

# Odd-Even Merge Sort

- Odd-even merge
- 0/1 principle

# Odd-Even Merge Sort

```
# note: the input sequence is indexed from 0 to (n-1)
for p = 1, 2, 4, 8, ... # as long as p < n
  for k = p, p/2, p/4, p/8, ... # as long as k >= 1
    for j = mod(k,p) to (n-1-k) with a step size of 2k
      for i = 0 to min(k-1, n-j-k-1) with a step size of 1
        if floor((i+j) / (p*2)) == floor((i+j+k) / (p*2))
          compare and sort elements (i+j) and (i+j+k)
```

# Bitonic Sort

- Bitonic sequence: monotonically non-decreasing then monotonically non-increasing, or a circular shift
- Bitonic split

# Bitonic Sort

```
// given an array arr of length n, this code sorts it in place  
// all indices run from 0 to n-1  
for (k = 2; k <= n; k *= 2) // k is doubled every iteration  
    for (j = k/2; j > 0; j /= 2) // j is halved at every iteration, with truncation of fractional parts  
        for (i = 0; i < n; i++)  
            l = bitwiseXOR (i, j); // in C-like languages this is "i ^ j"  
            if (l > i)  
                if ( (bitwiseAND (i, k) == 0) AND (arr[i] > arr[l])  
                    OR (bitwiseAND (i, k) != 0) AND (arr[i] < arr[l]) )  
                    swap the elements arr[i] and arr[l]
```

# $O(\log n)$ Depth Sorting Network

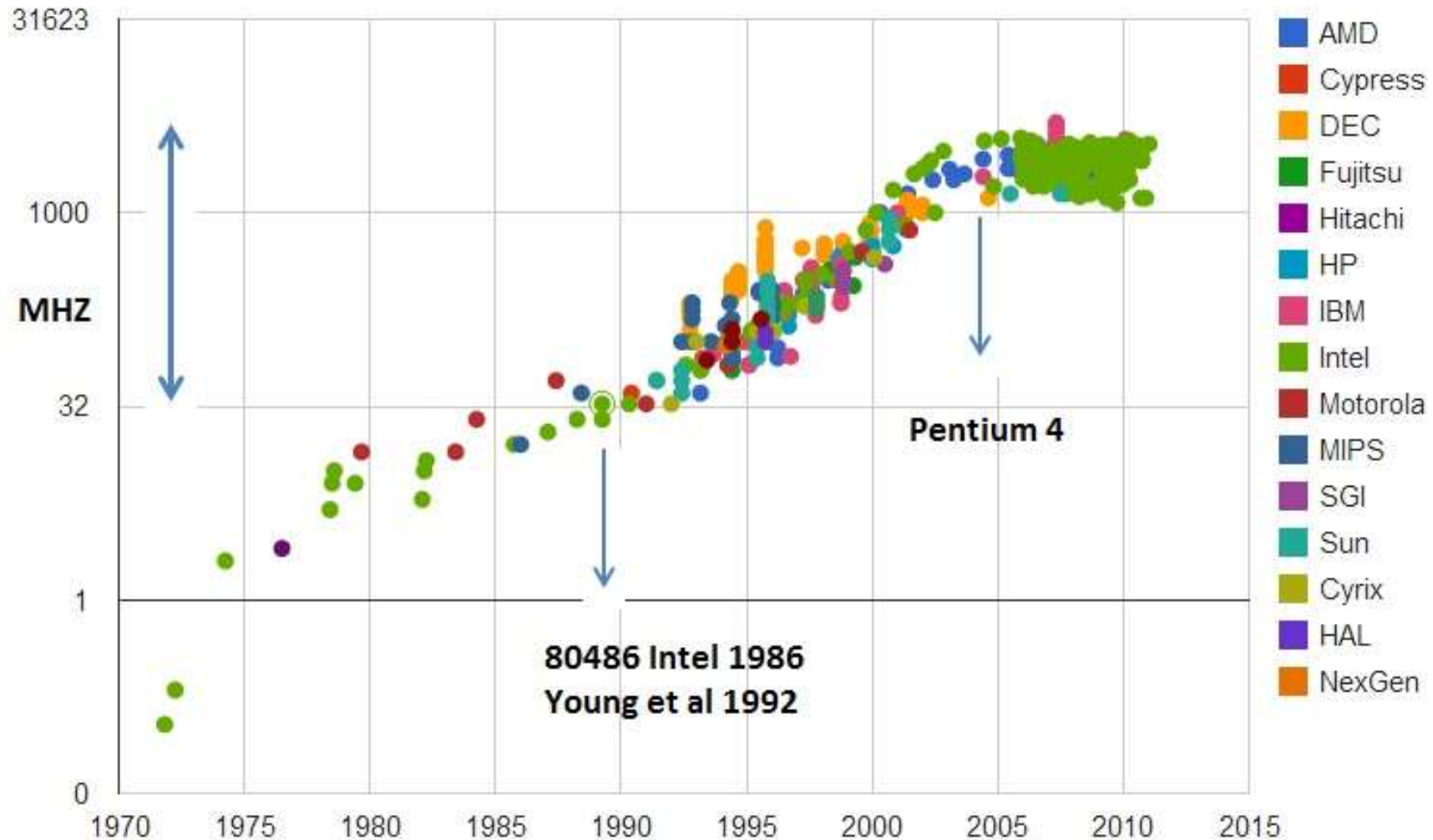
- Mikl6r Ajtai, J6no Koml6os, Endre Szemer6edi, An  $O(n \log n)$  sorting network. STOC, 1983.
- MS Paterson, Improved sorting networks with  $O(\log n)$  depth. Algorithmica, 1990.

# Multicore Computing

“Premature optimization is the root of all evil”

--- Sir Tony Hoare

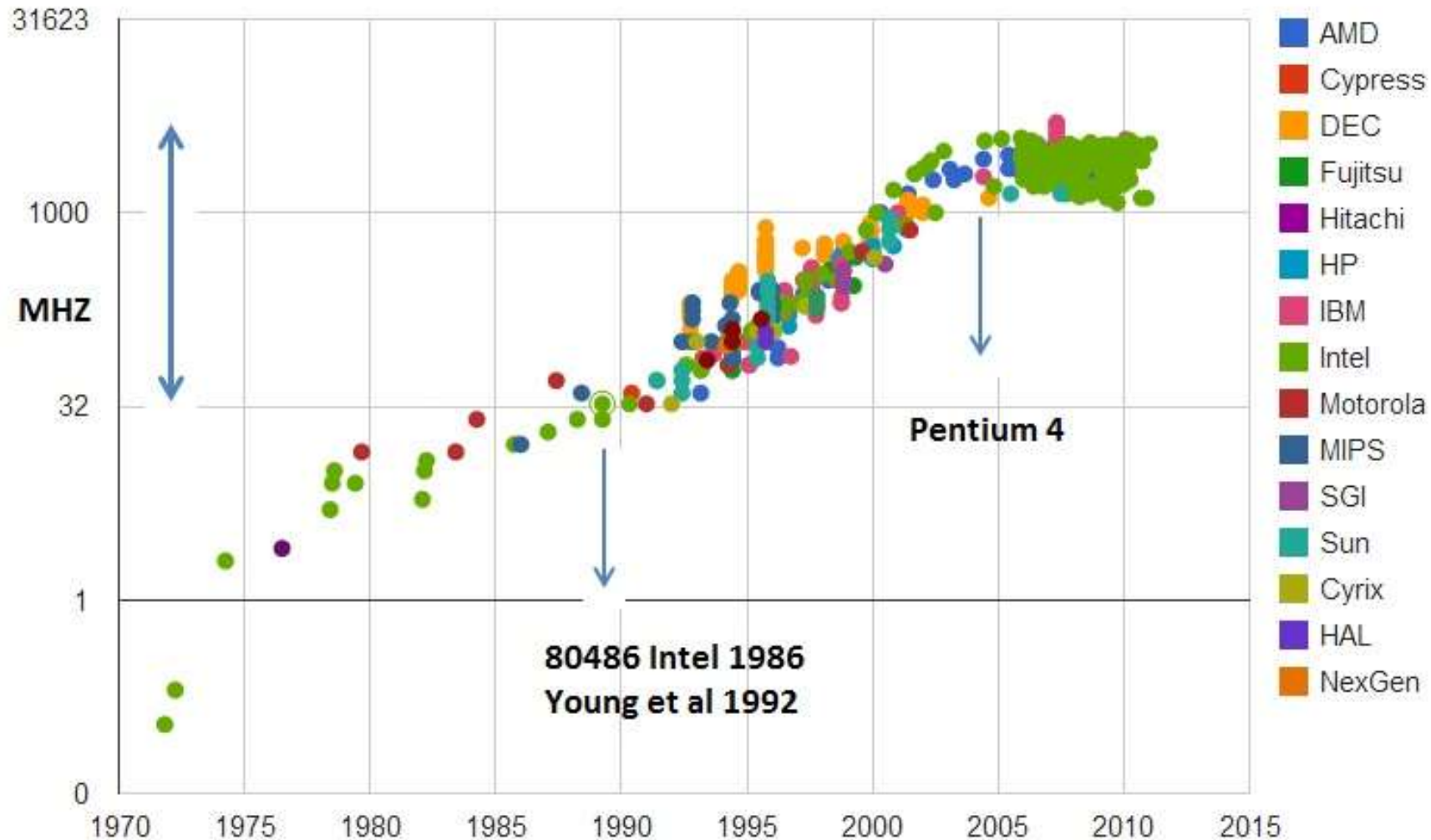
# CPU Clock Rate





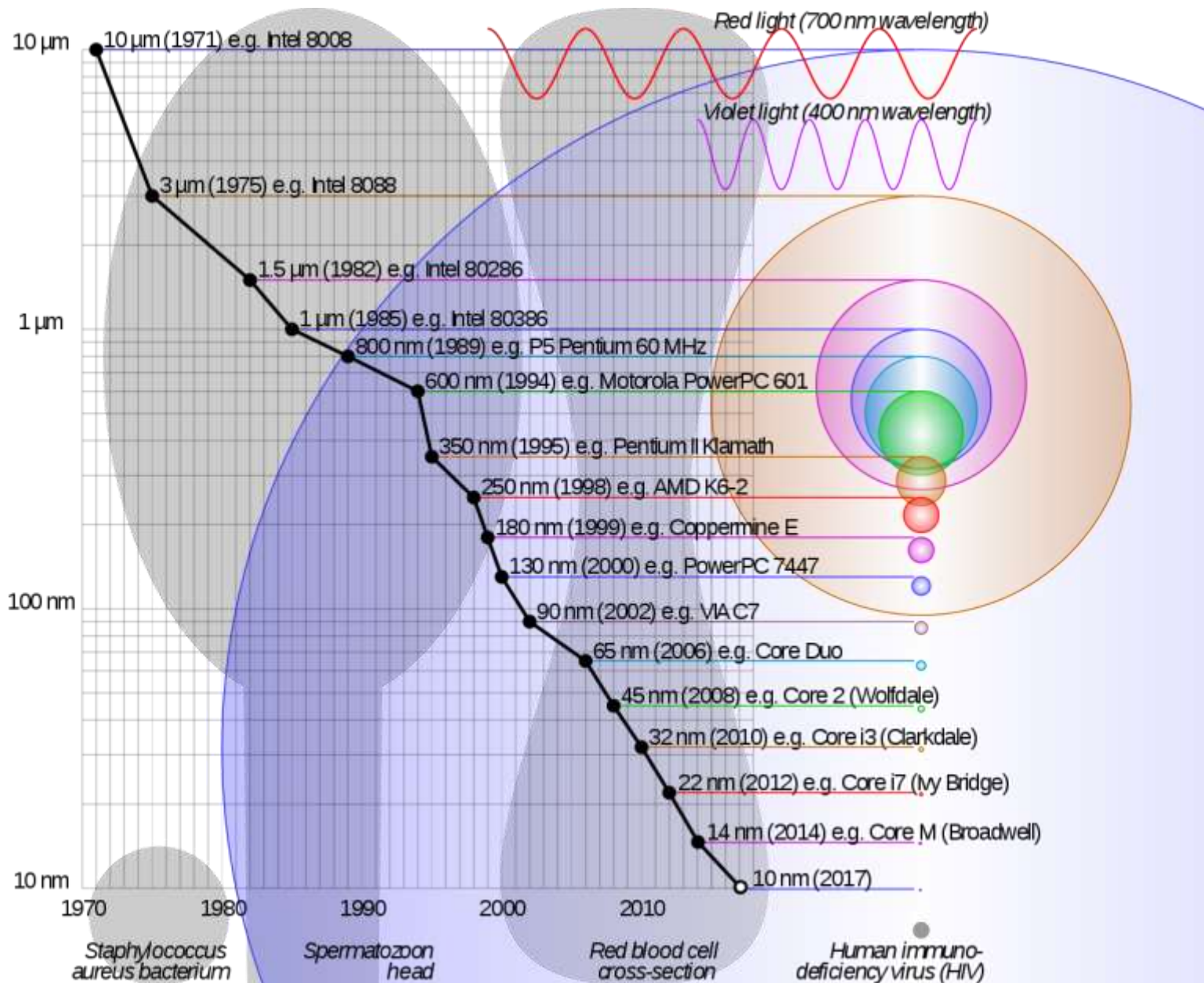
# CPU Clock Rate

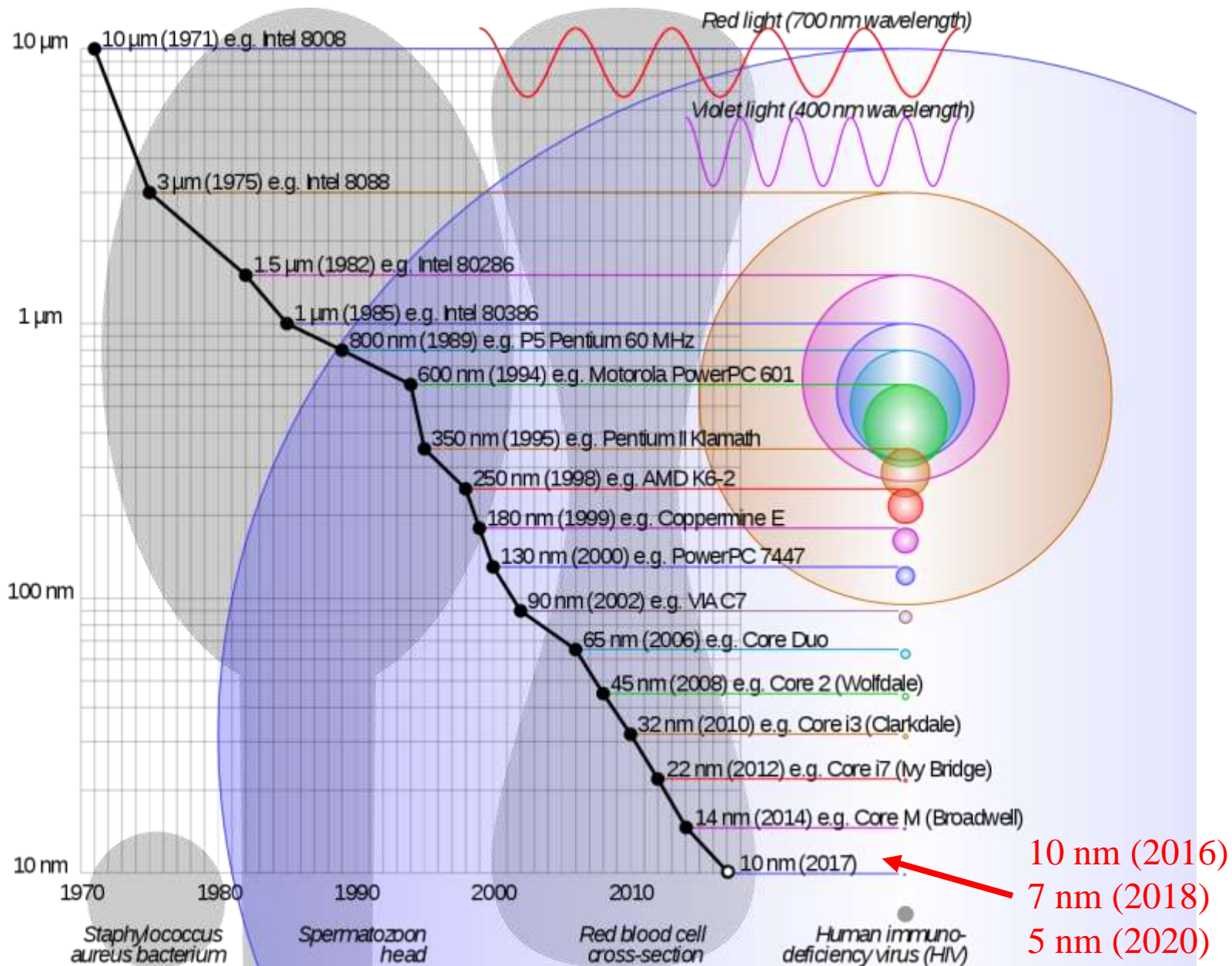
Now our CPU clock is still around 2-3 GHz

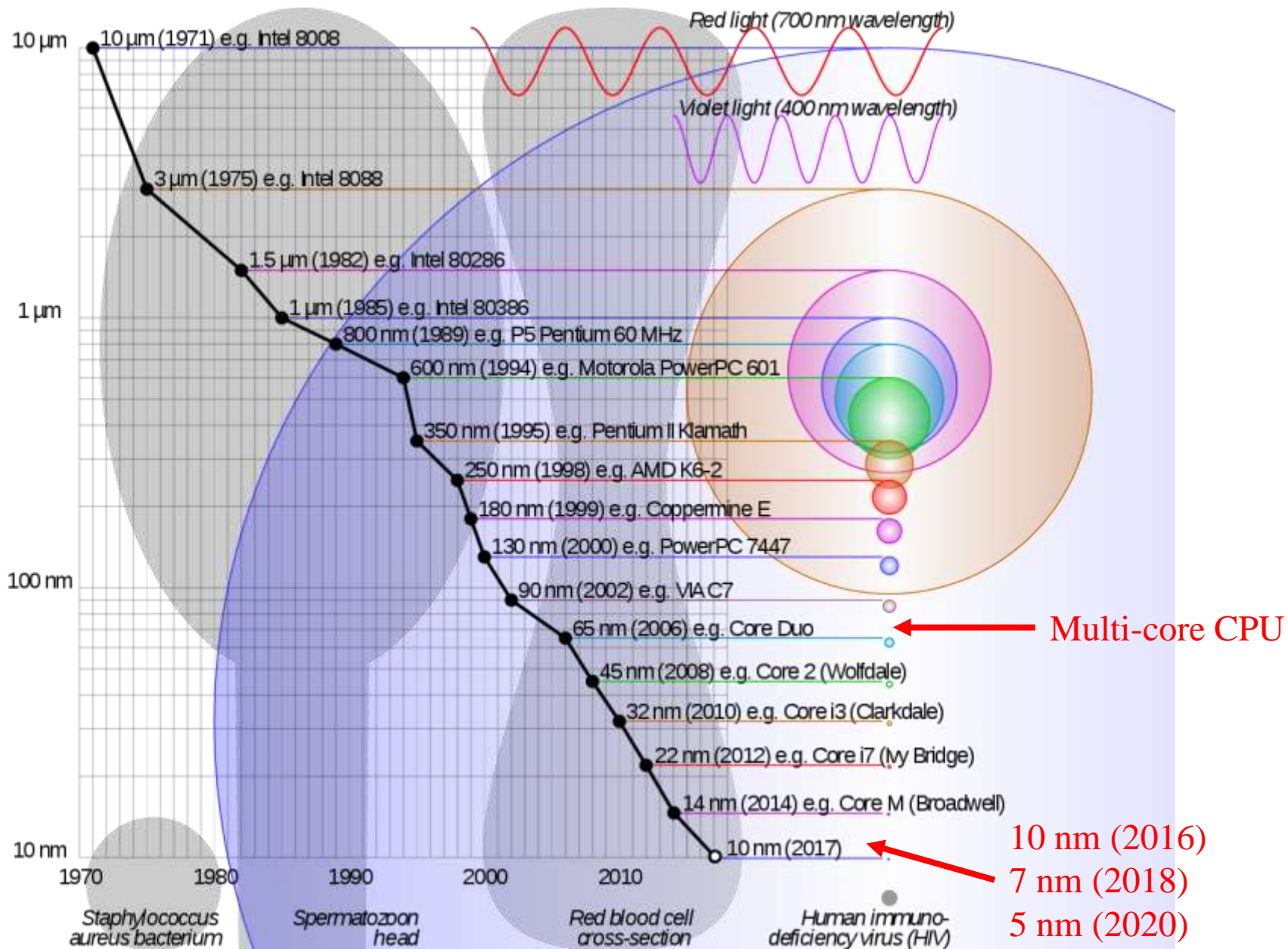


# Why the Clock Rate Does Not Increase?

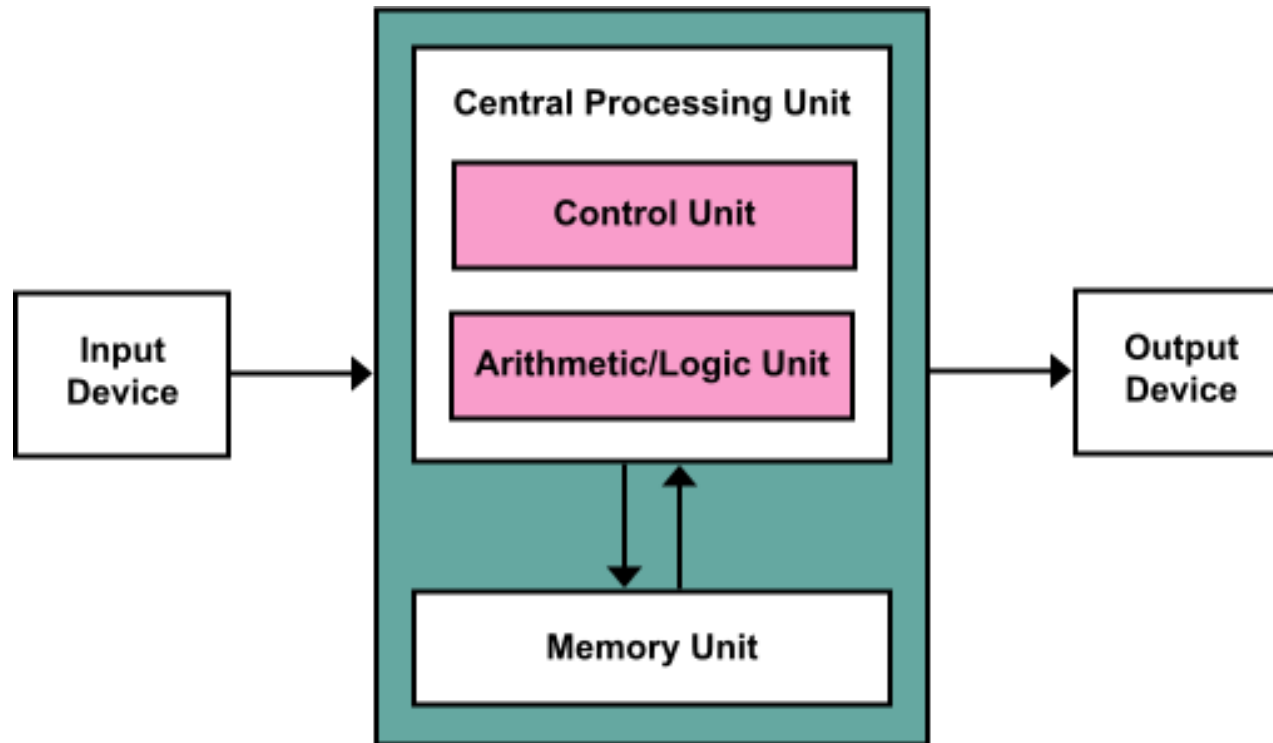
- Power density becomes extremely high
- Heating







# Major Components of a CPU



# Execution of Instructions

- Instruction Fetch
- Instruction Decode
- Memory Access
- Register Writeback

# Execution of Instructions

- Instruction-level parallelism
- SIMD Intrinsics
- Hyper-Threading
- Out-of-order-execution
- Branch Prediction
- Meltdown



# Threads

- Process Control Block
  - Process structuring information
  - Process State
  - Process Number (PID)
  - Program Counter (PC)
  - CPU Registers
  - Memory Management Information
  - Accounting Information
  - I/O Status Information
  - ...

# Thread Scheduling

- Context Switching
  - Save/Load PCB
- Thread Pool