1 *Introduction*

Empirical versus intuitive analysis

Origins of positivism

The study of human phenomena has provided the occasion for a sustained – and at times heated – battle between empiricists, eager to quantify both body form and function, and other investigators who have preferred a more intuitive approach. The positivist concept that body structures conform to natural, mathematically describable laws had a strong grounding in the empirical philosophy of such early writers as John Locke (1632–1704), George Berkeley (1685–1753), David Hume (1711–1776) and Auguste Comte (1798–1857). Much patient investigation finally established beyond question that fundamental physical laws such as the conservation of matter and energy applied to human body constituents.

Application of empiricism to studies of body composition

An important first step towards proving energy conservation *in vivo* was taken by Santorio Santorio (1561–1636). He apparently spent much of his life eating and sleeping in a specially constructed weighing chair (Fig. 1.1), accumulating valuable data on the mass of his ingested food and excreta over a period of some 30 years. A century later, Audry (1658–1742) gave tacit acceptance to the principle of energy conservation by prescribing increased exercise for patients who needed to 'lose weight', but still in the early nineteenth century people as well educated as Charles Dickens were wont to discuss the possibility that a person could die of spontaneous combustion. Disproof of such ideas required the development of closed-circuit metabolic chambers, in which animals (Von Regnault, 1810–1878) and humans (Voit, 1831–1909) could live, eat and work, while observers kept careful records of energy balance for the system.

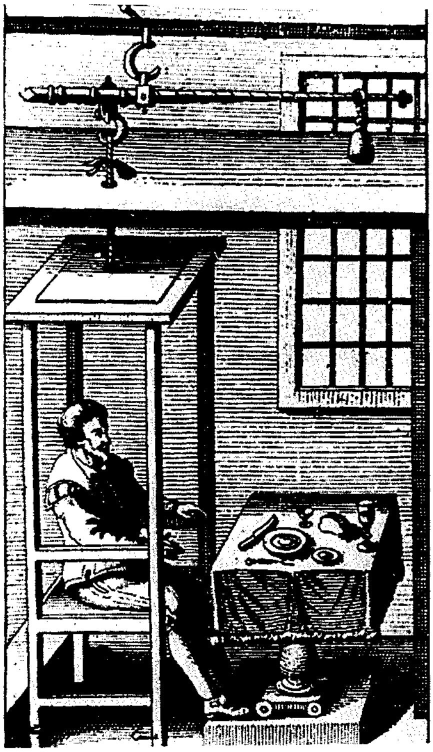

Fig. 1.1. The weighing chair used by Santorio in many of his long-term studies of body mass. Source: O. L. Bettman, 1956.

Information theory, empiricism and body composition

Arguments favouring an empirical approach to the study of body composition have now moved from philosophy and theology to the firmer ground of information theory. Information reduces uncertainty about an object or a phenomenon, and is usually conveyed most economically through the use of specific, numerical data rather than through a semantic or intuitive approach (Shephard, 1974).

In the context of body composition, a young woman might be described as 'pleasantly plump', but the uncertainty of a reader would be lessened if the author stated that the woman carried 20 kg of fat, and that this figure was two standard deviations above the actuarial ideal for her height and age.

Parnell (1965) has distinguished 'compositionists' who are interested largely in the chemical constituents of the body, 'nutritionists' who measure the proportions of the various tissue constituents, and 'behaviourists' who study the selective advantages of various types of body form and composition. The nutritionist or the behaviourist might note that a young man was 'very fat' or 'an extreme endomorph'. However, for most purposes the description would become more meaningful if reported as an average subcutaneous fat thickness of 30 mm relative to the norm for a young adult of 11 ± 6 mm.

Patterns of body composition

Pattern recognition is the main weakness of the empirical approach in general and computer analysis of body composition data in particular. There thus remains some justification for a descriptive approach when considering patterns of body composition. For example, Kissebah *et al.* (1982) and Krotkiewski *et al.* (1983) each noted the association between a 'masculine' distribution of accumulated body fat and vulnerability to heart attacks. It is easy to form a 'Gestalt' of the masculinity or femininity of body form, but the argument for a descriptive approach is not very strong; it remains statistically more satisfying to document any departure from the anticipated sexual dimorphism by comparing the thickness of specific skinfolds such as the hips (a typical location for a female accumulation of fat) and the front of the abdomen (a typical location for male fat accumulation).

Semantic descriptions of body form

More than 200 years ago, Hippocratic physicians distinguished the short, thick-set person with a 'habitus apoplecticus', typically a red-faced, jovial and forceful individual, liable to die of apoplexy, from the long and thin patient with a 'habitus phthysicus', commonly a more introspective subject who was liable to die of phthisis (tuberculosis). Halle (1797) noted four different body types: the fat 'abdominal' person, the strong 'muscular' individual, the long, slender-chested 'thoracic' form, and the large-headed 'cephalic' type. An appropriate body build is important to success in athletic competition (Tanner, 1964), and already in 1936 Kretschmer & Enke (1936) were distinguishing the round and compact form of the 'pyknic' contestant from the muscular 'athletic' build and the long, thin, asthenic 'leptosome'. More recently, Škerlj (1959) proposed developing vectors to describe four aspects of body form (sex, frame-size, amount and distribution of soft tissues). Likewise, Sheldon (1963) used standard photographs to classify his population in terms of fatness ('endomorphy'), muscularity ('mesomorphy') and linearity ('ectomorphy'). Each

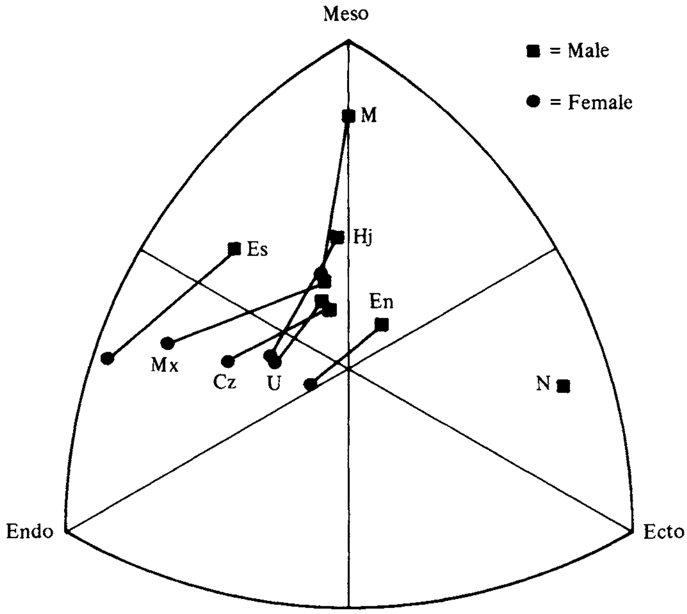

Fig. 1.2. Three dimensional plot to show ectomorphy, mesomorphy and endomorphy of selected national samples. Es = Eskimo, Mx = Mexican, Cz = Czechoslovak, U = United States, M = Manus, Hj = Hawaiian Japanese, En = English and N = Nilote. Source: J. E. L. Carter (1980). Reproduced with permission of the publishers, University Park Press.

variable was rated on an arbitrary seven point scale, yielding a three digit 'somatotype' (Fig. 1.2). Unfortunately, a large proportion of subjects occupy an intermediate position with respect to each of the rated characteristics. Sheldon estimated that in a well-nourished adult population there would be 7% endomorphs, 12% mesomorphs, 9% ectomorphs, and 72% of individuals who shared characteristics of two if not three of the proposed body types.

Subsequent development of somatotyping has seen a useful amalgamation of traditional subjective impressions with quantitative data (Carter, 1980, 1984). Technical issues of this hybrid methodology are reviewed in a companion volume (Carter & Heath, 1988). There is a close correspondence between 'endomorphy' and estimates of body fat, and an equally close relationship between 'mesomorphy' and empirical measurements of lean tissue mass per unit of stature. There thus seems much to commend a replacement of the semantic 'Gestalt' by specific numerical data describing body composition in precise mathematical terms.

'Reference' and 'normal' standards of body composition

'Reference' versus 'normal' standards

A 'reference' standard is an arbitrary value, usually based on data for healthy and well-nourished subjects (Waterlow, 1986); it offers a convenient basis for the comparison of populations, without making any judgements about the desirability of the chosen reference. For example, when assessing the body mass of young children, the World Health Organization (1983) has proposed adoption of data currently available from the US National Center for Health Statistics (Table 1.1), while the somewhat dated figures of Baldwin (1925, Table 1.2) have been commended for assessing the mass of older adolescents (World Health Organization, 1985).

Other authors have called for population-specific reference standards. These may be quite helpful when assessing selected groups such as athletes who are committed to a particular discipline. On the other hand, population-specific figures have more doubtful application when applied to average citizens, particularly in the less-developed parts of the world.

Table 1.1. *Desirable body mass of children.*

Age (years)	Girls (kg)			Boys (kg)		
	−2SD	Median	+2SD	−2SD	Median	+2SD
1	2.2	3.2	4.0	2.4	3.3	4.3
1/2	5.5	7.2	9.0	5.9	7.9	9.8
1	7.4	9.5	11.6	8.1	10.2	12.4
2	9.4	11.9	14.5	9.9	12.6	15.2
3	11.2	14.1	18.0	11.4	14.6	18.3
4	12.6	16.0	20.7	12.9	16.7	20.8
5	13.8	17.7	23.2	14.4	18.7	23.5
6	15.0	19.5	26.2	16.0	20.7	26.6
7	16.3	21.8	30.2	17.6	22.9	30.2
8	17.9	24.8	35.6	19.1	25.3	34.6
9	19.7	28.5	42.1	20.5	28.1	39.9
10	21.9	32.5	49.2	22.1	31.4	46.0

(Based on data of US Public Health Service HIHS growth charts, HRA 76–1120, 25, 3.)

Table 1.2. *Median body mass of adolescent boys and girls (kg) in relation to standing height.*

Height (cm)	Age (years) 10		11		12		13		14		15		16		17		18	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
120	—	22.3	—	—	—	—												
125	24.2	24.6	—	24.7	—	—												
130	26.8	27.1	27.0	27.9	—	27.3	—	—										
135	29.3	30.1	29.4	30.1	29.6	30.7	—	31.5										
140	32.2	32.9	32.2	33.1	32.4	33.2	32.4	34.1	—	34.8	—	—						
145	34.9	36.6	35.7	36.4	35.4	36.6	35.8	37.2	36.3	39.3	—	41.4						
150	38.1	38.8	38.5	40.2	39.0	39.9	39.1	41.1	39.3	43.0	39.2	44.6	—	45.9	—	46.4	—	—
155			41.5	44.0	42.1	44.8	42.7	45.0	43.4	47.0	43.5	48.1	44.8	50.2	—	50.4	—	51.4
160					46.2	48.9	46.7	49.2	47.4	49.8	48.0	51.5	49.8	51.9	51.5	52.8	53.9	53.1
165						52.6	50.9	53.1	51.4	54.0	52.3	54.2	53.1	54.8	55.1	55.4	57.1	55.9
170								56.8	55.6	57.6	56.5	58.0	58.1	58.9	59.1	58.9	60.5	60.1
175									59.7	60.0	60.4	60.8	61.9	61.2	63.5	62.1	64.7	62.9
180										61.3	65.1	62.2	65.7	63.0	66.1	63.9	67.7	64.4
185													69.5		70.3		71.3	

(Based on data of Baldwin, 1925.)

In such circumstances, it is difficult to undertake representative sampling and standards are quickly out-dated by secular changes in both growth patterns and adult size.

Some investigators have argued that if a world-wide 'reference' value were established for well-nourished subjects, this could be equated with a 'normal' standard, since the impact of any inherited differences of body composition is small relative to the departures from normality caused by an adverse environment (Graitcer & Gentry, 1981). In contrast, pragmatists have argued that if a world-wide 'normal' value were to be adopted, it would imply the existence of a standard that was both attainable and should be attained; in poor parts of the world, the setting of what might be perceived as unrealistically high figures could hamper practical planning.

'Ideal' body composition

Can one assume that the status quo, as seen in developed nations provides either a 'normal' or an 'ideal' standard of body composition? The concept of an 'average man' dates back to Quetelet (1796–1874), who applied concepts of error distribution when analysing the height of Belgian army recruits. However, the substantial social-class-related differences of stature in the nineteenth century raised the difficult issue as to whether a professional person or a labourer should be chosen as the reference standard.

There are good reasons to infer that the average body mass currently observed in North American adults exceeds an acceptable 'ideal' statistic. The dilemma of selecting an appropriate body mass for height has been faced by several generations of physicians, as they have compared tables of 'average' and 'ideal' weights. The average figures reported for insured North Americans show a steady increase over the span of adult life; on the other hand, 'ideal weights' such as those proposed by the Society of Actuaries (1959) and the Metropolitan Life Insurance Company (1983) generally assume a body mass that is independent of age.

There are many possible definitions of an 'ideal' body build and composition. One study of Canadian women university students from the early 1960s (Yuhasz, unpublished data, 1965) rated the ideal percentage of body fat in terms of personal appearance as judged by a male observer (Table 1.3). Current investigators would probably condemn this approach as sexist, although interestingly, the 'ideal' carried more lean tissue as well as less fat. Moreover, it is arguable that in the culture of the period, failure to conform to a masculine ideal of appearance may have

Table 1.3. *Comparison of average and 'ideal' body composition of female university students, judged on the criterion of 'optimal' physical appearance.*

	'Ideal' (17 women)	Average (75 women)
Body mass (kg)	54.8	59.4
Self-judged mass (kg)	56.5	56.5
Average skinfold thickness (6 sites, mm)	16.1	18.7
Fat mass (kg)	7.9	10.2
Per cent fat	14.3	17.3
Lean mass (kg)	50.0	49.0

(Based on unpublished data of M. Yuhasz, 1965.)

Table 1.4. *Ideal body mass, based on an average of the 'ideal' values proposed by (a) Society of Actuaries (1959) and (b) Kemsley* et al. *(1962), both adjusted for shoe height.*

	Ideal body mass (kg, indoor clothing)			
	Male		Female	
Height (cm, no shoes)	(a)	(b)	(a)	(b)
147.3	—	—	48.5	49.0
149.9	—	—	49.9	50.5
152.4	—	53.6	51.2	51.8
155.0	—	55.5	52.6	53.2
157.5	57.6	57.3	54.2	54.5
160.0	58.9	59.1	55.8	56.4
162.6	60.3	60.5	57.8	57.7
165.1	61.9	62.3	60.0	59.1
167.6	63.7	63.6	61.7	60.5
170.2	65.7	65.5	63.5	61.8
172.7	67.6	67.3	65.3	63.2
175.3	69.4	68.6	66.8	64.5
177.8	71.4	70.5	68.5	65.9
180.3	73.5	72.3	—	—
182.9	75.5	73.6	—	—
185.4	77.5	75.5	—	—
188.0	79.8	77.3	—	—
190.5	82.1	—	—	—
193.0	84.3	—	—	—

had a significant impact upon the marriage prospects of female students and thus the perpetuation of particular anthropometric characteristics.

'Ideal' body mass

Life assurance companies and epidemiologists have chosen as their 'ideal' a body mass associated with minimal mortality over a specified interval, or with maximal life expectancy (Fig. 1.3; Table 1.4). Actual values have been biassed by the technicalities of data collection (Jarrett, 1986), including:

(i) use of a self-reported mass, which in some populations deviates systematically from the measured body mass (Table 1.5; Perry & Leonard, 1963; Wing *et al.*, 1979; Stunkard & Albaum, 1981);
(ii) day-to-day variations of body mass (Adams *et al.*, 1961; Durnin, 1961; Khosla & Billewicz, 1964; Robinson & Watson, 1965; Edholm *et al.*, 1974);
(iii) uncertain allowances for the height of shoes and the mass of clothing;

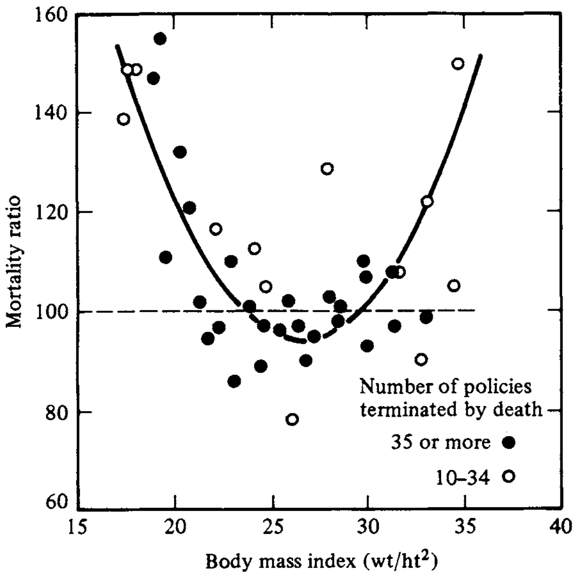

Fig. 1.3. Relationship between mortality rate and body mass index. Source: R. Andres (1985). Reproduced with permission of publishers, McGraw-Hill.

Table 1.5. *Relationship of observed to reported body mass (kg).*

Measurement location	Body mass: Measured (kg)	Reported (kg)	Coefficient of correlation
US gynaecologist's office	60.2	59.7	0.99
US internist's office	66.3	66.5	0.99
US obesity treatment			
– medical school	97.7	95.7	0.98
– medical school	95.1	93.3	0.99
– union	85.5	84.6	0.99
– psychiatrist	91.5	90.0	0.98
US pre-employment	78.6	77.4	0.99
Danish men <40 yrs	77.0	75.9	0.95
>40 yrs	79.4	78.1	0.96
Danish women <40 yrs	61.1	59.5	0.97
>40 yrs	62.7	60.3	0.91

(Based in part on data of Stunkard & Albaum, 1981.)

(iv) a secular trend to an increase of stature in young adults (Waller & Brooks, 1972), but a continuing decrease of stature with aging (Shephard, 1987);

(v) non-random sample selection (insurance companies deal predominantly with high-income white-collar workers), and

(vi) the age of the individual when statistics were recorded (on purchase of an insurance policy, usually as a young adult), whereas there is now growing evidence that the optimum body mass rises with age, (Andres, 1985; Fig. 1.4).

Bones are substantially denser than muscle. One important determinant of body mass is thus the size of a person's frame (Welham & Behnke, 1942; Clark *et al.*, 1977). The Society of Actuaries (1959) arbitrarily classified their data into ranges of ideal mass for individuals rated as having small, medium and large frames. Unfortunately, the rating of frame size tends to be influenced by the build of the observer. Pryor (1940) suggested that the interpretation of body mass could be made more precise if objective measurements of frame size were taken, and this proposal has now been adopted by the Society of Actuaries (1980). While a person with large bones now avoids penalisation, a muscular person can still be classed as 'overweight', despite a relatively low percentage of body fat (Clark *et al.*, 1977).