, so that at sexual maturity the differences in body-weight which existed at 19 d within a line were removed. Thus in the mice suckled as groups of two the underlying genetic difference in body-weight reappeared. Although Stainer & Mount (1972) did not record mature body-weights of the large and small mice they noted a higher growth rate post-weaning in small mice suckled in groups of eight compared to those suckled in groups of four until 25 d of age. They were unable to find such a difference in large mice.

The findings presented in this paper are contrary to those for rats (Widdowson & McCance, 1960; McCance & Widdowson, 1962; Widdowson & McCance, 1963) in which the effects of under- and overnutrition in the pre-weaning period were manifest at all subsequent stages of development. The pattern of development in rats reported by Winick & Noble (1965) is different to that for Q-strain mice (Rucklidge, 1981) and it is possible that the failure to affect permanently the growth of Q-strain mice reported in this paper is related to these differences in the nature of growth. However, more recently Sands *et al.* (1979) have refuted the findings of Winick & Noble (1965). They have reported a pattern of growth for rats similar to that of the Q-strain mice in which animals, on a whole-body basis, neonatal growth involves an increase in protein: DNA rather than a marked increase in body DNA (Rucklidge, 1981). Sands *et al.* (1979) also concluded that the stages of

development during which permanent stunting could be produced were not related to an exclusively hyperplastic pattern of growth (whilst not disputing that neonatal undernutrition could affect subsequent growth).

The level of neonatal undernutrition in the present study (groups of eight) was not as severe as that imposed by previous workers (Widdowson & McCance, 1963; Winick & Noble, 1966) when working with rats. It is possible therefore that the results should not be interpreted as an inter-species difference in the response to neonatal nutrition but one related to the extent of over- or undernutrition in the pre-weaning period.

One of the factors which could be involved in the control of the rate of growth following a period during which the plane of nutrition has been altered is the voluntary intake of food. McCance & Widdowson (1962) reported that the intake of food at an early critical phase of development had considerable influence on subsequent food intake, growth rate and mature body size of the animal. However between 19 and 42 d of age the food intake within the lines of mice was the same irrespective of the size of the group in which they had been suckled. Although by 42 d of age the body-weights within a line were the same, over the post-weaning period taken as a whole, the mean body-weights of the groups of two were higher than their respective groups of eight. Consequently the food intake per unit metabolic body-weight was lower for QLF-2 and QSC-2 mice than for QLF-8 and QSC-8 mice respectively. QLF mice ate more food than QSC mice but the rates of food intake per unit metabolic body-weight were the same between groups QLF-8 and QSC-8 and between groups QLF-2 and QSC-2.

All the lines and groups studied in these experiments had very low efficiencies of energy deposition when compared with rats (Pullar & Webster, 1977) or pigs (Reeds *et al.* 1980) receiving a similar intake of energy per unit metabolic body-weight. The factors which might give rise to such poor energetic efficiency have been discussed previously by Rucklidge (1981). However the efficiency of the deposition of energy as protein and fat by QSC-2 mice was particularly low between 19 and 42 d (Table 5). The shortfall in energy deposition in these animals was associated with a reduction in fat deposition in the post-weaning period so that body compositions of QSC-2 and QSC-8 mice were similar at 42 d. The differences between QLF-8 and QSC-8 mice with respect to their energetic efficiencies imply a higher maintenance heat production for QSC mice and this has been discussed previously (Kownacki & Keller, 1978; Rucklidge, 1981). However, culling litters of QLF and QSC mice does not significantly change their relative maintenance heat production ($\text{kJ/kg body-weight}^{0.75}$ per d; QLF-2 1212, QLF-8 1220, QSC-2 1274, QSC-8 1244). These values were obtained by adopting the partial energetic efficiencies of fat and protein deposition published by Kielanowski (1972) and assume that these values were not altered either by selection for a high or low body-weight or by the effects of under- or overnutrition in the pre-weaning period. The apparent anomaly that groups of two eat similar amounts of food yet do not show a similar rate of weight gain or have an elevated maintenance heat production compared with groups of eight can be explained by the fact that they deposit less protein in the post-weaning period than the groups of eight and consequently deposit less water.

It is apparent that the selection of Q-strain mice on the basis of a large or small body size at 6 weeks of age completely overshadows any influence which an increased plane of nutrition might have with respect to mature body-weight despite differences which are apparent at 19 d. The effect of an increased plane of neonatal nutrition appears to increase the body fat concentration in QSC-2 mice by 19 d of age with a corresponding decrease in body water. This difference is however only temporary because by 42 d body-weights and compositions of QSC-2 and QSC-8 mice are not significantly different.

QLF-2 mice however do not exhibit an altered body composition at 19 d compared to

QLF-8 despite differences in body-weight. However by 42 d of age their body-weights are similar but the QLF-2 mice are fatter with a corresponding decrease in water concentration compared with QLF-8 mice.

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