Wellcome Film Project

Cell Division in the Cartilage Plate During Bone Growth

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Computer animation sequences by Norman Kember using the Dimfilm facility and package at the University of London Computer Centre.
Graphics by Paul Wilks.

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Black-and-white
Duration: 00:07:18:22

00:00:00:00

<Opening titles>

<Narration over film showing: longitudinal section through long bone; photomicrograph of rat growth plate; computer animation of bone cell growth. Poor sound quality>

The growth of the long bone is dependent on cell division in the cartilage growth plates. This film will demonstrate the sequence of events which take place in this region as the bone grows. This photomicrograph of a rat growth plate shows how the cells are organised into columns which are parallel to the direction of growth.

The computer representation of the cells between the epiphyseal bone plate on the left and the metaphysis on the right is by ellipses that expand and change shape during growth. Within each column, there are 3 regions or zones: a proliferation zone of dividing cells, about 6 or 7 cells long; a maturation zone, 4 or 5 cells long, where

the cells expand; and a zone of hypertrophic cells – the calcification of these cells is symbolised by the horizontal line.

Two processes take place in the proliferation zone: DNA synthesis and cell division. The doubling of the DNA content takes time and the growing spectre within the cell represents the progress of the synthesis. When the synthesis is complete, there is a resting phase before cell division begins. During division the cell splits laterally into 2 daughter cells. These then rearrange themselves into the columnar pattern. In the computer model, the cells divide at intervals that are chosen at random from a major distribution of cell cycle times. In the growing rat, this whole process could take 15 to 20 hours.

The relation between adjacent columns is important. Here each column proceeds at a rate that reflects a random selection of cell division times. Cells in the proliferation zone divide and displace cells to their right. The displaced cells move into the maturation zone. Here they expand until they become calcified in the hypertrophic zone. The cells arrive at the hypertrophic region with a range of sizes. This reflects their residence time in the maturation zone and this is controlled by the rate of cell division and, more precisely, by the width of distribution of the cell cycle time. Here is the result of increasing that width by 50%. This range of cell cycle times is due to too wide a range of sizes of hypertrophic cells.

The sequence – division, maturation and calcification – taking place in the growth plates results in bone growth. Note that during growth, the width of the growth plate stays constant. With the computer model, the family history of each dividing cell can be followed. Cells spend a sufficient time in the proliferation zone for several generations to follow from one primary division. Counting the cell at the left as zero, its division produces a first generation cell, here labelled 1. When that cell divides, it produces a second generation cell. In the model, each cell in a family is labelled with its generation number. And the total number of cells in a family is shown on the left of each column. The final length of a bone depends on the number of cell families produced before the plate closes. Here is this sequence again. Watch the relative motion of cells in adjacent columns. Despite the random selection of cells for

division, this relative velocity is small. So that the classic model produces growth patterns that match the regularity maintained across the whole plate for weeks or months of natural growth.

<End credits>