# HOW DO WE STORE INFORMATION?

A variety of media have arisen over the years to store information in the form of digital data. Each new generation of storage device has brought with it improvements such as an increased capacity for storage, but has also presented new challenges, which engineers have sought to overcome through innovation.

**1916**
**1928**
**1951**
**1971**
**1982**
**1995**
**2016**
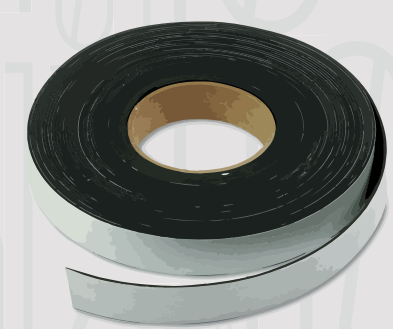
## MAGNETIC TAPE
## HARD DISK DRIVE
## RAM
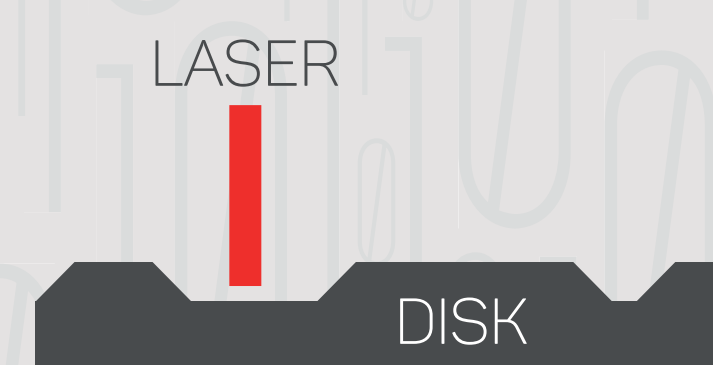## FLOPPY DISK
## CD
## FLASH SSD
## DVD

### MAGNETIC STORAGE

Information is stored in the 2 possible orientations of a magnetic dipole.

### OPTICAL DISC

Information is stored as pits and lands on a reflective layer.

LASER · DISK

*Blu-ray*

*Blu-ray technology has a ... blue laser. Blue light has a shorter wavelength than red, thus more information can be stocked on the same disk size.*

### FLASH

Each cell in flash memory stores information in terms of the amount of charge held.
Charge cannot be reduced from an individual cell, an entire block has to be erased.

ARRAY OF BLOCKS · CELL
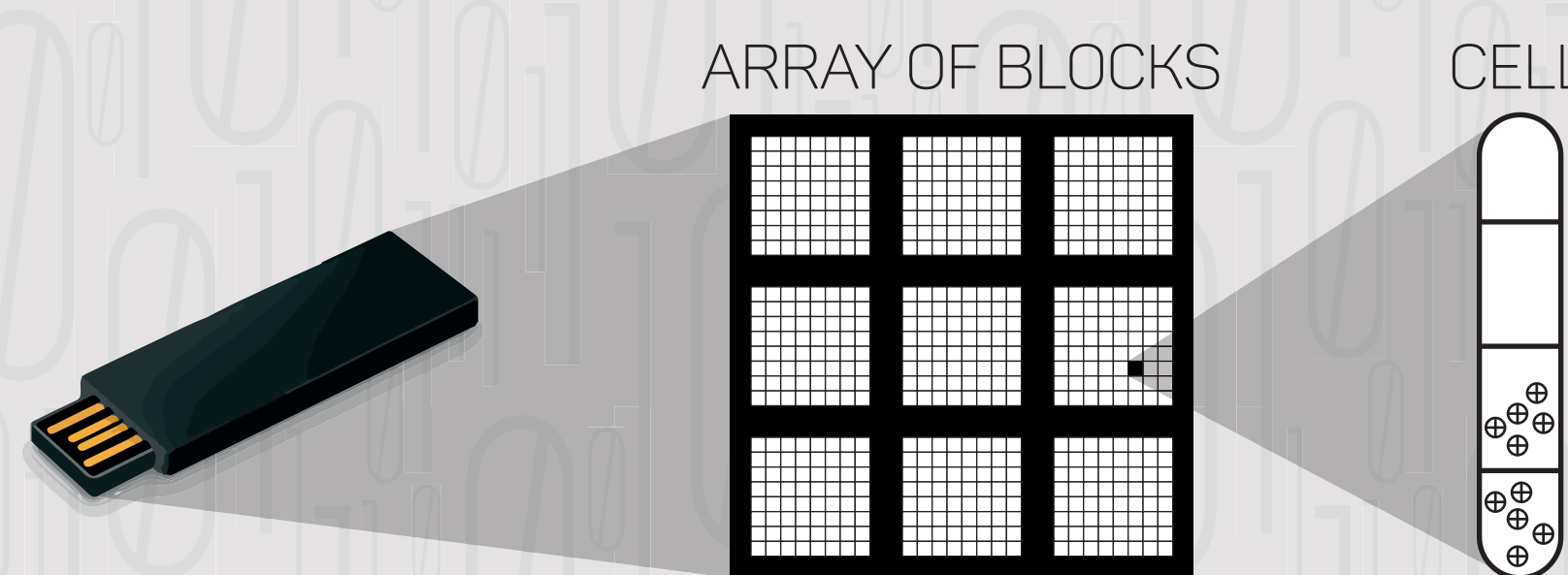
*Data in the cloud physically resides in storage warehouses such as the Google data center shown here.*

## SOME KEY ENABLING TECHNOLOGIES

**Error-Correcting Codes** work by adding redundancy in the form of parity symbols and can range from simple replication to the more sophisticated Reed-Solomon and LDPC codes.

*A message with content and clarity*
*Has gotten to be quite a rarity;*
*To combat the terror*
*Of serious error,*
*Use bits of appropriate parity.*

*Solomon W. Golomb*

**Run-length limited coding** places upper and lower limits on the number of 0's between two successive 1's to help synchronize and limit adjacent-symbol interference (ASI).

**Partial-Response Signaling with Maximum-Likelihood Detection (PRML)** technology permits denser packing of data by allowing a controller amount of ASI through proper pulse shape selection. The ASI is then handled by using a trellis-based decoder that keeps track of past symbols. Additionally, a powerful LDPC error-correcting code is used.
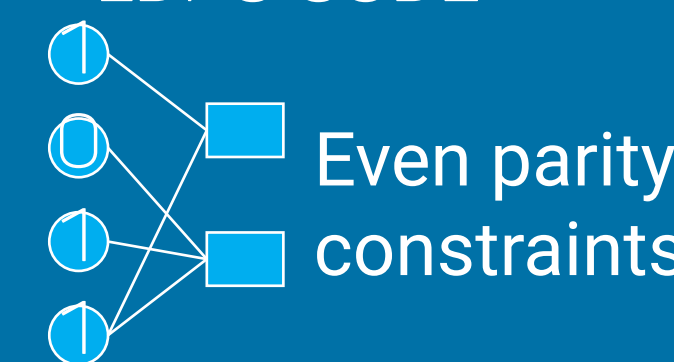
CONTROLLED PULSE SHAPE

TRELLIS-BASED DECODER
00 01 10 11
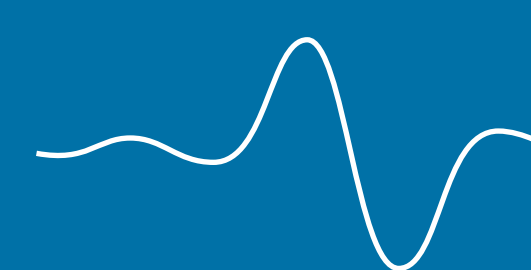
AN EXAMPLE LDPC CODE
Even parity constraints
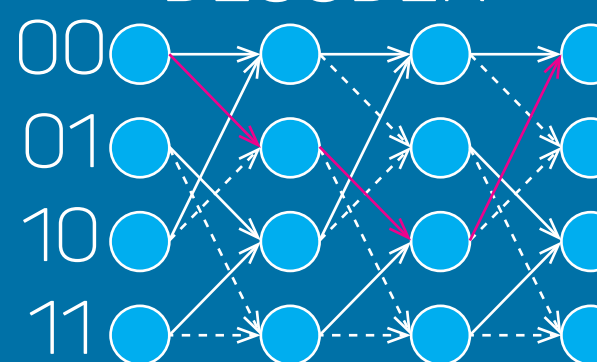
## STORAGE TECHNOLOGIES ON THE HORIZON

**DNA Storage:** A single gram of DNA can store 455 exabytes of data for centuries.

**Phase Change Memory (PCM):** Heating chalcogenide shifts it between a low and high resistance state.

**Memristors:** Change in resistance of devices depends upon charge supplied.

**Holographic Storage:** Storing data throughout the 3D volume of the storage medium.

## The Human Brain
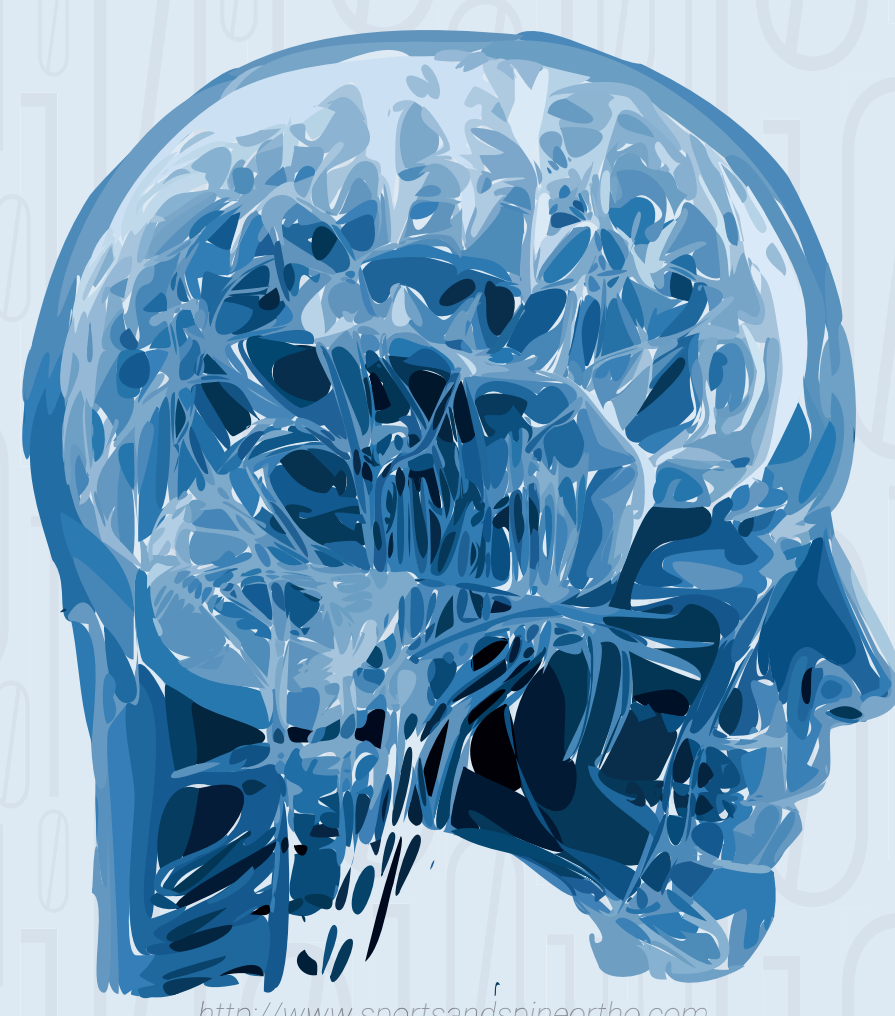
– Information is stored in the strengthening or weakening of synapses which govern signal transmission between neurons
– Estimated to store between 1 terabyte and 2.5 petabytes of data!

## NEW TECHNOLOGIES, FRESH CHALLENGES!

**Two-dimensional Coding** for magnetic and optical disks.

Novel techniques to handle correlated errors.

**Flash Memory:** Overcoming the charge leakage problem.

Rank modulation codes store data in terms of the relative charge levels in different cells.

**Data Centers:** Efficient recovery from node failure.

Regenerating codes minimize data download; Codes with Locality minimize no. of helper nodes.