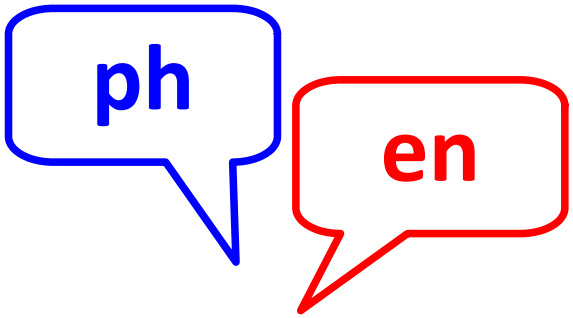
CMSC 180
Introduction to Parallel Computing

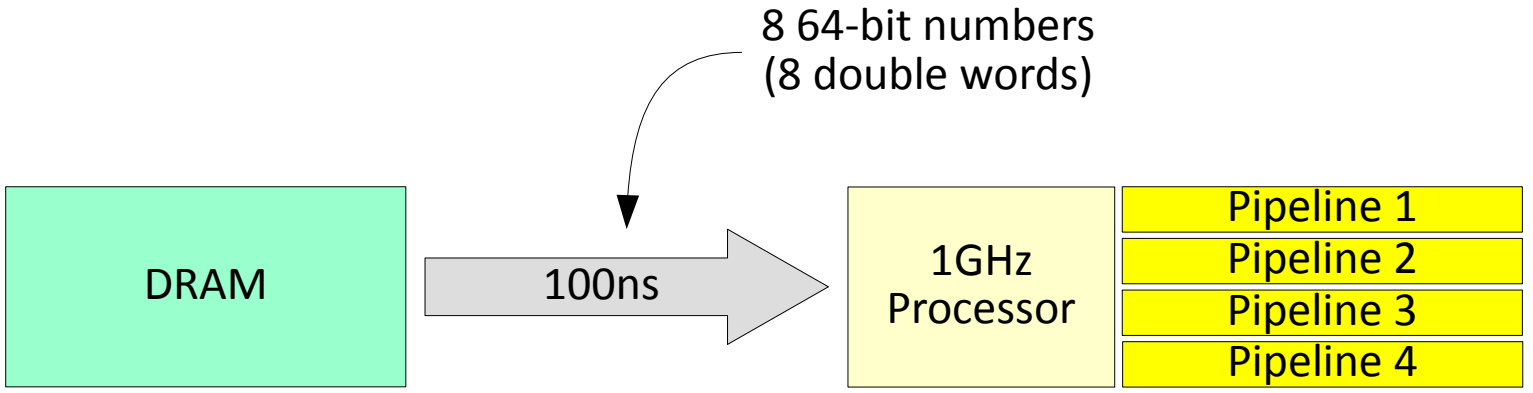


OUTLINE

- What is the effect of memory bandwidth 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)
3. Datapath: 8 double-precision floats (512 bits)



EXAMPLE APPLICATION

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

vector **A** vector **B**

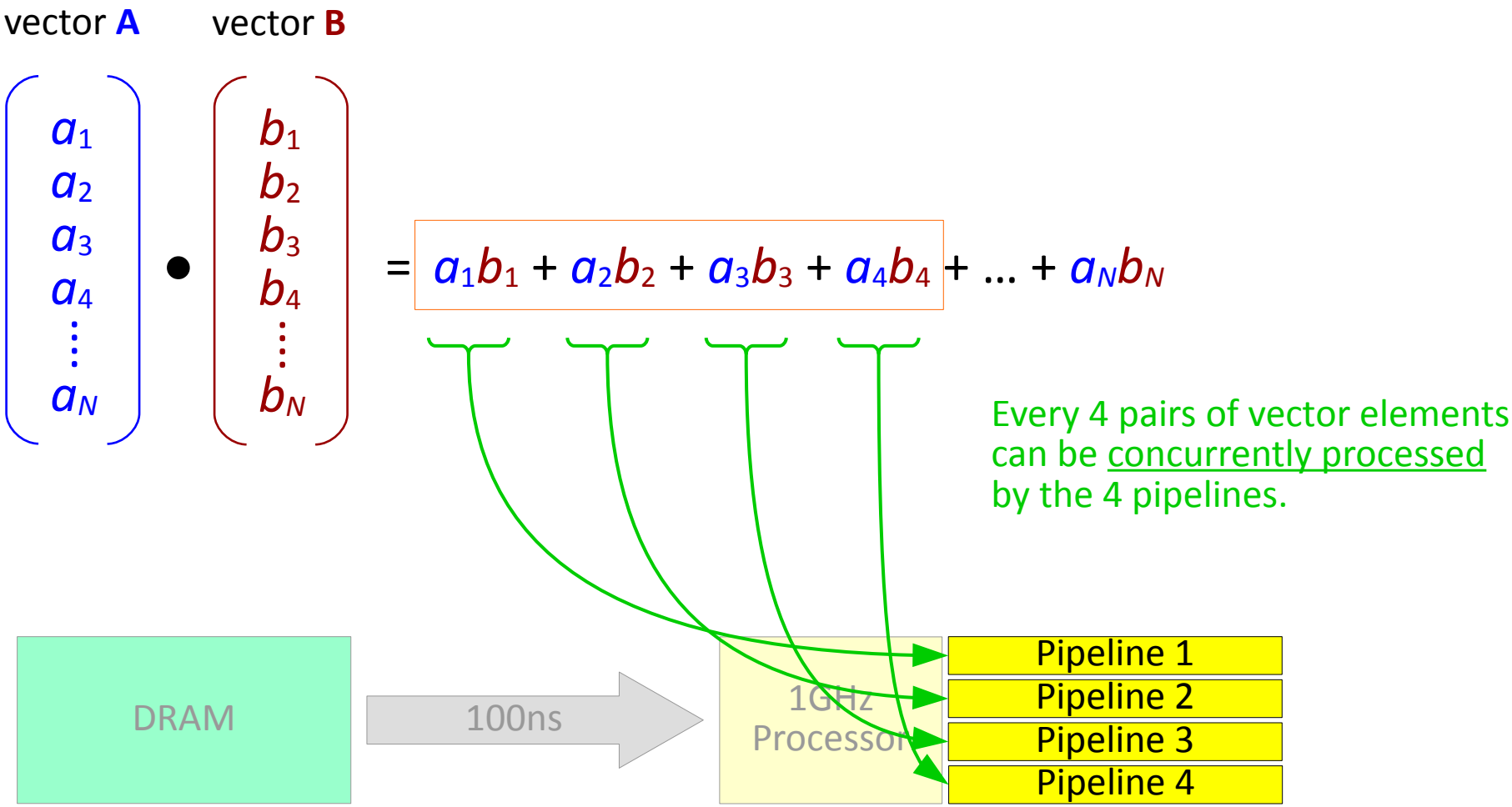
$$\begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ \vdots \\ a_N \end{pmatrix} \bullet \begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ \vdots \\ b_N \end{pmatrix} = \overbrace{a_1b_1 + a_2b_2 + a_3b_3 + a_4b_4 + \ldots + a_Nb_N}$$

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

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

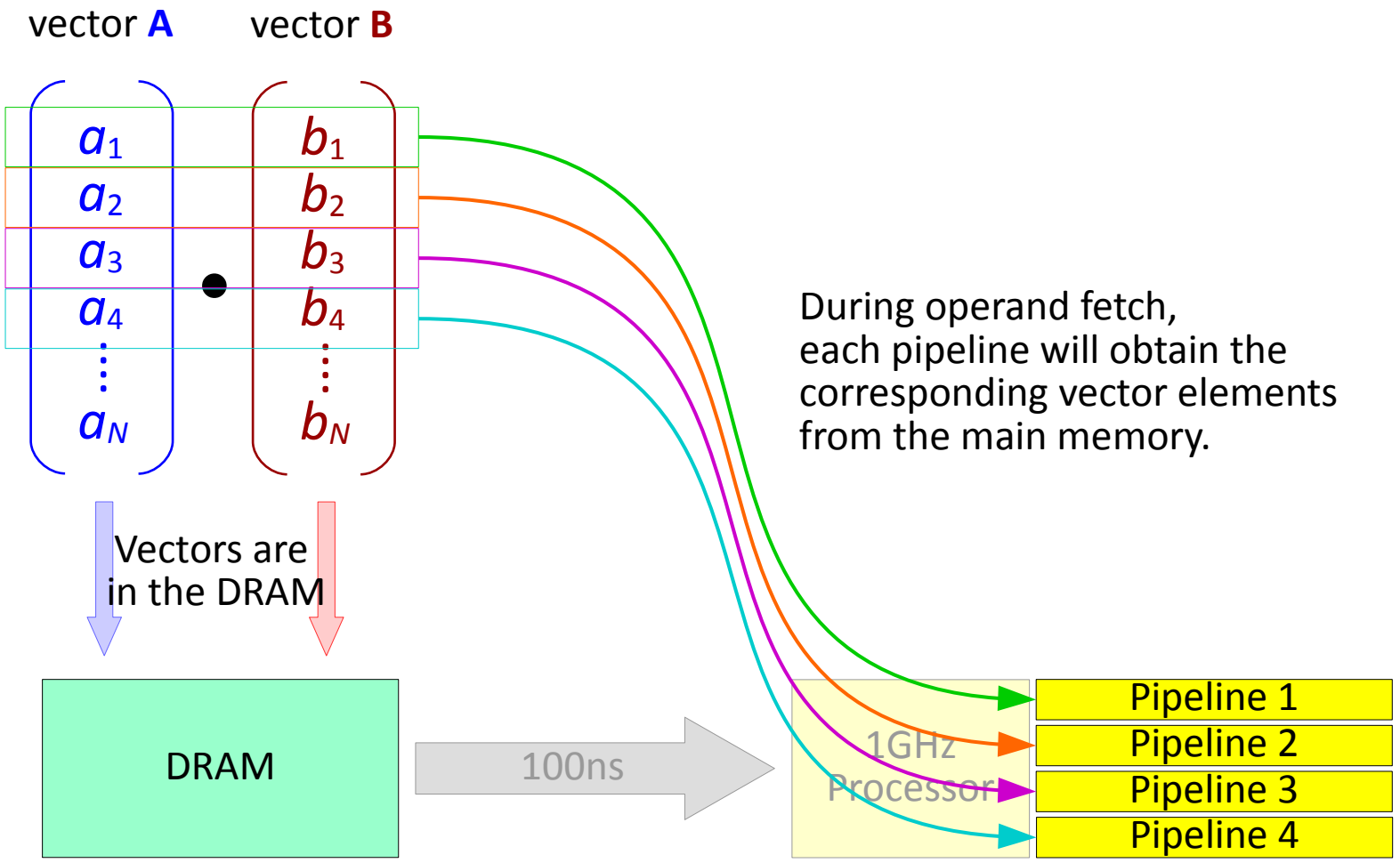
EXAMPLE APPLICATION

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



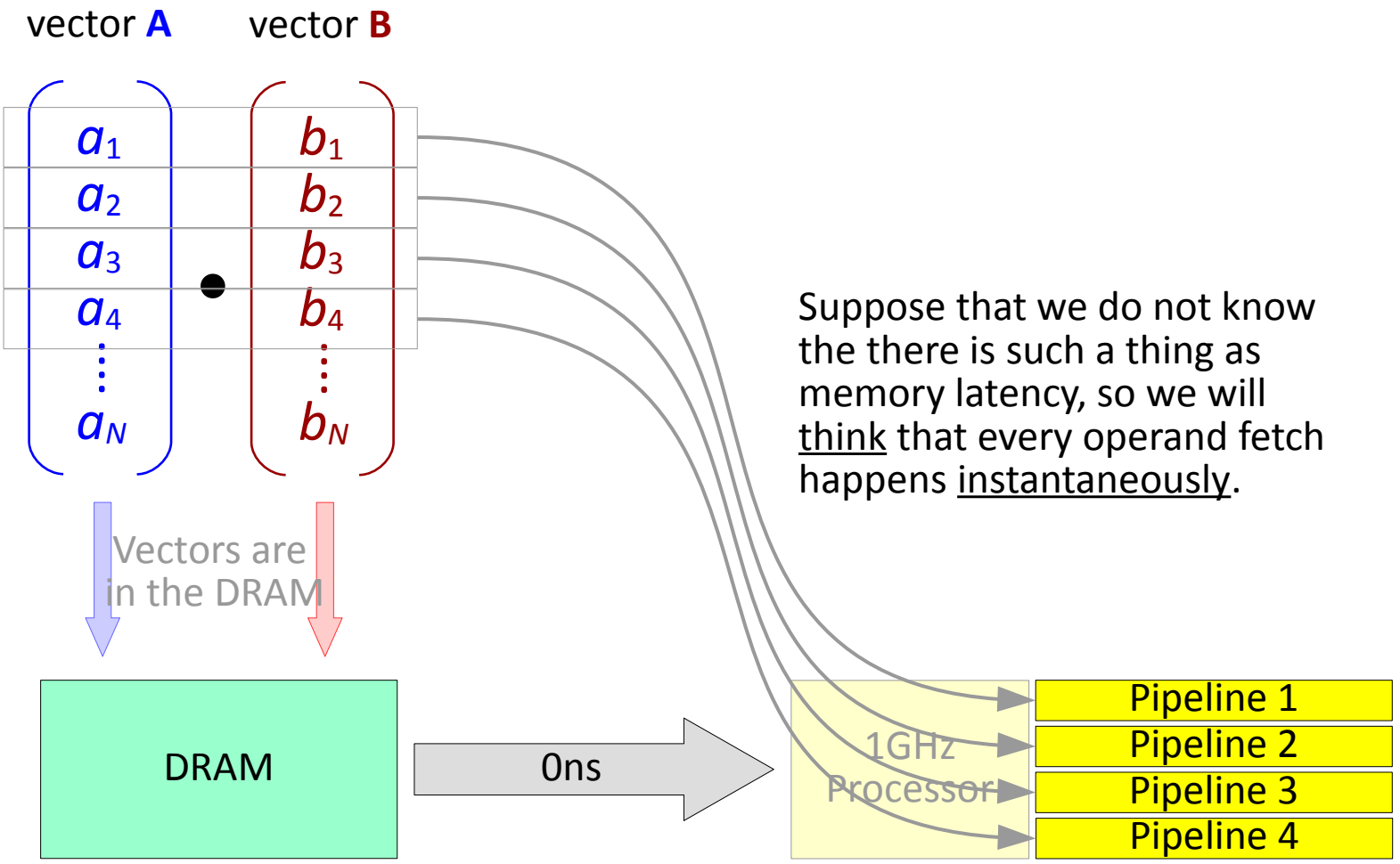
EXAMPLE APPLICATION

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



PROCESSOR RATING

- Theoretical processor rating



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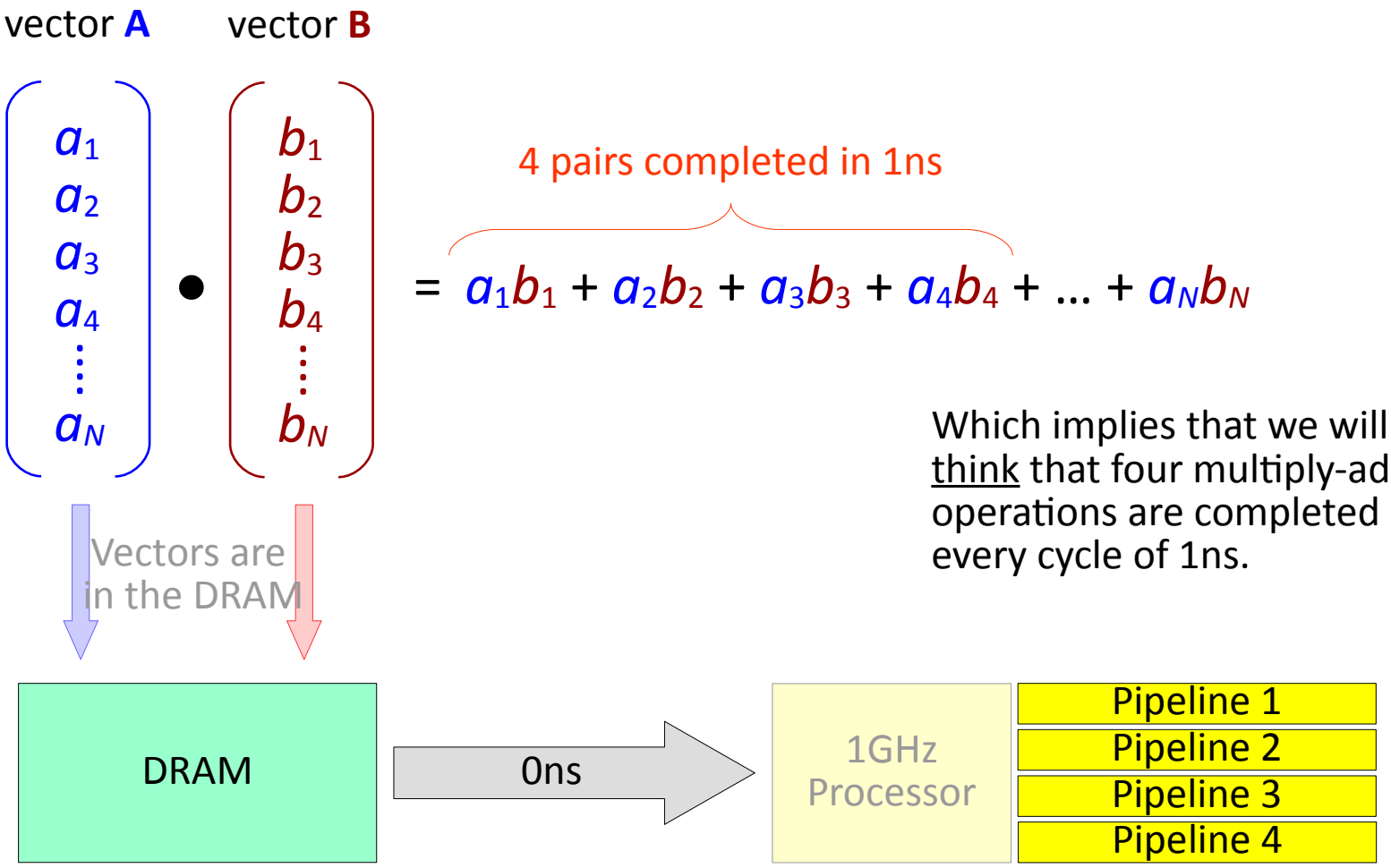
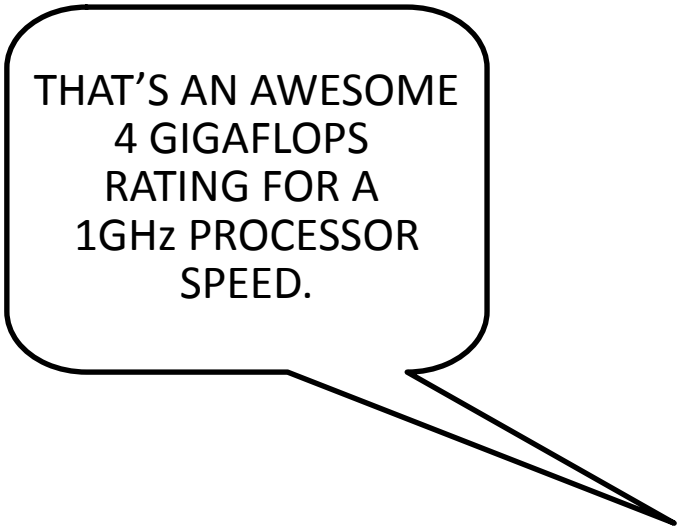


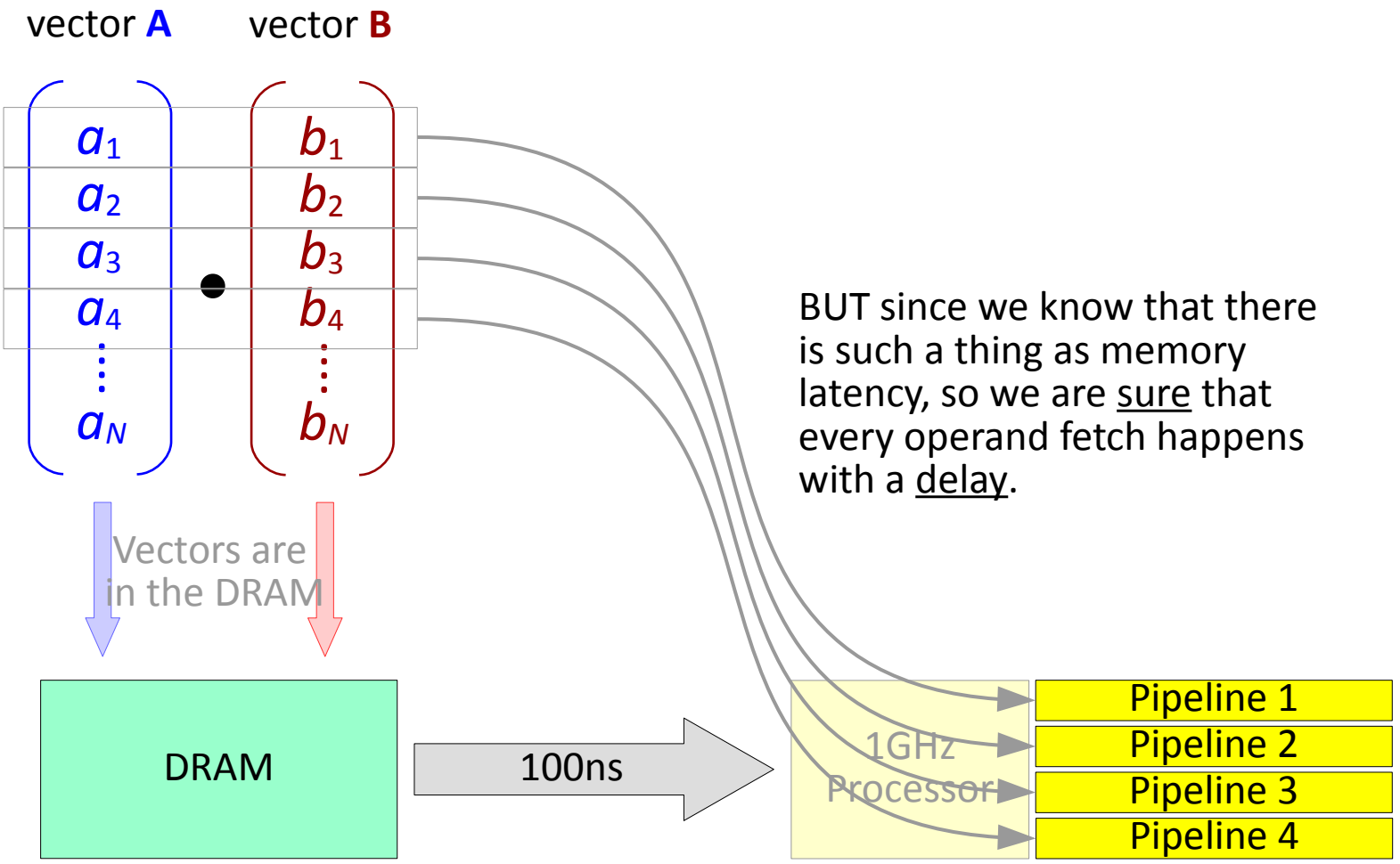
PROCESSOR RATING

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



PROCESSOR RATING

- **Actual** processor rating:



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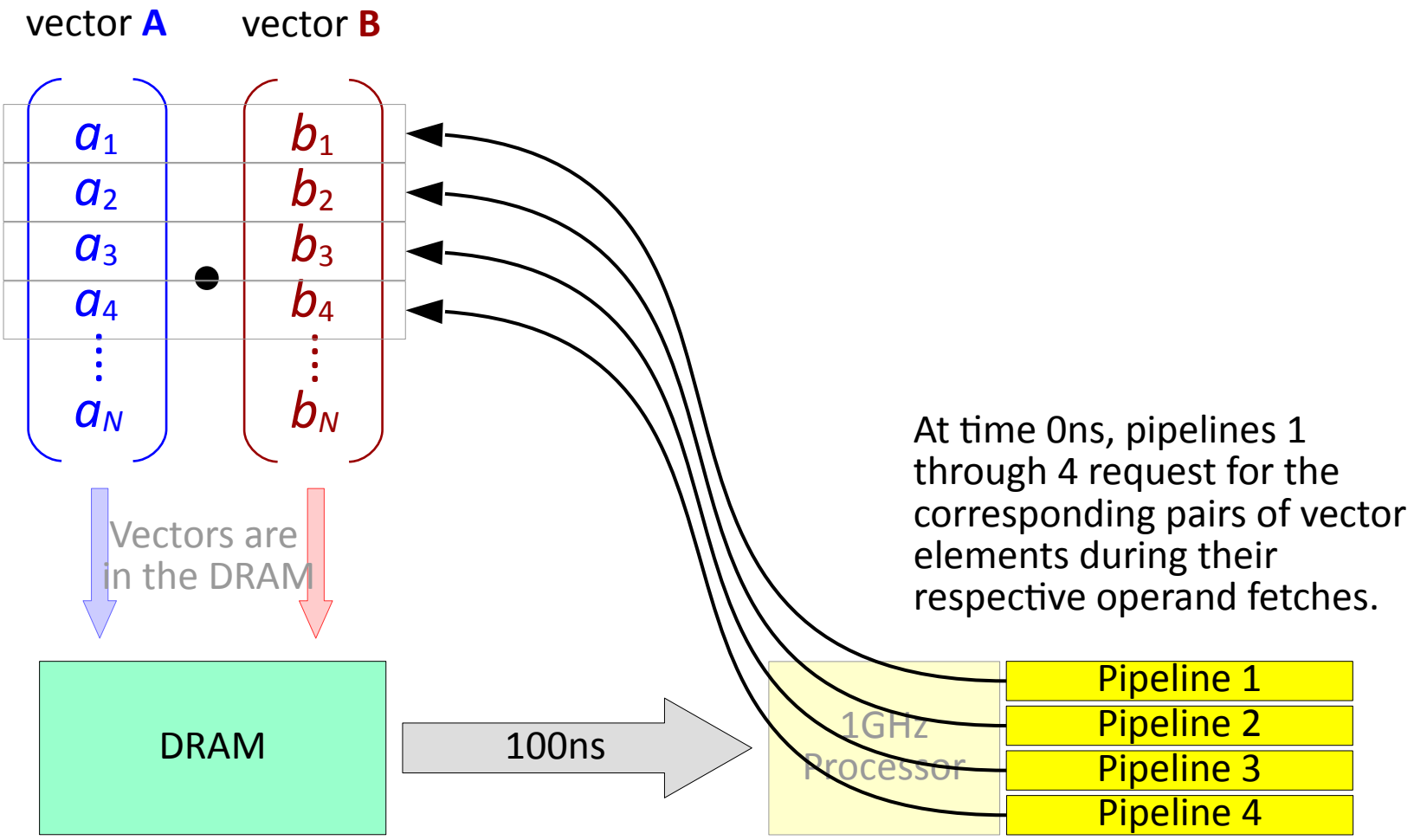

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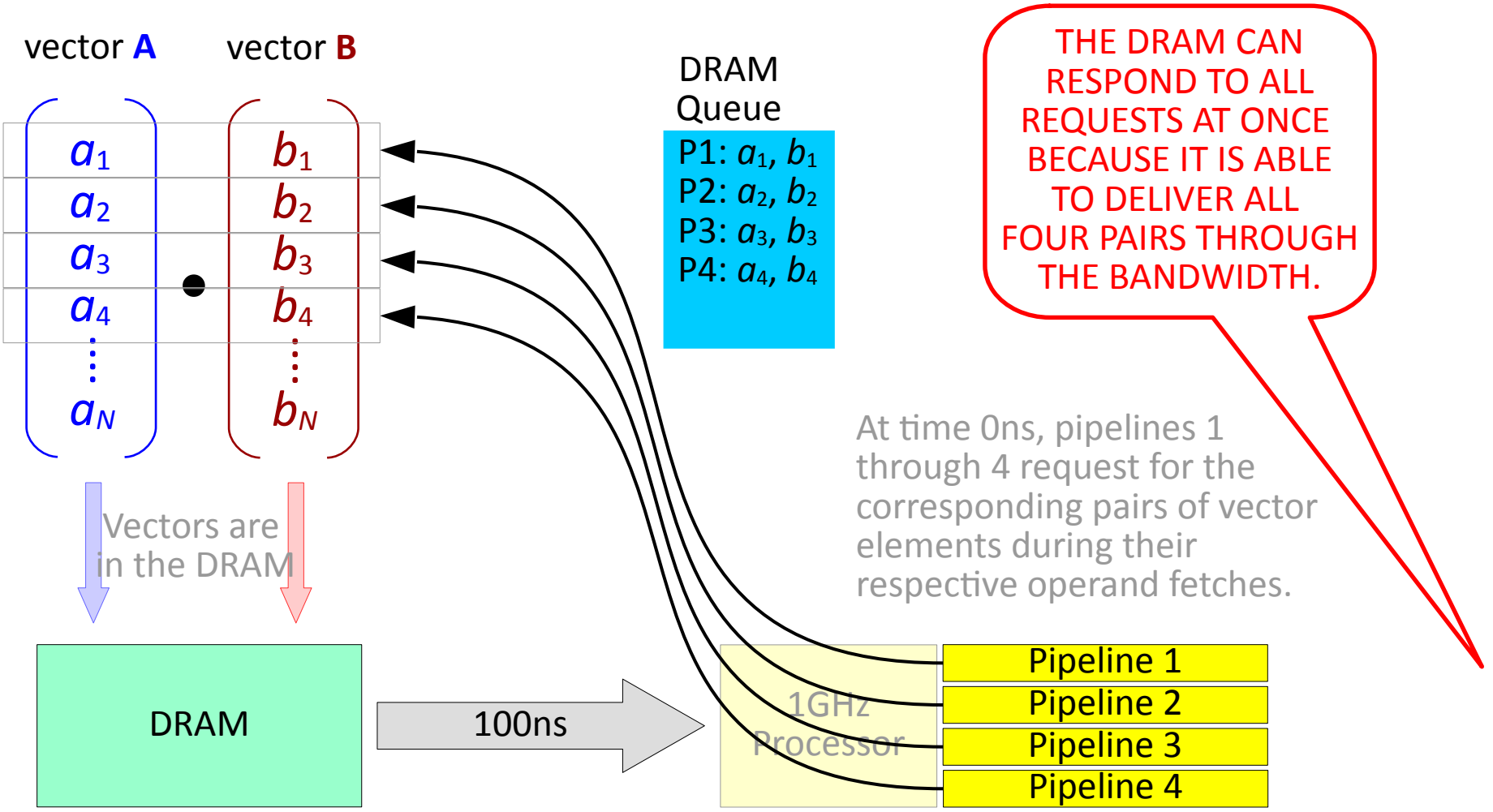

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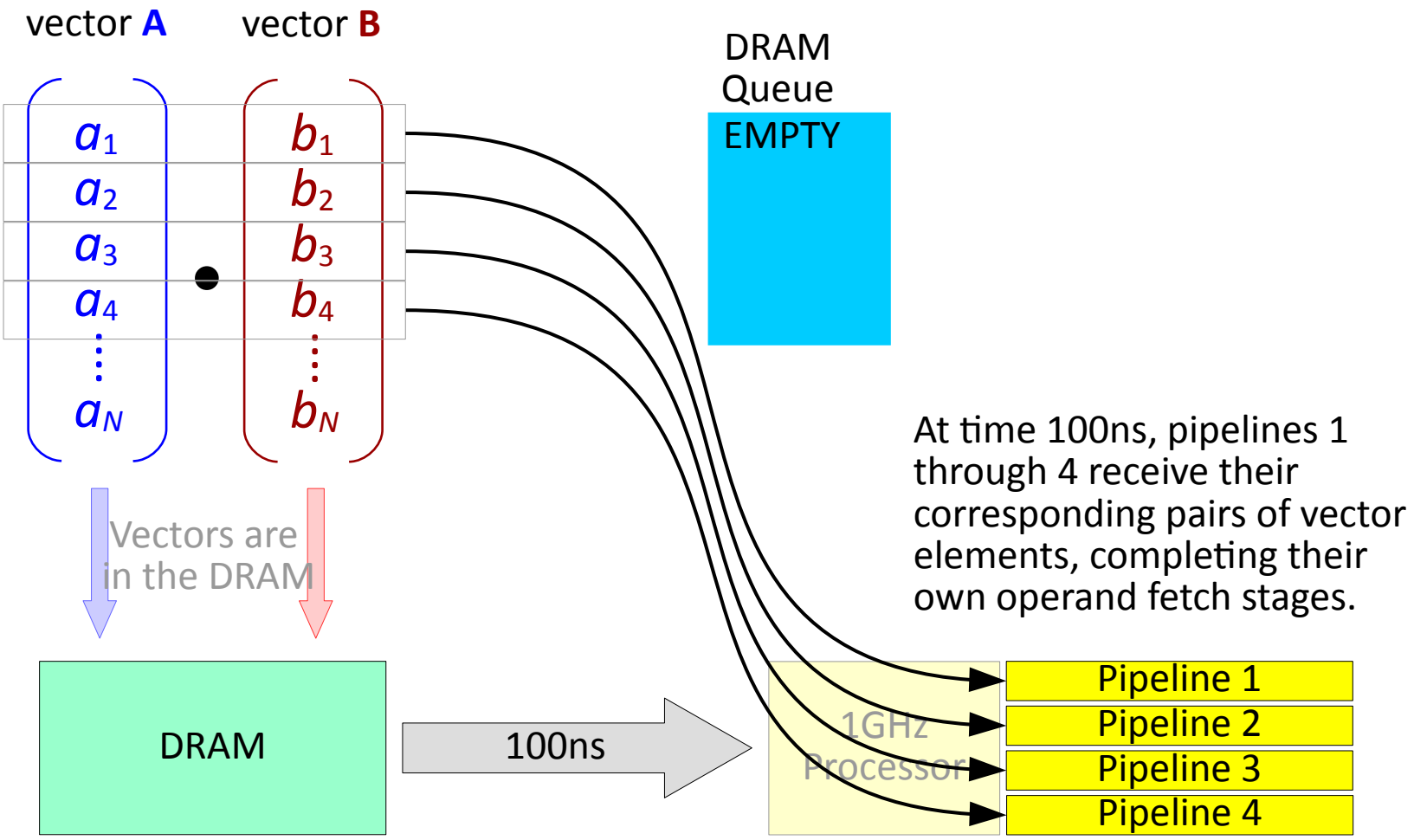

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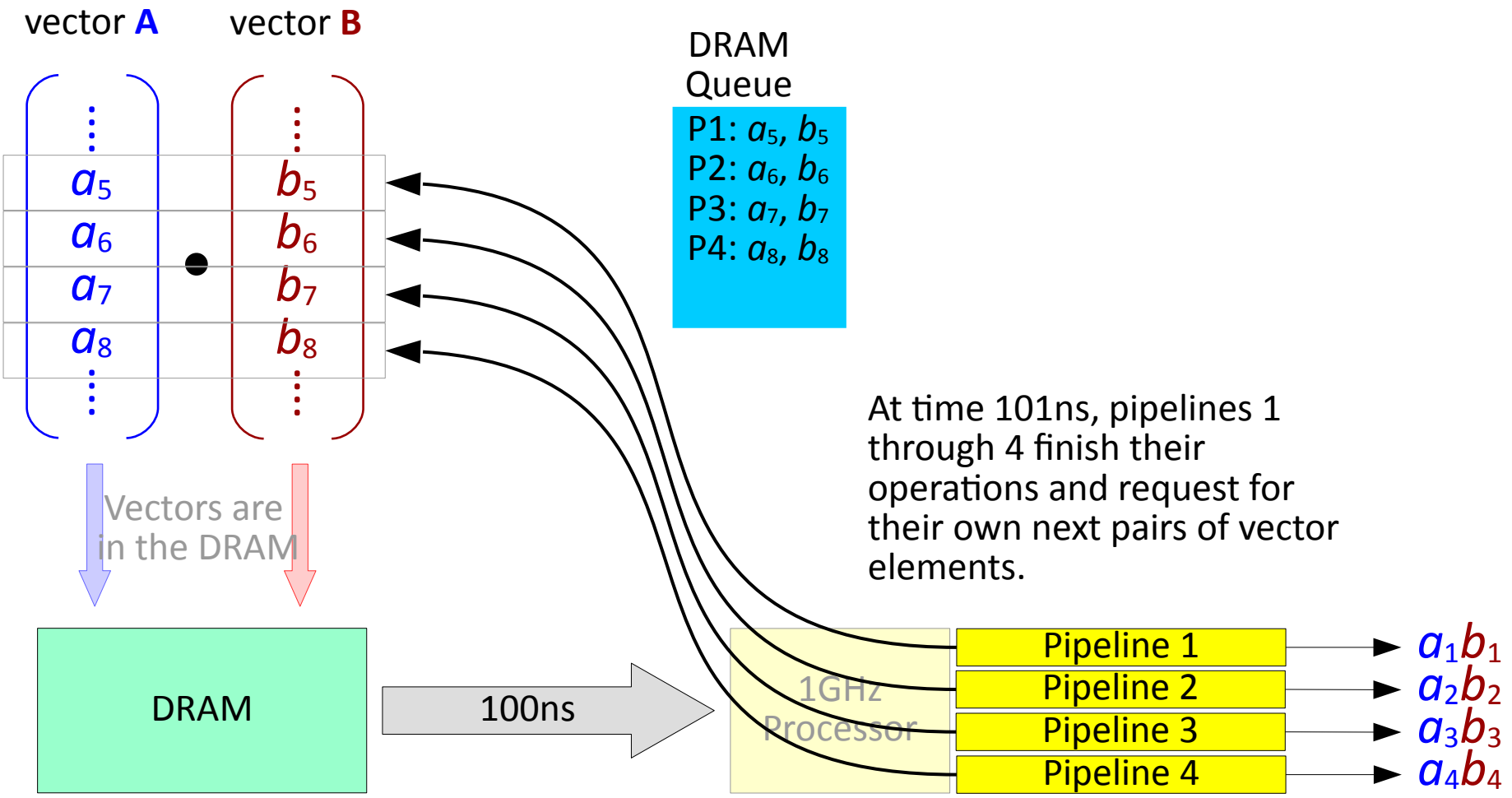


PROCESSOR RATING

- **Comparison**:
  - Theoretical/Peak Rating: 4GFLOPS
  - Actual Rating: 40MFLOPS
  - Only 1% of what we expect
  - Makes the 4 pipelines useful

PROCESSOR RATING

- **Comparison**:

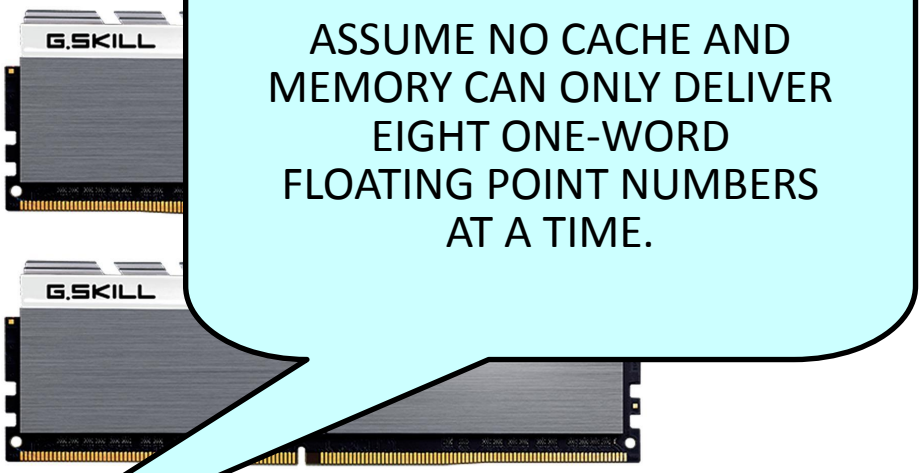
	Theoretical	Poor Bandwidth	Better Bandwidth
Rating	4GFLOPS	10MFLOPS	40MFLOPS
Expect	100%	0.25%	1%

Memory Latency = 100ns

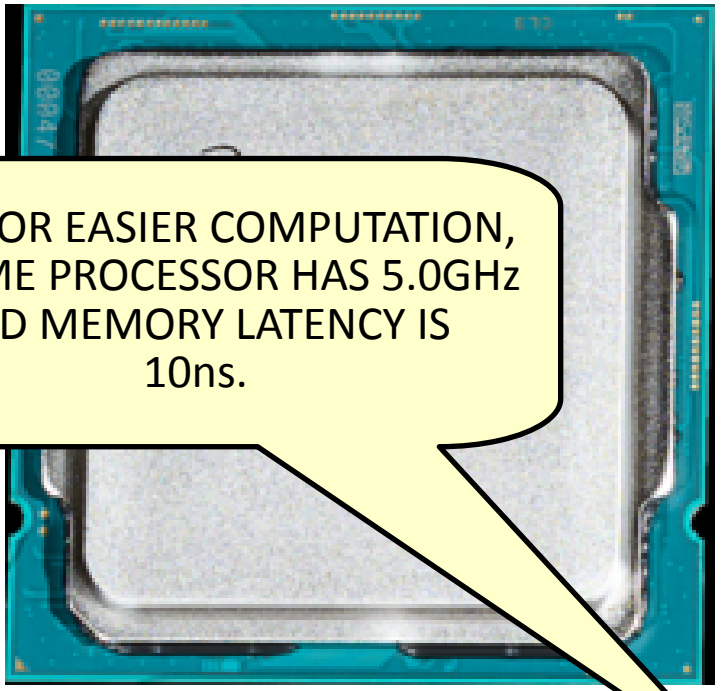
Poor Bandwidth: 2 double-precision floats
Better Bandwidth: 8 double-precision floats

SOME PRACTICAL STUFF

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



ASSUME NO CACHE AND MEMORY CAN ONLY DELIVER EIGHT 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 Cache