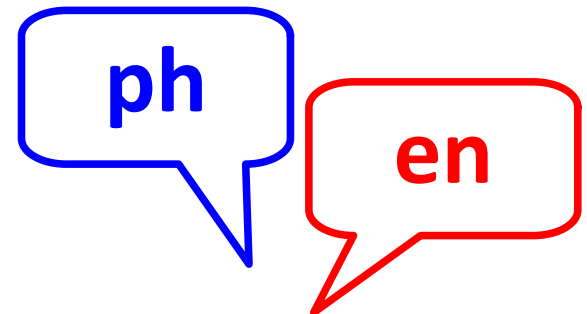


# CMSC 180

## Introduction to Parallel Computing



# OUTLINE

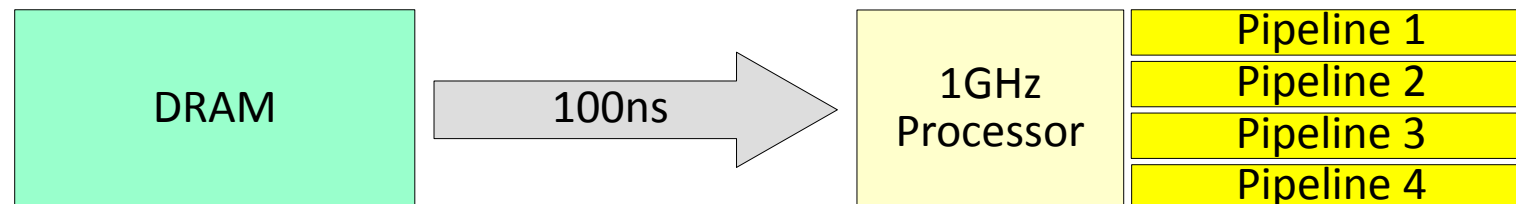
- What is the effect of memory latency on the performance of computations?
  - Example specifications of processor and memory
  - Example computation: Dot product of two vectors
  - Compare :  
theoretical processor rating vs. actual processor rating
  - Practical stuff

# EXAMPLE HARDWARE SPECS

## 1 Processor:

- 1GHz clock speed (1 clock tick per 1 ns)
- Can execute 4 instructions per 1 cycle (1 ns)

## 2 DRAM: 100ns latency (no cache)



# EXAMPLE APPLICATION

- Dot-product of two vectors: **A** and **B**

vector **A**

vector **B**

$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ \vdots \\ a_N \end{pmatrix}$$

•

$$\begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ \vdots \\ b_N \end{pmatrix}$$

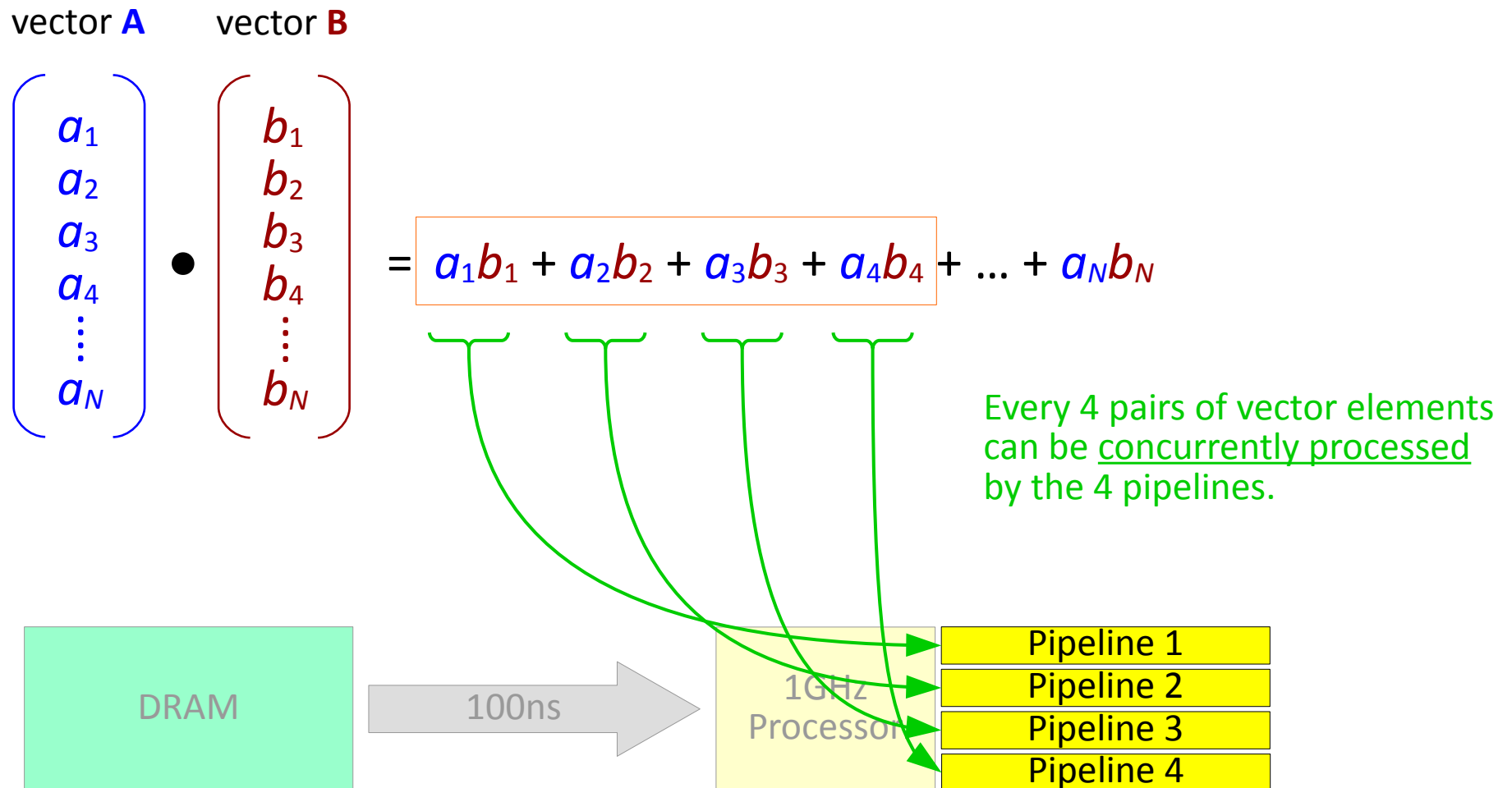
Exactly  $N$  independent multiplications  
and almost  $N$  independent additions.

$$= a_1b_1 + a_2b_2 + a_3b_3 + a_4b_4 + \dots + a_Nb_N$$

LET'S ASSUME THAT  
ONE INSTRUCTION  
COMPLETES  
ONE MULTIPLY AND  
ONE ADD  
OPERATIONS

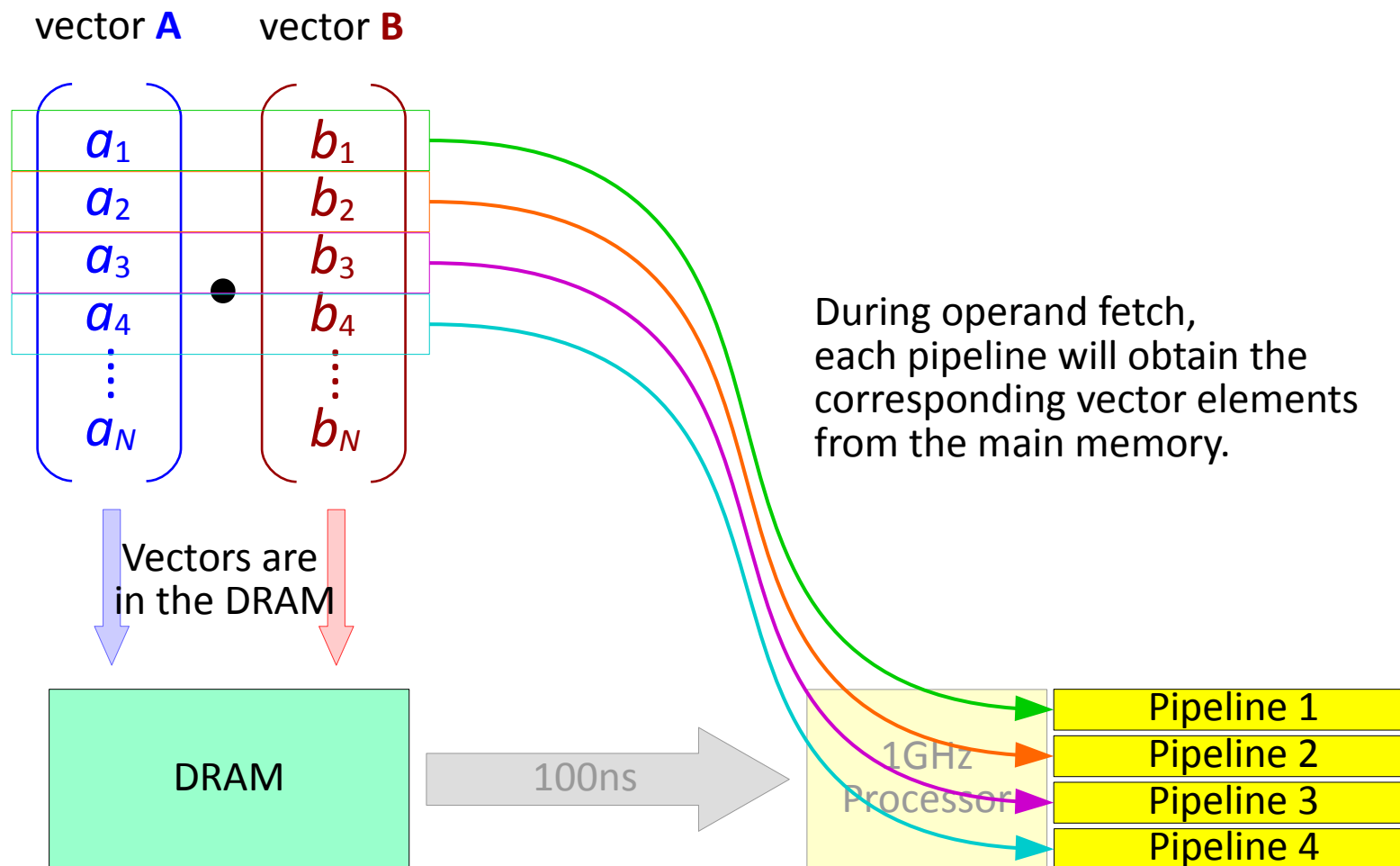
# EXAMPLE APPLICATION

- Dot-product of two vectors: **A** and **B**



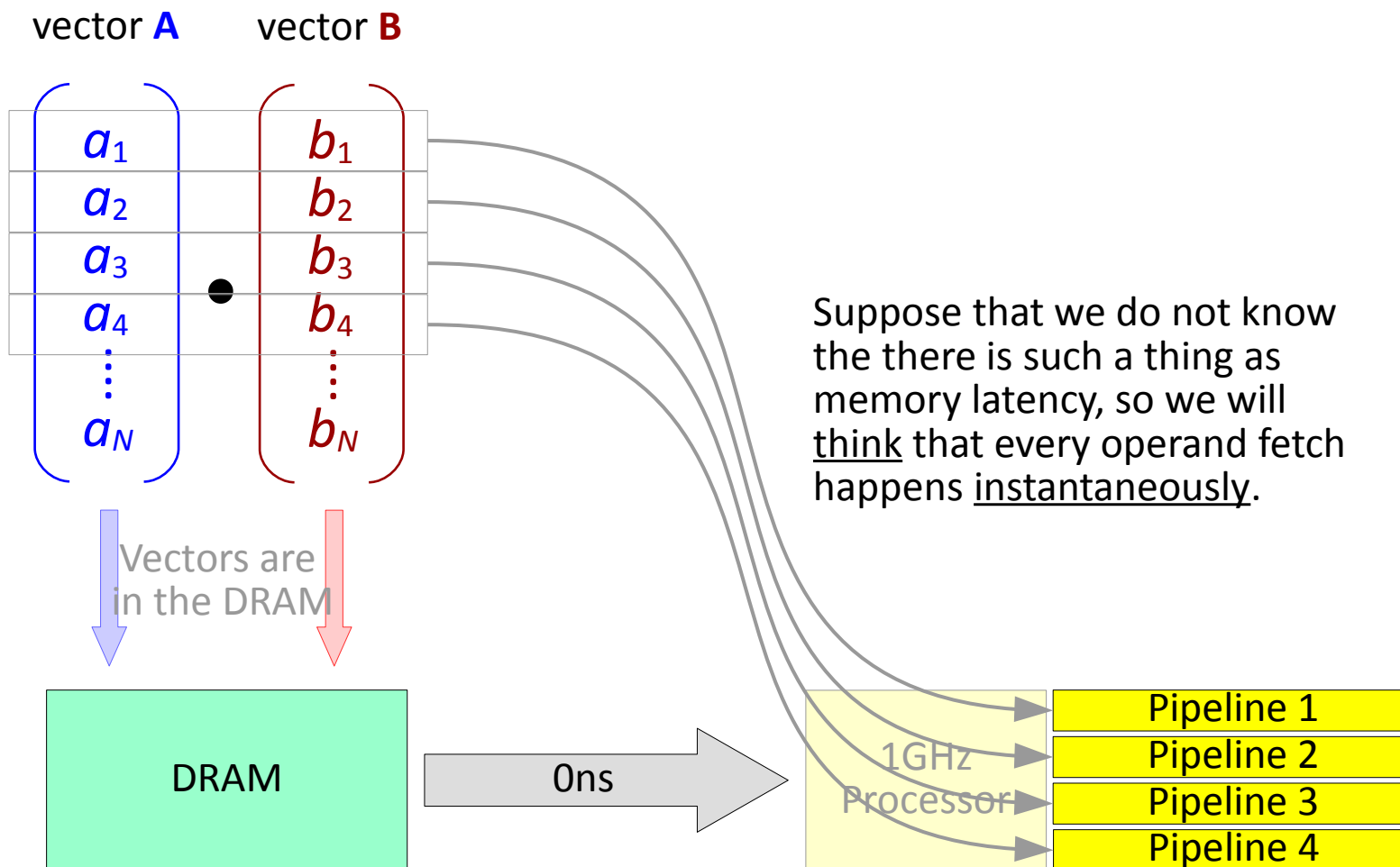
# EXAMPLE APPLICATION

- Dot-product of two vectors: **A** and **B**



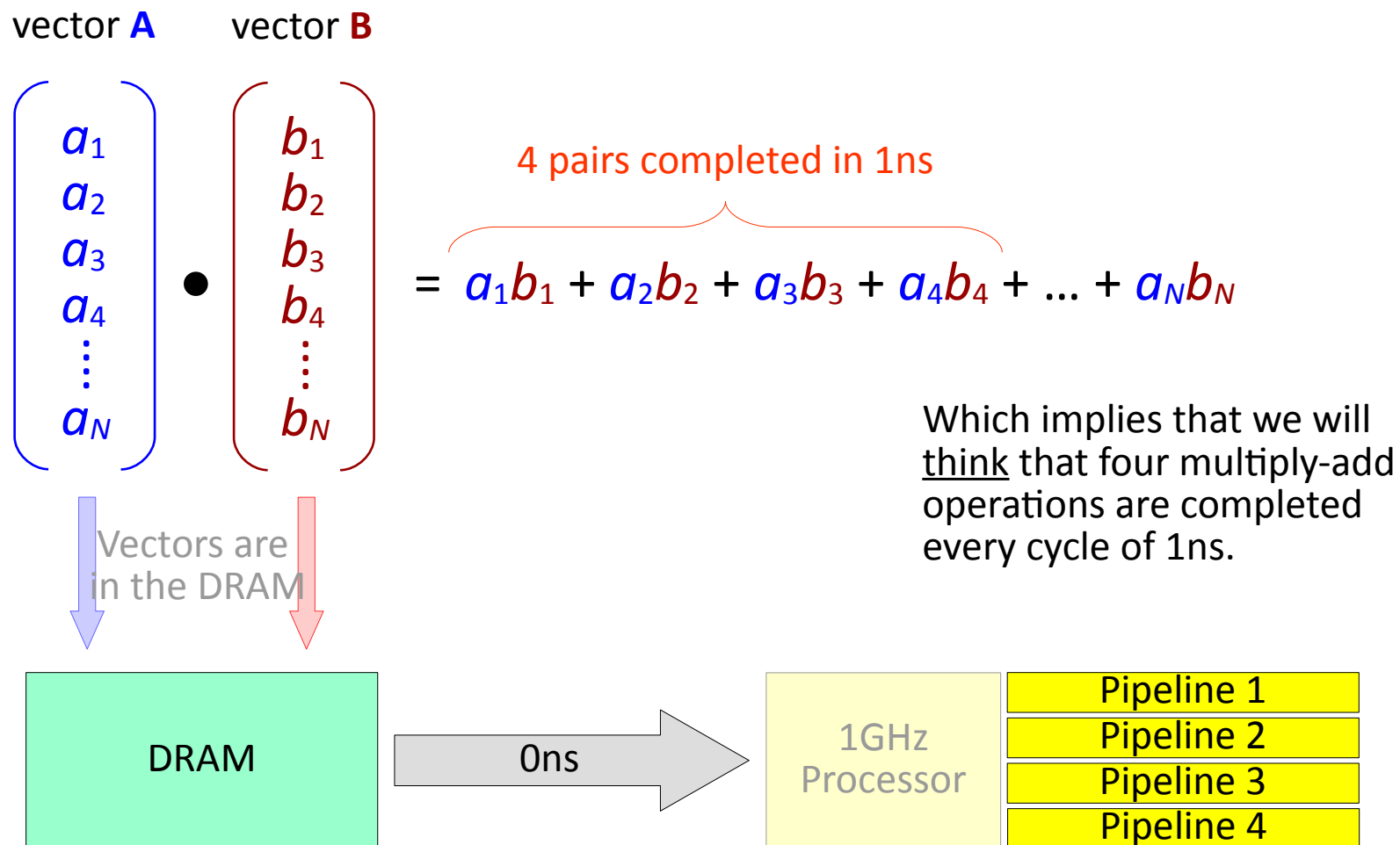
# PROCESSOR RATING

- Theoretical processor rating



# PROCESSOR RATING


- Theoretical processor rating





# PROCESSOR RATING

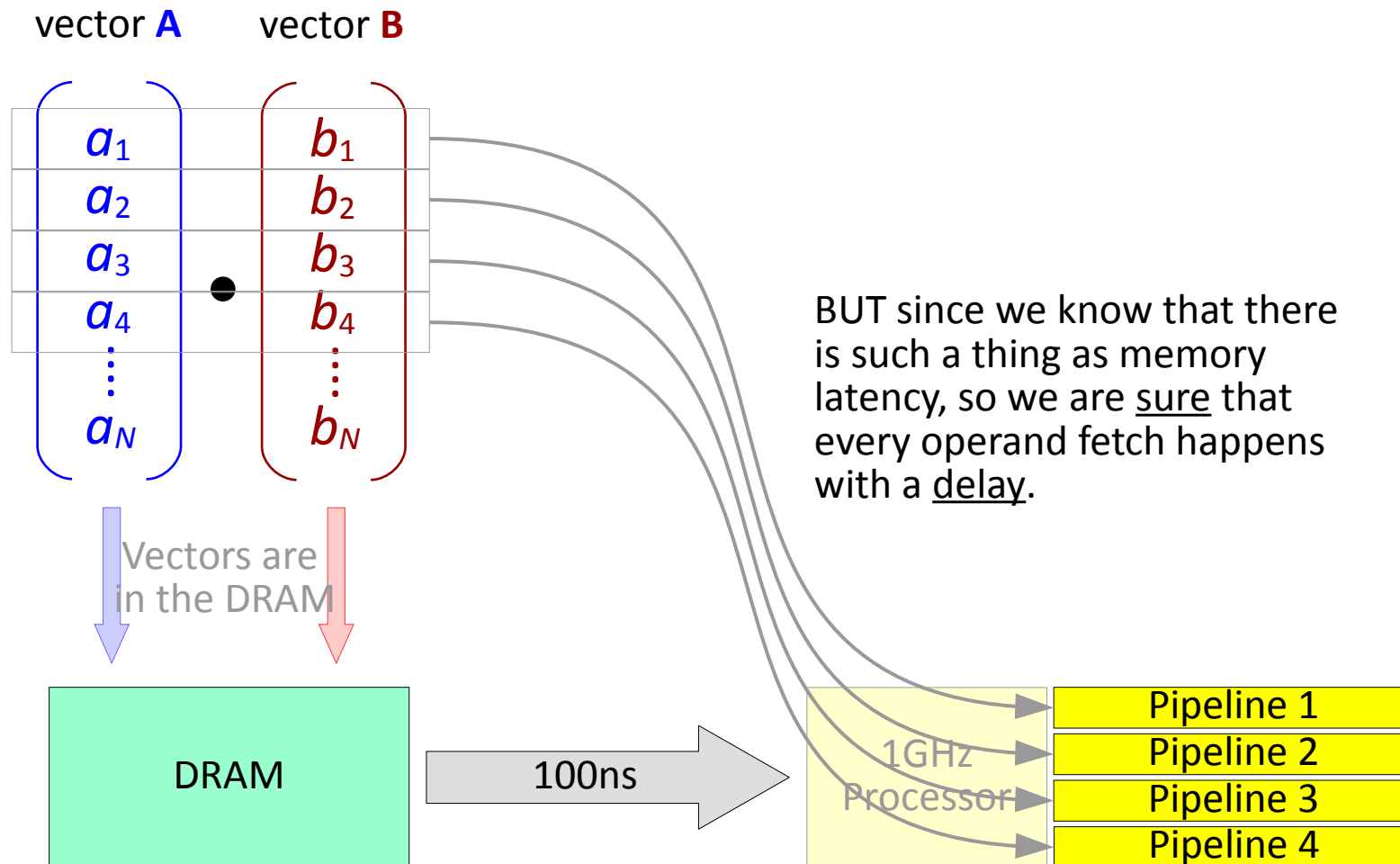
- Theoretical processor rating:
  - ▷ Four billion multiply-add operations in a second
  - ▷ Four billion floating-point operations per second
  - ▷ 4GFLOPS



THAT'S AN AWESOME  
4 GIGAFLOPS  
RATING FOR A  
1GHz PROCESSOR  
SPEED.

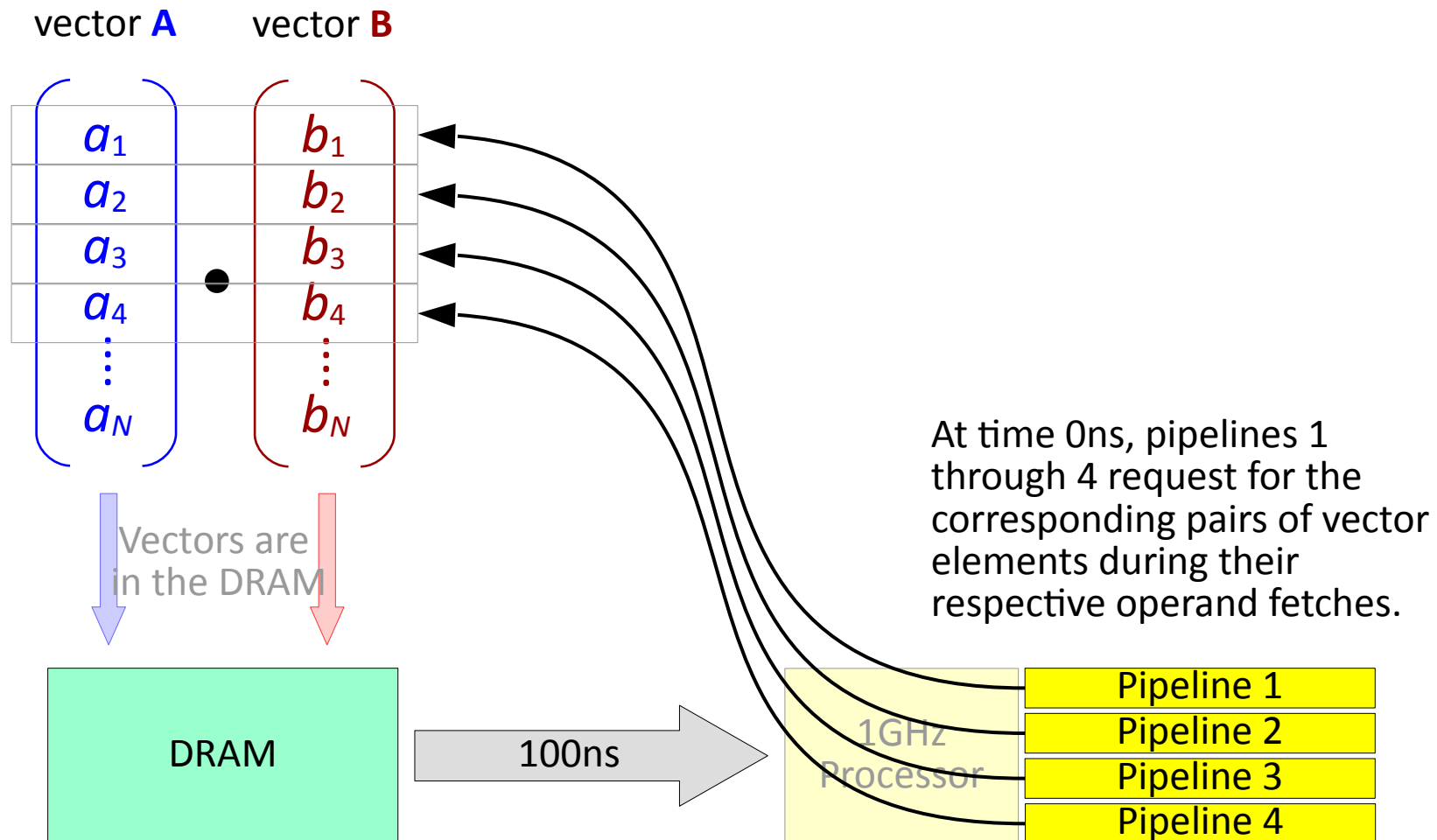
# PROCESSOR RATING

- Actual processor rating:



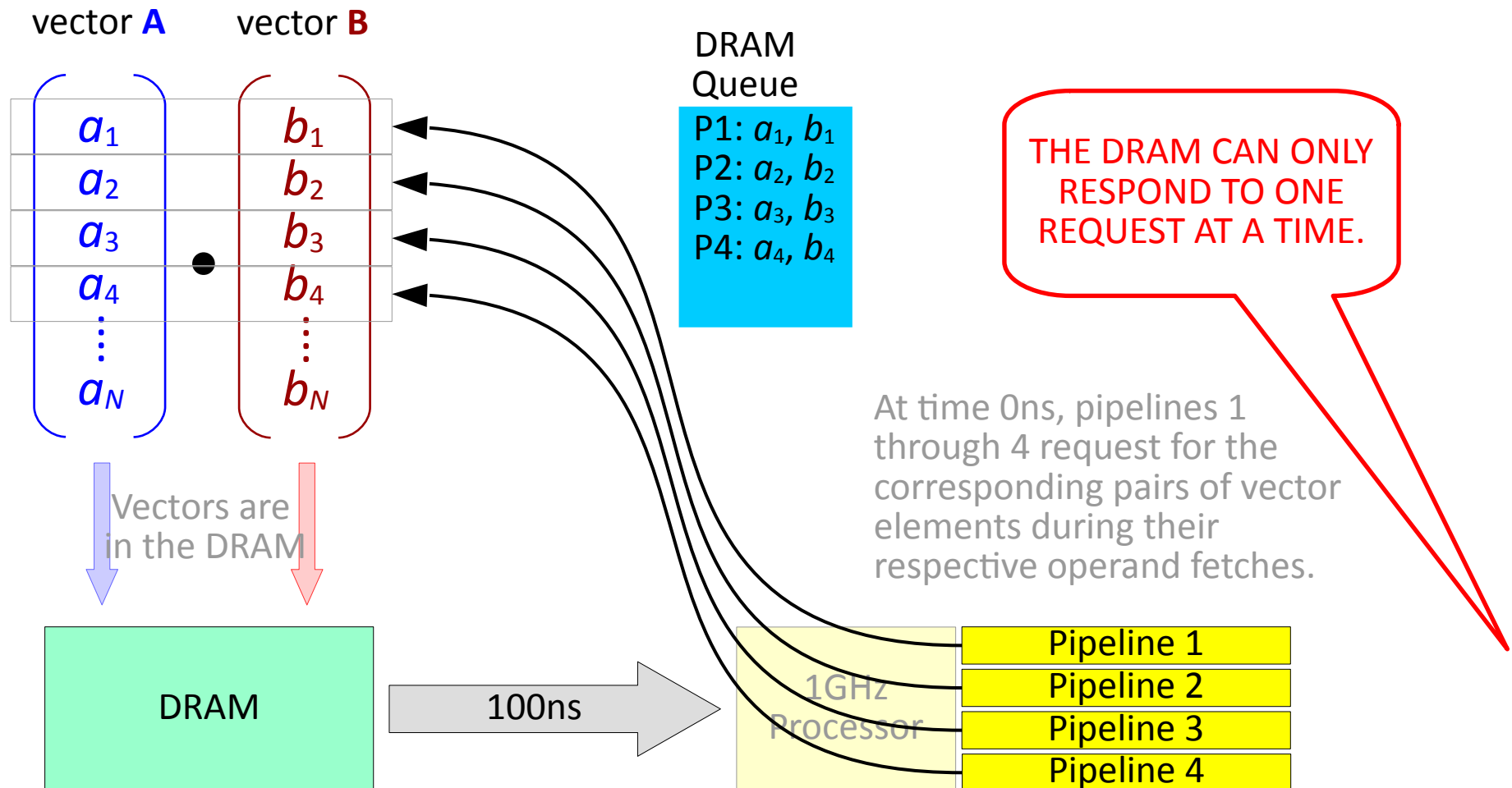
# PROCESSOR RATING

- Actual processor rating:



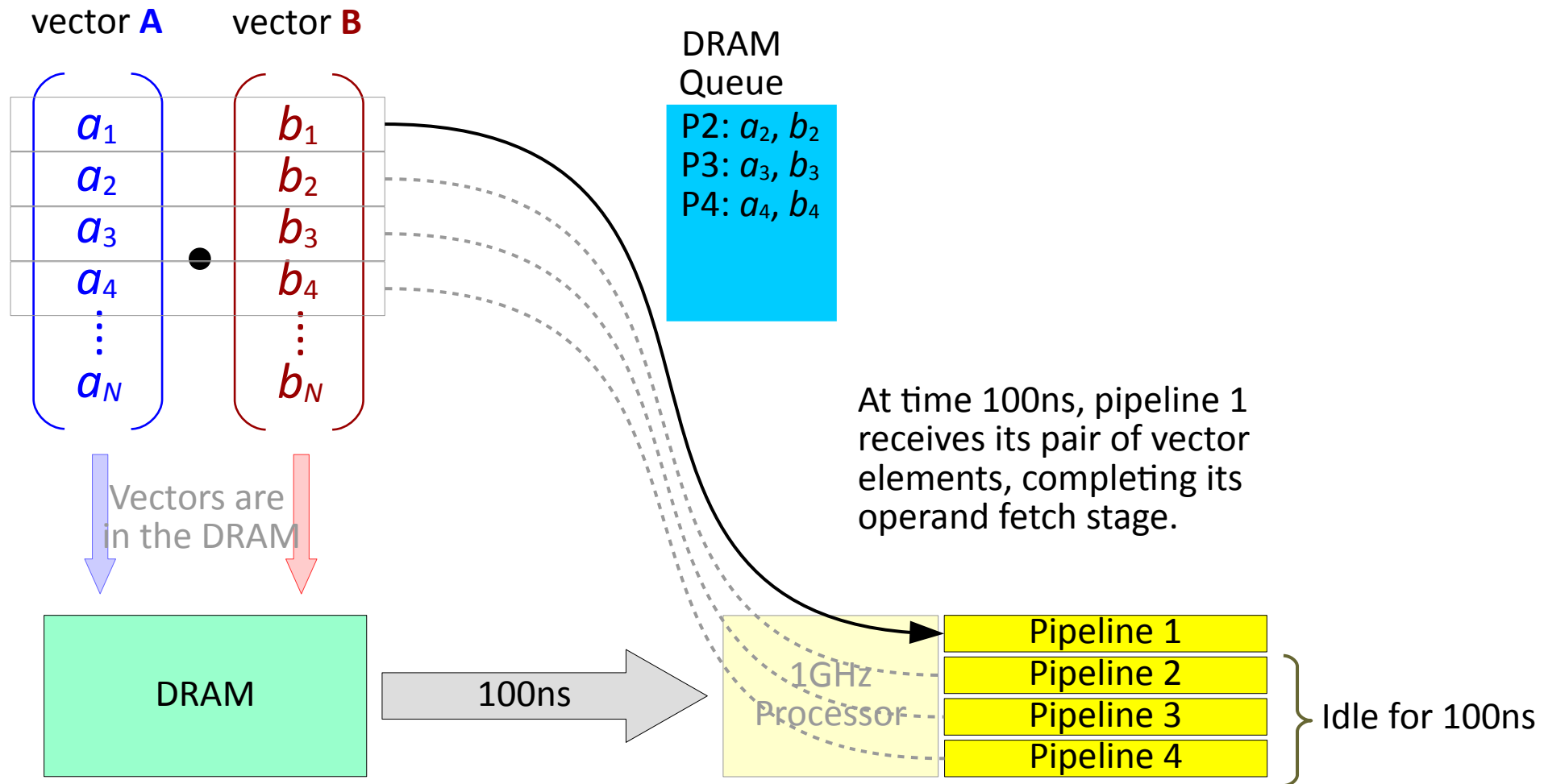
# PROCESSOR RATING

- Actual processor rating:



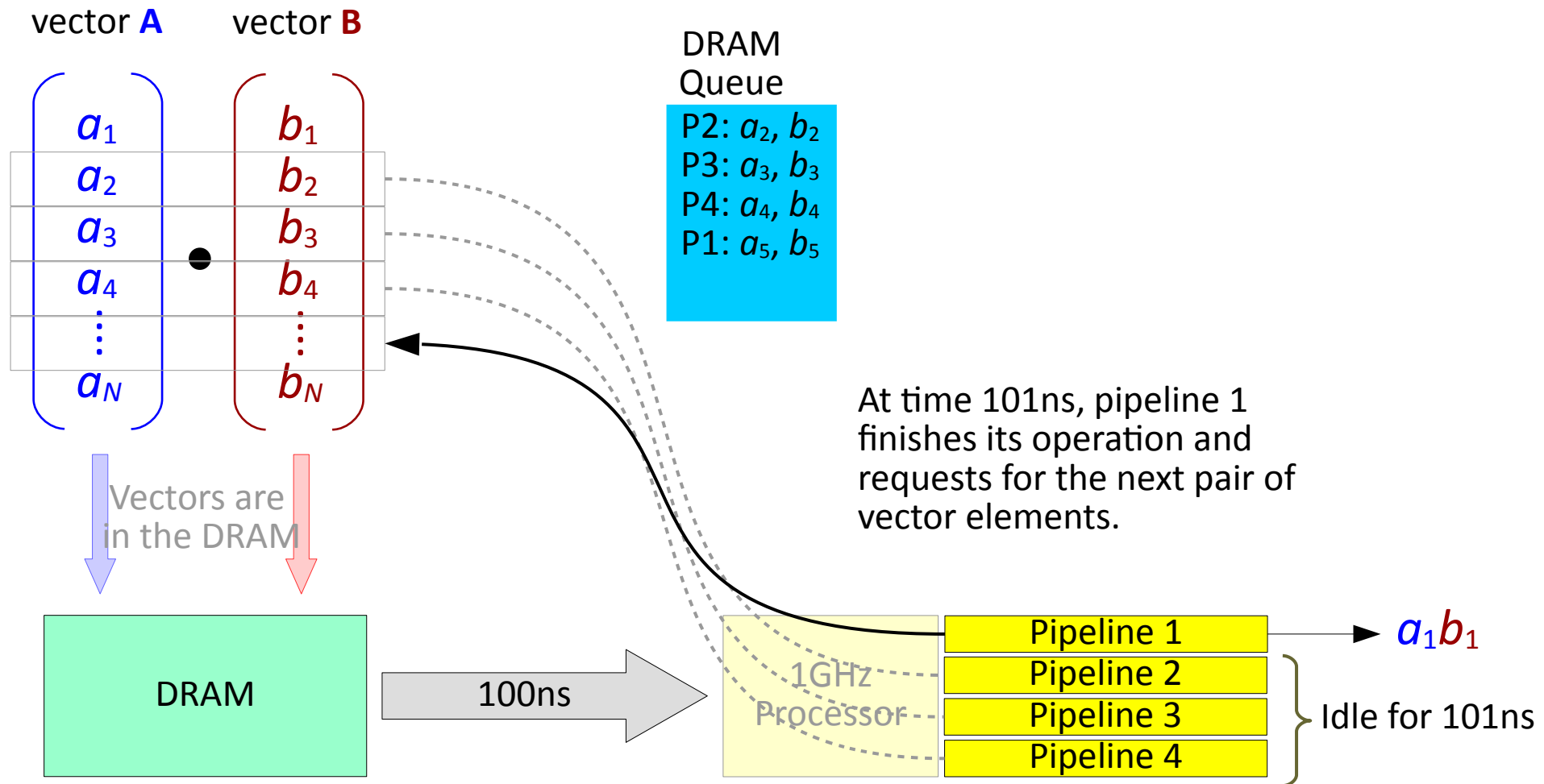
# PROCESSOR RATING

- Actual processor rating:



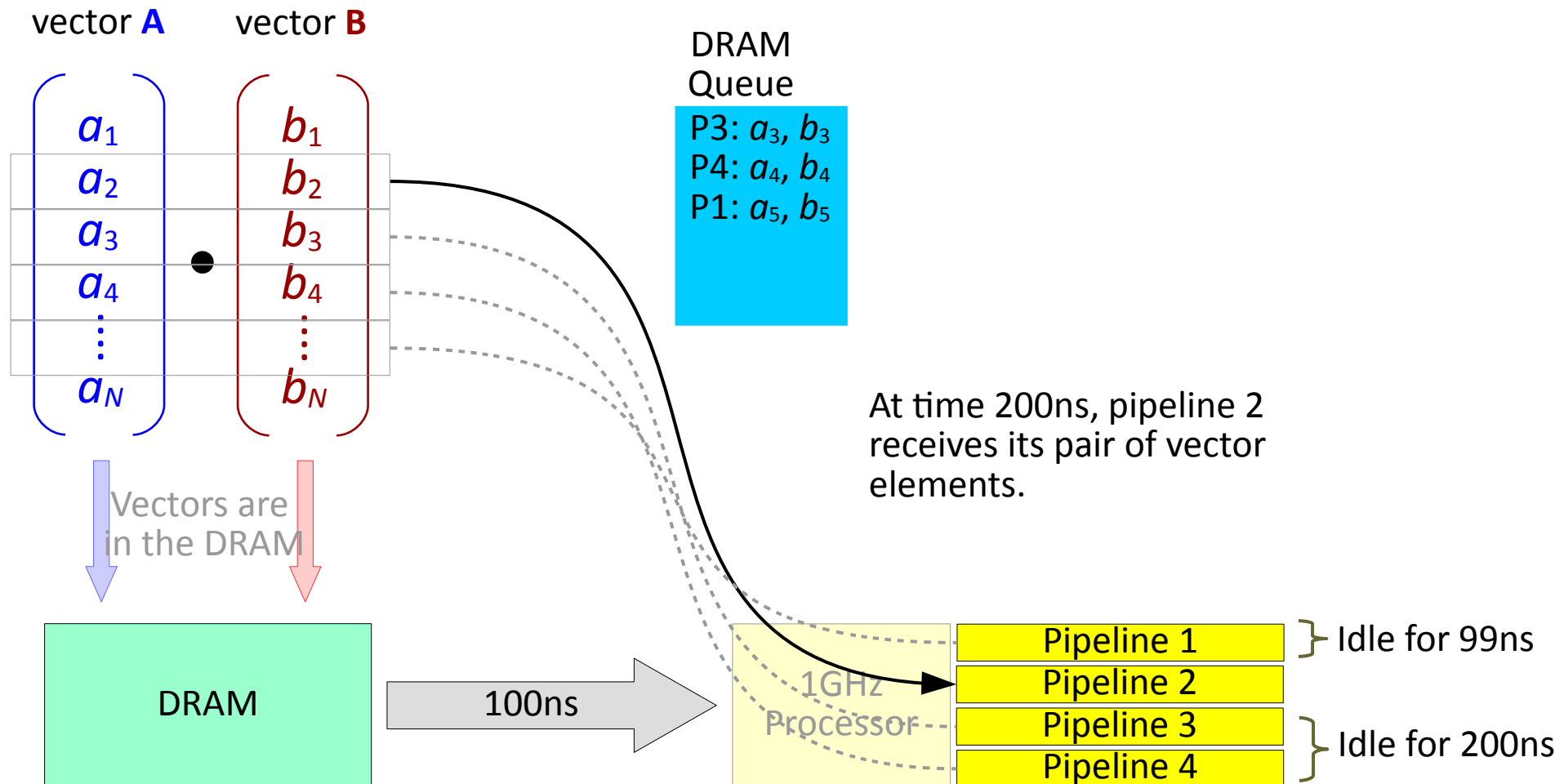
# PROCESSOR RATING

- Actual processor rating:



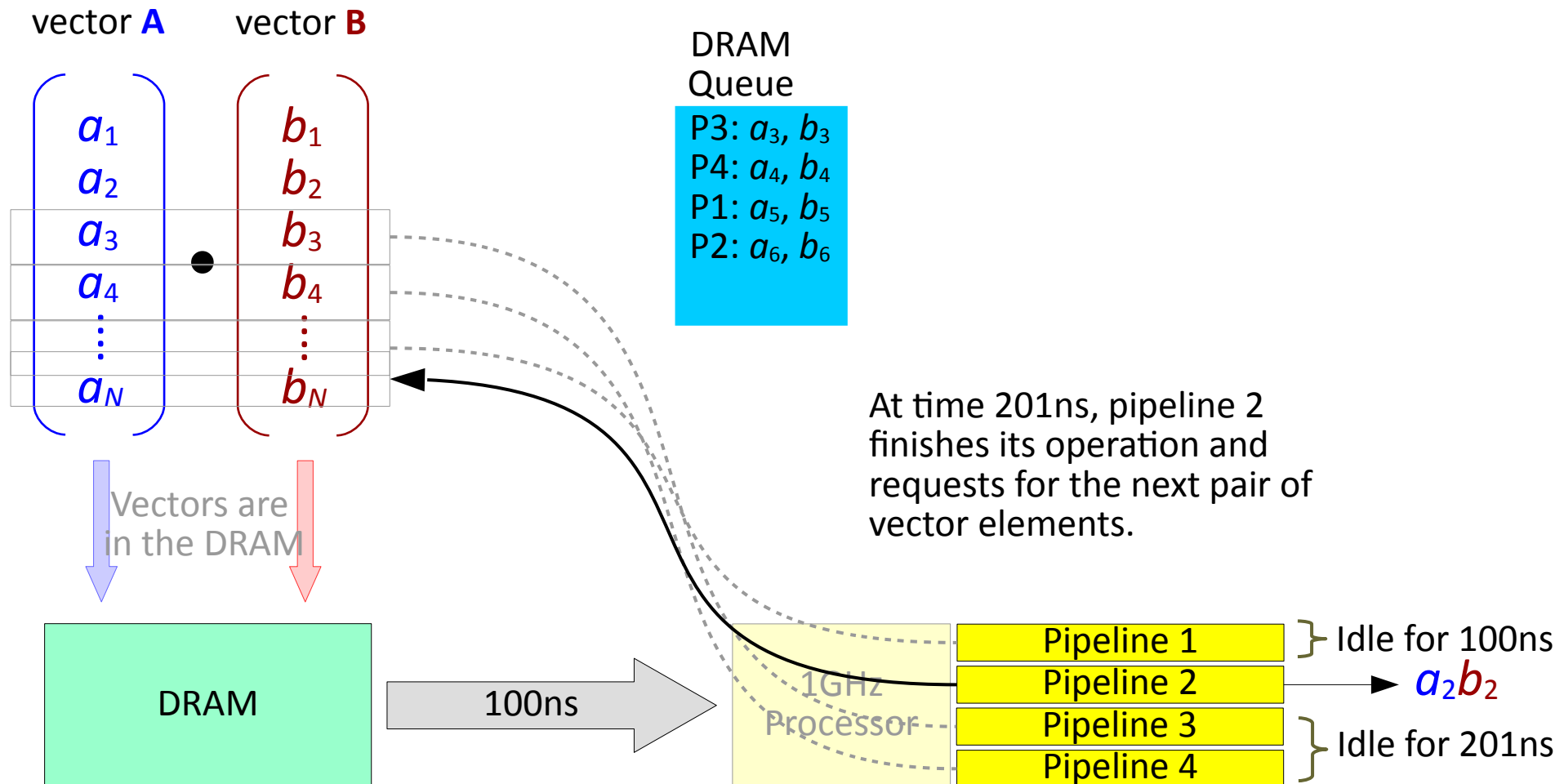
# PROCESSOR RATING

- Actual processor rating:



# PROCESSOR RATING

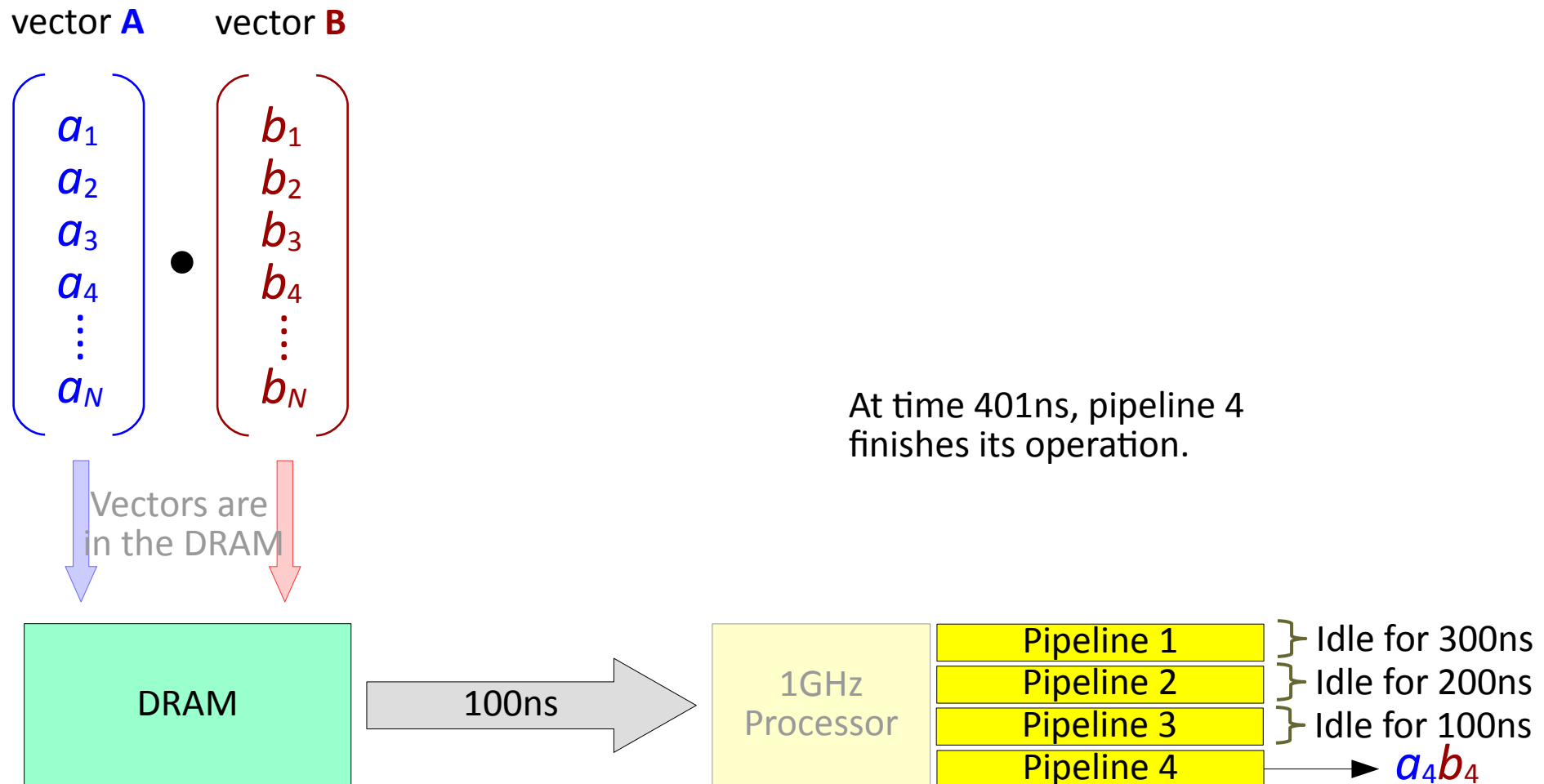
- Actual processor rating:





# PROCESSOR RATING

- Actual processor rating:



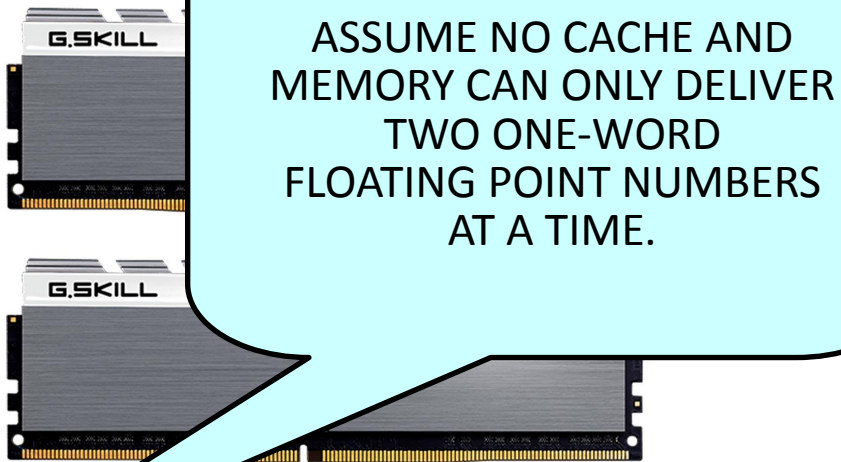
# PROCESSOR RATING

- **Comparison:**

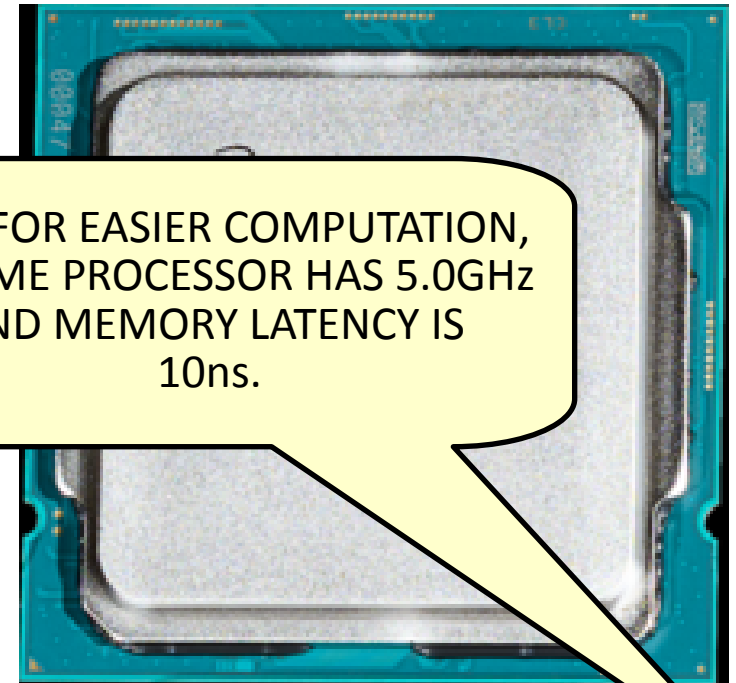
- ▷ Theoretical/Peak Rating: 4GFLOPS
- ▷ Actual Rating: 10MFLOPS
- ▷ Only 0.25% of what we expect
- ▷ Renders the 4 pipelines useless

# SOME PRACTICAL STUFF

- Best specs of 2021:
  - Intel Core i9-10900K 5.3GHz (Turbo Boost Max)
  - DDR4-4600 SDRAM 8<sup>th</sup> Word Latency: 9.35ns



ASSUME NO CACHE AND  
MEMORY CAN ONLY DELIVER  
TWO ONE-WORD  
FLOATING POINT NUMBERS  
AT A TIME.



AND FOR EASIER COMPUTATION,  
ASSUME PROCESSOR HAS 5.0GHz  
AND MEMORY LATENCY IS  
10ns.

**NEXT DISCUSSION...**

**Effect of  
Memory Bandwidth**