The Meter Stick of Higher Organisms

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One of the key unsolved problems in modern biology is how living things measure lengths. The body parts and organs of plants and animals, even very primitive ones, have characteristic sizes and shapes essential to their function. These things are sophisticated, and it is not clear how chemistry alone could determine the requisite lengths with the necessary reliability and flexibility. Reaction-diffusion mechanisms, for example, do measure lengths, but they are inherently noise-prone and require customization for each new length needed. Chaining together of an integral number of small parts with known sizes, as viruses do when they self-assemble, is cumbersome and anyway won't work on large scales because the accumulating errors destroy shapes. Given how elementary these design difficulties are, and the failure over many decades to find a way around them, there is reason to suspect that an important physical element of some kind is missing, something difficult to detect by conventional chemical means. In this talk I will explore the possibility that the missing dimension is time. Were a team of engineers assigned the task of designing autonomous, reproducing, self-assembling machines, they would never make their designs dependent on diffusion or little tiny meter sticks. They know perfectly well that lack of reliability would prevent the design from working. They would instead measure lengths by counting fringes of some wave motion, such as light or sound. The constant wave speed would not only make the lengths stable, it would enable every one of the time scales they made by chemical means to become a length, thus generating flexibility for future design changes. It turns out that existing experiments have very little to say about time-dependent biological machinery, the chief reason being that time is difficult to measure in small systems that are not dead. I will illustrate the main points using elementary mitosis. We wish to understand (1) how the dividing cell locates its midpoint fission plane, (2) how the centrosomes locate an axis perpendicular to this plane and the poles thereof, (3) which centrosome goes to which pole, (3) how the spindles that grow out of them know to bow outward and cross the fission plane at right angles and (4) which copy of the DNA goes up and which copy goes down when the cell divides.