Chapter 1

GROWTH AND ORGAN DEVELOPMENT

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1. INTRODUCTION

The study of human growth conventionally focuses on the whole body, notably the linear and volumetric measures of height and weight, plus the derived ratio body mass index (weight/height$^2$). Body volume and body surface area are also important for some aspects of nutrition, either measured directly or estimated from weight and height. By contrast linear dimensions of body parts are studied for particular purposes, e.g. head circumference, sitting height or triceps skinfold thickness, but weights or volumes of body parts, particularly organs, are not routinely considered in the same way. The reason why is obvious – they are difficult to measure non-invasively, and before the relatively recent technological advances that have occurred in ultrasound and imaging they could only be measured at post-mortem. For this reason paediatric pathology has in the past tended to be the discipline most knowledgeable about organ development.

But times change. Developments in ultrasound in recent decades have made the assessment of fetal organ development routine, insofar as organ size can be inferred from two-dimensional ultrasound images. Brain size for example is highly correlated with head size, as measured in utero by biparietal diameter or head circumference, while abdominal circumference is a proxy for central organ development. With this ready access to measures of fetal organ size has come an increased interest in organ development, in health and disease, considering both short-term outcomes in early life and later child and adult outcomes.
The aims of this chapter are threefold: a) to describe the process of normal organ growth in the embryo, fetus and child, showing how it relates to growth in the whole organism; b) to consider some factors that affect the susceptibility of growth to external insults, particularly plasticity and critical periods of growth, and c) to summarise the common patterns of abnormal fetal growth as they impact on organ development.

2. THE FOCUS OF GROWTH

The brain is known to be a critically important organ for *homo sapiens*. Bogin\(^1\) compared average organ weights in adult humans and higher primates, adjusting for body size, and showed a strikingly larger brain and smaller gut in humans, while the other organs were broadly comparable across species. This emphasis on brain development is also seen in the human pattern of brain growth, the brain being relatively enormous in the embryo and becoming progressively smaller compared to body weight through gestation, infancy and childhood. Brain growth effectively stops before puberty, in contrast to the other organs which continue increasing until adulthood. Brain-sparing, the preferential protection of the brain when organ growth is under threat, is important for a proper understanding of the process of organ development.

2.1 The processes of cell proliferation and expansion

Organ growth proceeds in three stages. The first is cell differentiation, the process of organogenesis where organs are first assembled, and this takes place while the fetus is still an embryo, 3 to 8 weeks after ovulation.

The second stage is cell proliferation or hyperplasia, when the number of cells in the organ increases sharply, and this takes place typically in the first half of fetal life after the embryonic stage. For most organs cell number stabilises during the latter half of pregnancy and thereafter increases little. Clear exceptions to this are fat mass and muscle mass, where cell number increases throughout childhood and stabilises after adolescence.

The third stage is cell expansion or hypertrophy, when the size of cells increases. This stage occurs throughout pregnancy and into childhood, but is more important in terms of its contribution to organ growth once cell number has stabilised.

Winick distinguishes three phases of cell growth – increasing cell number alone, increasing cell number and cell size, and increasing cell size alone.\(^2,3\) These distinctions are important for later discussions about critical periods.