The Highest Packing Density of Information

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The greatest known density of information is that in the DNA of living cells. The diameter of this chemical storage medium is d = 2 nm, and the spiral increment of the helix is 3.4 nm (1 nm = 10^{-9} m = 10^{-6} mm). The volume of this cylinder is $V = h \times d^2 \times \pi/4$

$V = 3.4 \times 10^{-6}$ mm $\times (2 \times 10^{-6}$ mm$)^2 \times \pi/4 = 10.68 \times 10^{-18}$ mm^3 per winding.

There are 10 chemical letters (nucleotides) in each winding of the double spiral (= 0.34×10^{-9} m/letter), giving a statistical information density of

ρ = 10 letters/(10.68×10^{-18} mm^3) = 0.94×10^{18} letters per mm^3.

This packing density is so inconceivably great that we need illustrative comparisons.

Firstly: What is the amount of information contained in a pinhead of DNA? How many paperback books can be stored in this volume?

Example: The paperback “Did God Use Evolution” has the following dates:

Thickness = 12 mm
160 pages
LB = 250,000 letters/book

Volume of a pinhead of 2 mm diameter (r = 1 mm):

$VP = 4/3\, \pi\, r^3 = 4.19$ mm^3

How many letters can be stored in the volume of 1 pinhead?

$LP = VP \times \rho = 4.19$ mm$^3 \times (0.94 \times 10^{18}$ letters/mm$^3) = 3.94 \times 10^{18}$ letters

How many books can be stored in the volume of 1 pinhead?

$n = LP/LB = 3.94 \times 10^{18}$ letters / (250,000 letters/book) = 15.76×10^{12} books

What is the height of the pile of books?

$h = 15.76 \times 10^{12}$ books $\times$ 12 mm/book = 189.1×10^{12} mm = 189.1×10^{6} km

Distance to the moon M = 384,000 km

How many distances to the moon are this?

$m = h/M = 189.1 \times 10^{6}$ km /384,000 km = 492.5 times

Secondly: The human genome has 3×10^9 letters (nucleotides). In body cells there are 6×10^9 letters.

The length of the genome LG is given by

$LG = (0.34 \times 10^{-9}$ m/letter$) \times 3 \times 10^9$ letters $= 1.02$ m

The volume of the human genome VG is

$VG = LG/\rho = 3 \times 10^9$ letters$/(0.94 \times 10^{18}$ letters/mm$^3) = 3.19 \times 10^{-9}$ mm^3

Volume of a pinhead of 2 mm diameter: $V = 4/3\ \pi\ r^3 = 4.19$ mm^3

How many human genomes are contained in 1 pinhead?

$k = 4.19$ mm^3 / $(3.19 \times 10^{-9}$ mm$^3) = 1.313 \times 10^9$ times

These are the genomes of more than thousand million people or one sixth of the population of the world.

Thirdly: A huge storage density is achieved, manifold greater than can be attained by the modern computers. To grasp the storage density of this material, we can imagine taking the material from the head of a pin with a diameter of 2 mm and stretching it out into a wire, which has the same diameter as a DNA molecule. How long would this wire be?

Diameter of the DNA molecule d = 2 nm = 2×10^{-6} mm (radius r = 10^{-6} mm)

Cross-section A of the DNA molecule:

$A = r^2\ \pi = (1\ \text{nm})^2\ \pi = (10^{-6}\ \text{mm})^2\ \pi = 3.14 \times 10^{-12}$ mm^2

Length of the wire LW = Volume of the pinhead VP / Cross-section A

$LW = VP/A = 4.19$ mm^3 / $(3.14 \times 10^{-12}$ mm$^2) = 1.33 \times 10^{12}$ mm $= 1.33 \times 10^6$ km

Length of the equator = 40,000 km

$k = 1.334 \times 10^6$ km/ 40,000 km = 33.3 times

If we are stretching out the material of a pinhead into a wire with the same thin diameter as a DNA molecule it would have a length more than 30 times around the equator.

These comparisons illustrate in a breath-taking way the brilliant storage concepts we are dealing with here, as well as the economic use of material and miniaturisation. The highest known (statistical) information density is obtained in living cells, exceeding by far the best achievements of highly integrated storage densities in computer systems.