

## Body Composition of the Fetus

Except during the nine months before he draws his first breath,  
no man manages his affairs as well as a tree does.

*George Bernard Shaw*

During the past 100 years several dozen human fetuses and newborns have been analyzed for water, electrolytes, minerals, and fat by chemical techniques. German scientists were the first to make such studies, with several reports in the late 1800s and early 1900s; Americans came on the scene in the 1930s; then in the 1950s British workers, led by Dr. Elsie Widdowson of Cambridge University, began their extensive observations. Dr. Widdowson and Professor R. A. McCance and their associates were responsible for generating a renewed interest in body composition, and together they have produced a vast amount of data on this topic. Much of the data to be presented in this chapter is the direct result of their work.

For more than a century and a half it has been known that young animals differ from adults in regard to certain aspects of body composition. Water contents are higher and ash contents (per unit weight) lower in the young (*ash* is the residue remaining after removal of water and organic material—the word derives from the mineral ash left after the burning of wood or coal). It is reasonable to ask whether there are changes in body composition during fetal life: does the young fetus differ from the newborn, just as the newborn differs from the adult? Are the changes in the same direction, and how rapidly do they occur?

The many chemical analyses that have been done on fetuses and newborns provide the answers to these questions. References to the original works can be found in publications by Widdowson and Dickerson (1964) and Forbes (1981a). The analyses published by Trotter and Peterson (1969) show that the dry fat-free weight of the skeleton (osseous portion) makes up an increasing fraction of total body weight during fetal life. Between a body weight of 227 g (the smallest fetus analyzed) and term, relative skeletal weight almost doubles, from 1.7% to 3.2% of body weight. What is the situation for other elements? As will be seen subsequently, the change in element content varies: some elements such as Ca increase in concentration during fetal life, whereas others decrease.

Information on body composition during fetal life also has its practical

side. It permits one to construct the time course of accretion of nitrogen and minerals from the earliest weeks of gestation to term, and these accretion rates provide a means for judging that portion of the maternal nutritional needs during pregnancy that must be assigned to the fetus. They also serve as a point of departure for estimating the nutrient needs of infants who are born prematurely. Today such infants are living longer than ever before, so adequate nutrition is of paramount importance if they are to thrive.

## Fetal Growth

We will begin with the overall growth rate of the fetus. Protected as it is from external influences, and spared the work of breathing and the chores of maintaining its body temperature and of working against gravity, the fetus grows at a rapid rate relative to its body weight. In percentage terms the rate is greater than at any subsequent time, including the growth spurt during adolescence. In addition to the advantages just mentioned, which act to reduce its energy needs, the fetus also enjoys the luxury of having an excellent source of nutrients (the placenta), the most efficient brand of "total parenteral nutrition" yet devised. Under such favorable circumstances, the fetus might grow even faster were it not restrained by the size of the uterus.

There are two ways of looking at the growth rate. Most commonly, this is considered in absolute terms,  $dW/dt$ , or change in weight per unit time. During the embryonic and early fetal stages, this rate is very slow; then it rises to reach a maximum at about the 36th week of gestation, whereupon it declines as term approaches.

The second way is to consider relative growth rate,<sup>1</sup>  $dW/Wdt$ , or change in weight per unit weight with time. When multiplied by 100, this is "percentage growth rate," which is a more familiar term. In this manner growth velocity is related to body size. The need for such a construction is obvious when one considers that it is common practice to prescribe nutrients for prematurely born infants on the basis of body weight; i.e., so much of a given nutrient per kilogram body weight per day. About a third of the total energy requirement of small infants is needed for growth.

The contrast between these two ways of viewing the growth rate of the fetus and young infant is made clear in the two figures that follow. Figure 3.1 shows the absolute growth velocity from the 16th week of gestation through the 25th week of postnatal life (not shown is the brief period of neonatal weight loss, when velocity is negative). There are two velocity peaks, one at about the 36th week of gestation, the other a week or two after birth. The drop in velocity toward the end of pregnancy may be due

<sup>1</sup>Sometimes called a "specific growth rate."

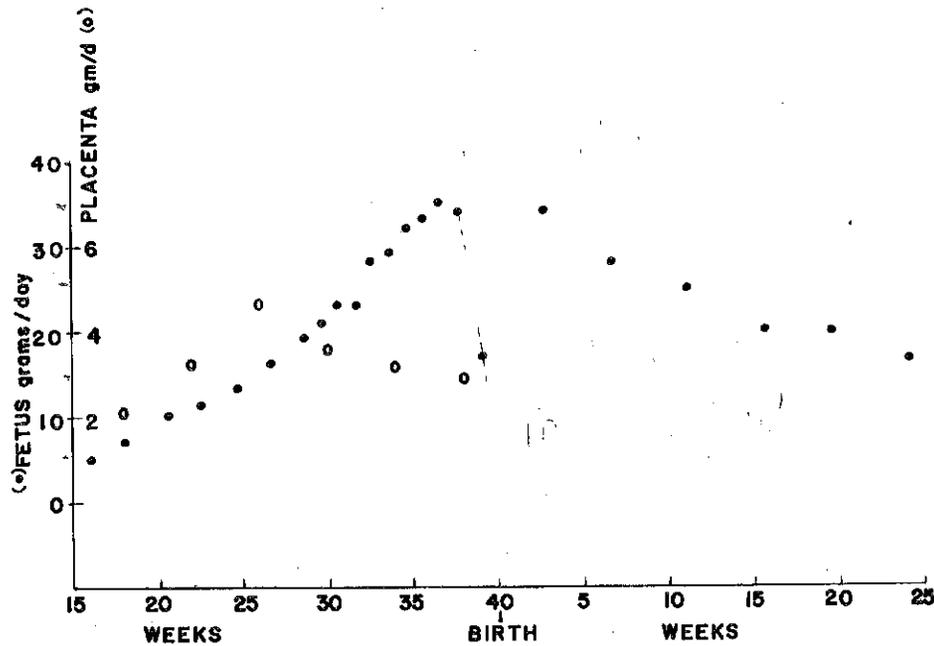


FIGURE 3.1. Velocity of growth from 15th week of gestation to 25th week of post-natal life, based on data of Falkner (1966), Naeye and Dixon (1978) and Fomon et al. (1982) (solid circles). Velocity of placental growth (g/day, open circles), from Hytten and Leitch (1971).

to constraints imposed by the uterus. There may be a limit to uterine size, and it is known that relative uterine blood flow diminishes as gestation proceeds (Hytten and Leitch, 1971). Placental size is also a consideration. The placenta/fetus weight ratio in the rhesus monkey falls progressively during gestation, the equation being placenta, g =  $31.5 + 0.139$  fetus, g ( $r = 0.89$ ) for the period encompassing fetal weights between 50 and 450 g. Hence the ratio falls from 0.77 at a fetal weight of 50 g to one of 0.21 at a fetal weight of 450 g (Hill, 1975).

In the human, the placenta actually weighs more than the fetus early in gestation; by 20 weeks the placenta/fetus ratio is 0.57, then drops to 0.19 at term (Hytten and Leitch, 1971). Late in pregnancy the calcium content of the placenta increases, suggesting some arterial degeneration. It is likely, therefore, that fetal nutrition has been compromised toward the end of gestation, which could account for a slower fetal growth rate. Figure 3.1 includes an estimate of placental growth rate, which peaks shortly after mid-gestation and then declines.

The problem with this hypothesis, however, is the fact that the combined weight of twin fetuses is greater than that of a singleton fetus with a placenta of similar size. For example, the data graphed by McKeown and

Record (1953) show that the ratio of placental to fetal weight is only half as large for twins as for singletons. In light of these data, placental insufficiency *per se* would not appear to be responsible for the slowdown in fetal growth velocity during the last weeks of pregnancy. McKeown and Record (1952) also point out that twins tend to be born about 20 days earlier than singletons, triplets about 15 days earlier than twins, and quadruplets about 10 days earlier yet; the respective average birth weights were 3.45, 4.8, 5.5, and 5.6 kg for these human "litters." They are of the opinion that intrauterine crowding is a factor in the slowdown in fetal growth late in pregnancy.

Once out of the uterus, and after taking a few days to adjust himself to the extrauterine world and to its new source of food, the infant resumes his former rapid rate of growth. Were it not for this perinatal pause, one could conceive of the entire course of growth velocity in Figure 3.1 as one smooth curve, rising rapidly during fetal life to reach a maximum, extending for a brief period into the postnatal phase, and then falling. One could entertain the hypothesis that there is indeed a perinatal growth spurt (analogous to the adolescent growth spurt), which would be unbroken were it not for the exigencies attendant on waning placental function and/or uterine size, and neonatal adjustments.

Incidentally, there is a progressive fall in growth velocity during infancy and childhood, to reach a nadir at about age 4 years, then a gradual increase finally culminating in the adolescent growth spurt. Whereas higher primates exhibit roughly similar patterns of growth velocity, other mammals have a distinctly different pattern. Velocity is slow all during fetal life, with no evidence of a spurt in late gestation; then there is a sharp velocity spurt after birth that then wanes as time goes on.

The course of relative growth velocity is rather different (Figure 3.2). In percentage terms velocity is extremely high in early fetal life—in excess of 10% per day—so that it was not convenient to plot it in the diagram. As shown in the figure, relative velocity continues to decline until about the 28th week of gestation, when there is an intervening plateau lasting about 6 weeks before a further fall just before birth. The rate of about 1.5% per day at the plateau in the curve is much higher than it will be at any subsequent time during infancy and childhood. For example, at the peak of the adolescent growth spurt, which is ordinarily perceived as representing a very rapid phase of growth, the relative growth velocity is only about 0.04% per day.