CprE 381: Computer Organization and Assembly Level Programming

Henry Duwe
Electrical and Computer Engineering
Iowa State University

Administrative

- Lab 1 is this week!
- Textbook
  - Great reference
  - Support lecture
    - Won't include stuff not touched on in lecture
  - Homework problems
- HW0 posted (due next Wed Jan 23)
- HW policies:
  - Published ~1 week prior to due date
  - Due on Canvas as **typeset** pdf
  - Due just before Midnight (**11:59pm**) on due date
    - HW solutions automatically released after due date → no late assignments accepted
  - 12 HWs: HW0 + highest 6 of HW1-10 + HW11 counted
- OH: 321 Durham (3pm Wed, 1:30pm Friday) starting **today**

Review

- Processors everywhere
- Processors generally look the same at high-level
- Computer Architecture != Magic

- Relevant to all, even programmers

Concept Map In-Class Assessment

- Help you connect **new information** to your existing knowledge
- Deepen **understanding** and **comprehension**
- Important for this class:
  - Organize the relatively broad topics covered in lecture and homework
  - Help me understand how you are conceptualizing the content of the course
  - Will continue to use during exam reviews

Concept Map In-Class Assessment

1. Brainstorm concepts relating to main concept
2. Organize into categories
3. Draw arrows between related categories (and main concept)
   - Label the connections as well

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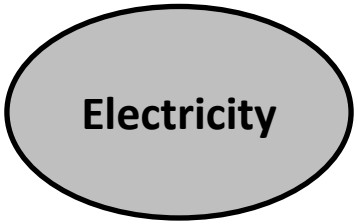

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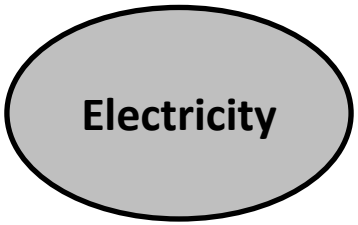
- Energy
- Lightning
- Generator
- Solar panel
- Power
- Computers



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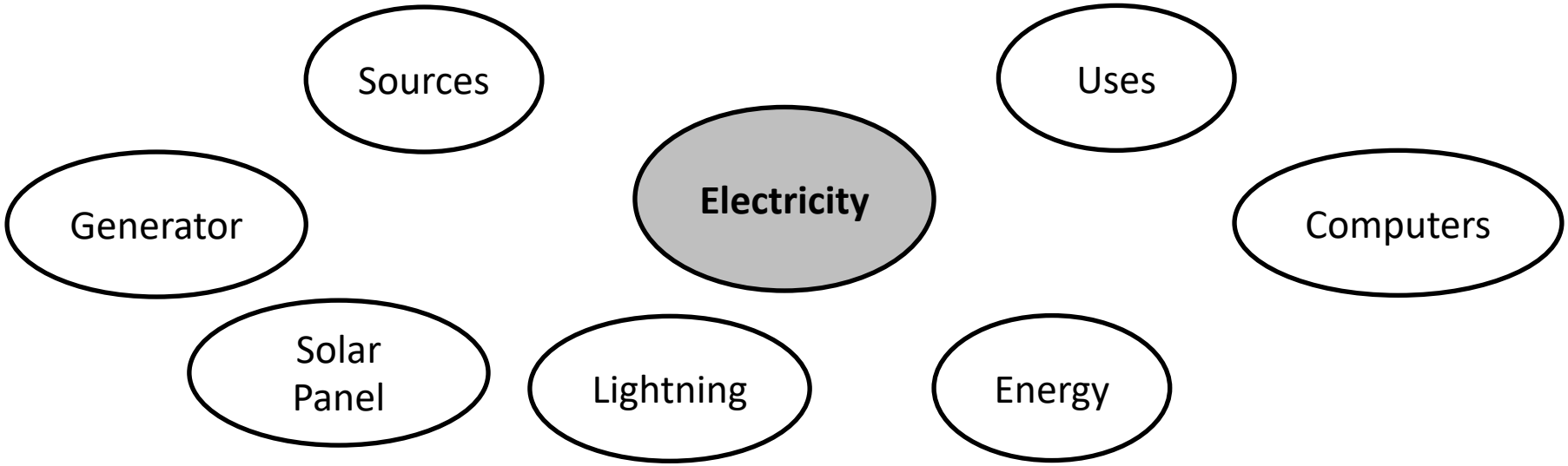

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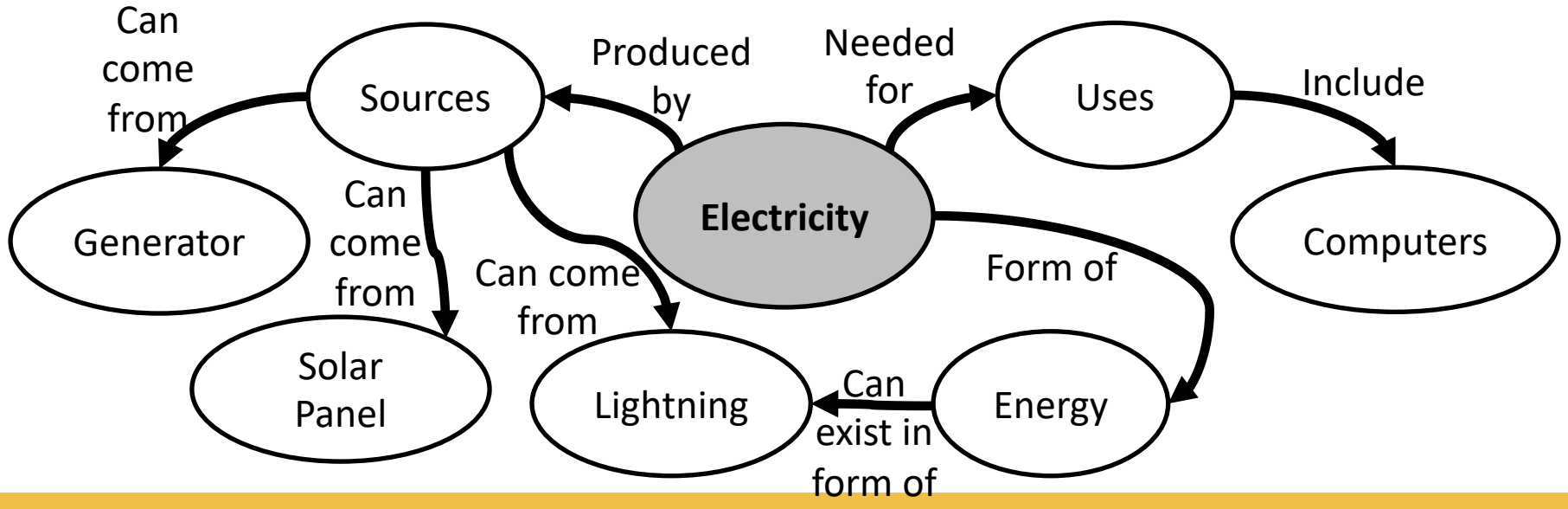

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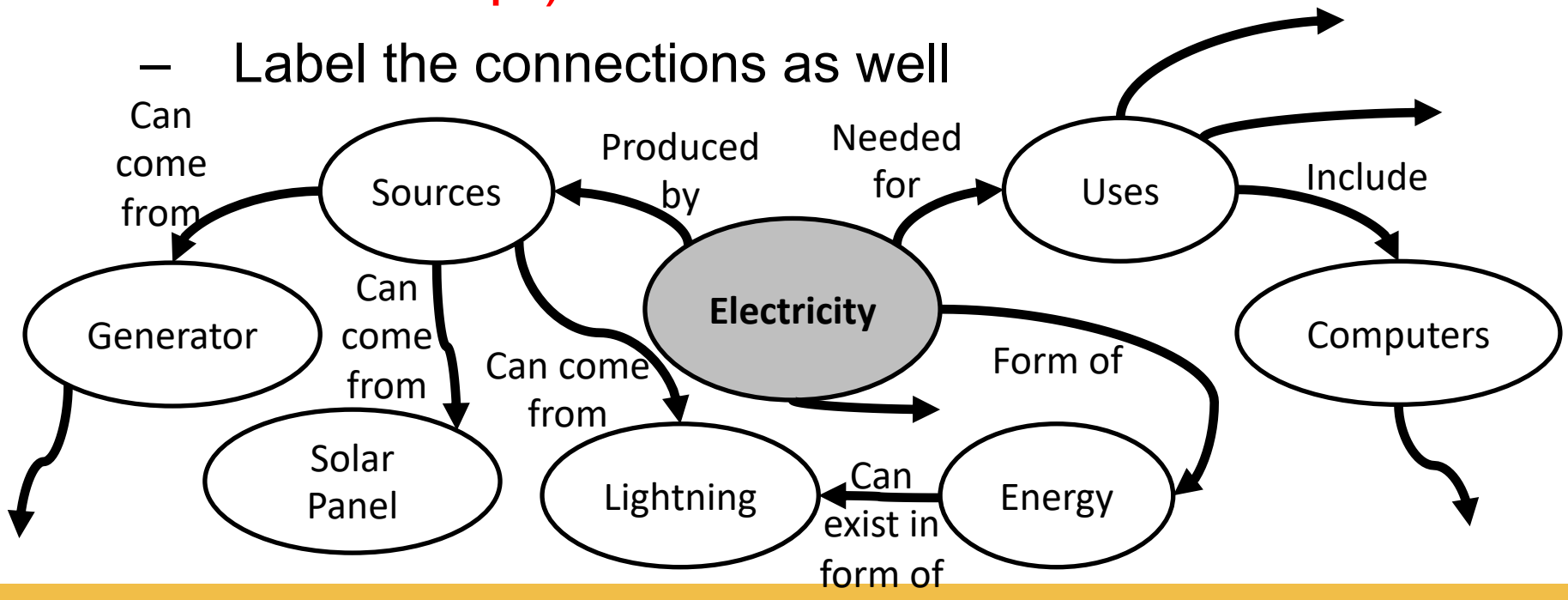

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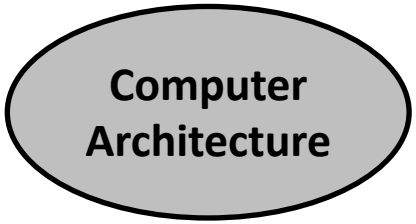
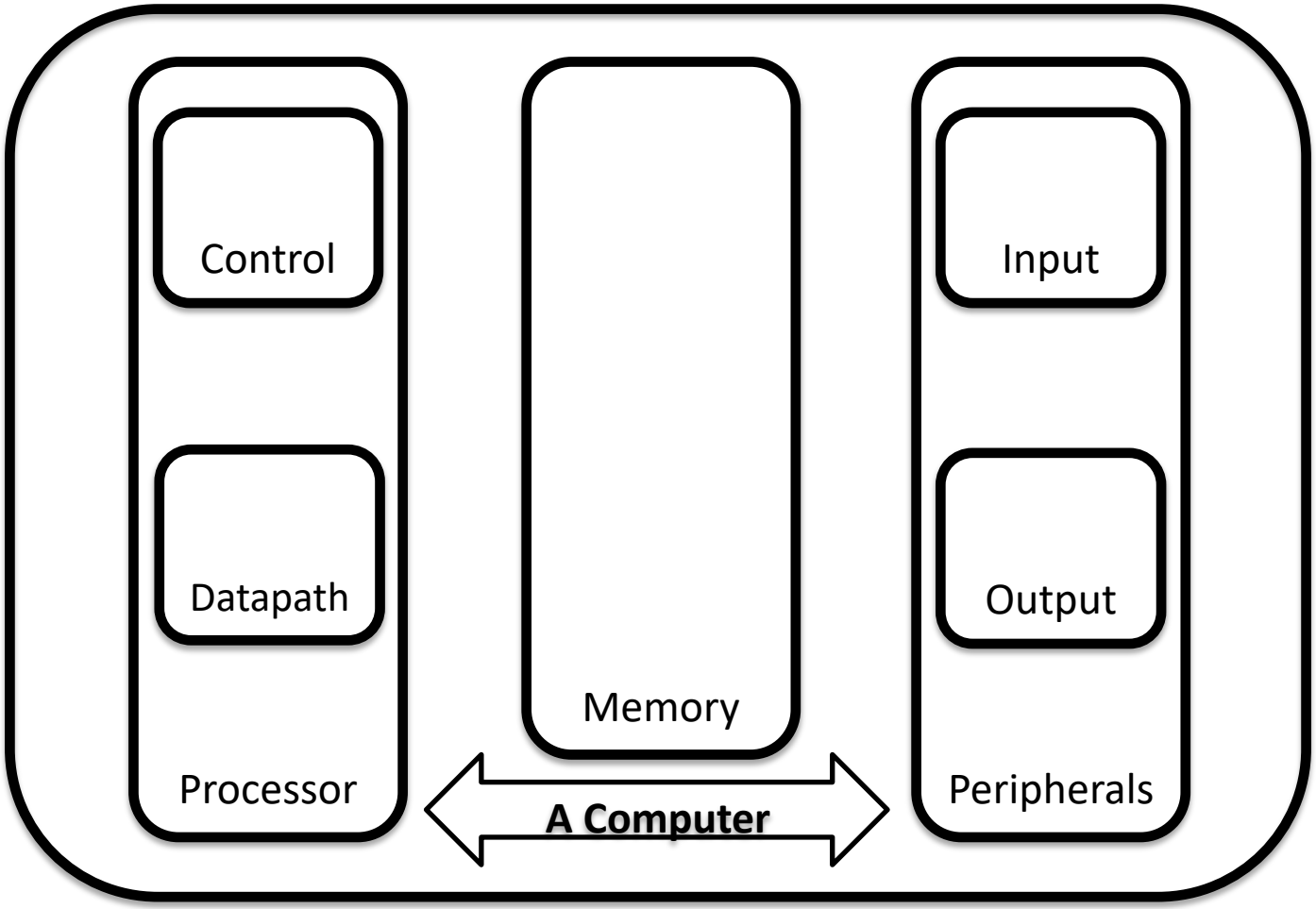
Your 

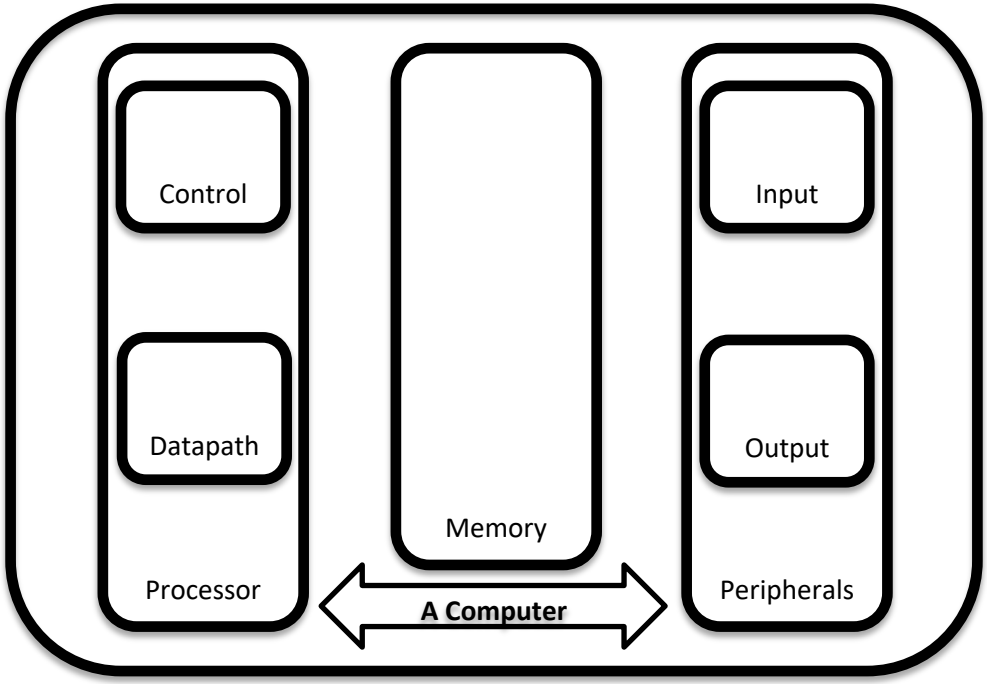
turn

Computers


Control
Datapath
Processor
Memory
Input
Output
Peripherals
A Computer

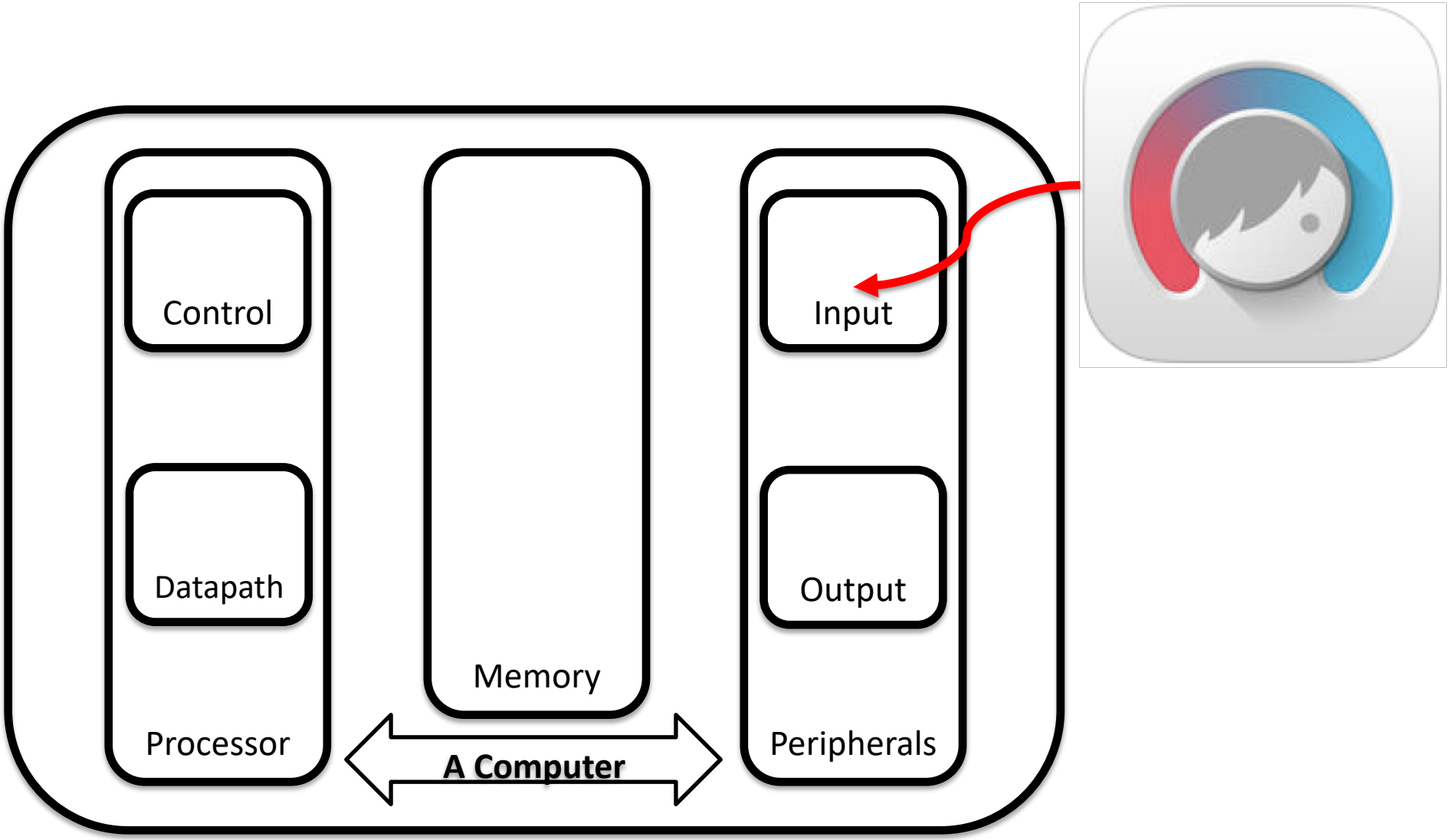
Stored Program Computers

- A la von Neumann Model / Architecture



- Two key properties:
  - Instructions stored (as data) in a linear memory array
  - Sequential instruction processing

Input Device Inputs Object Code



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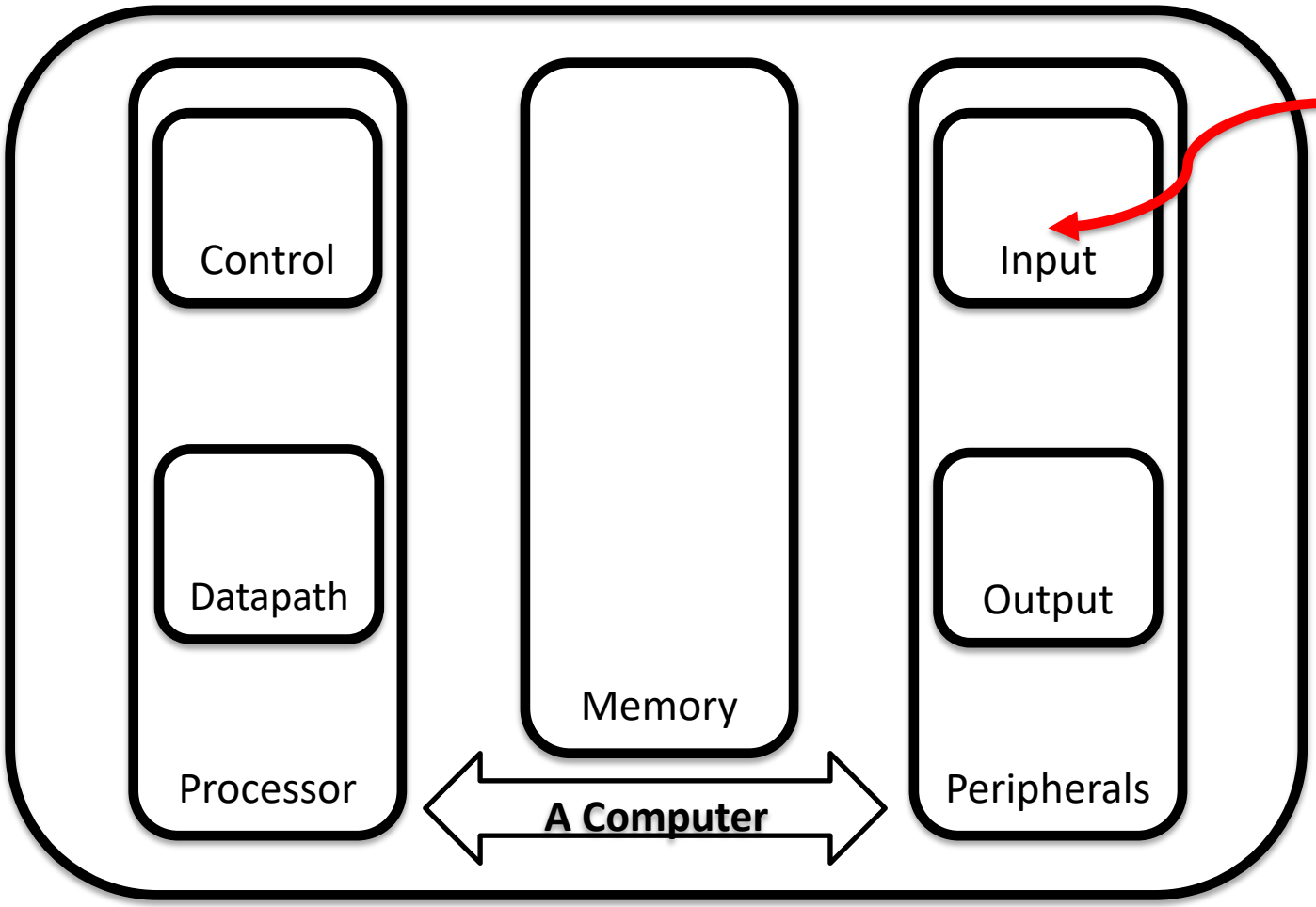

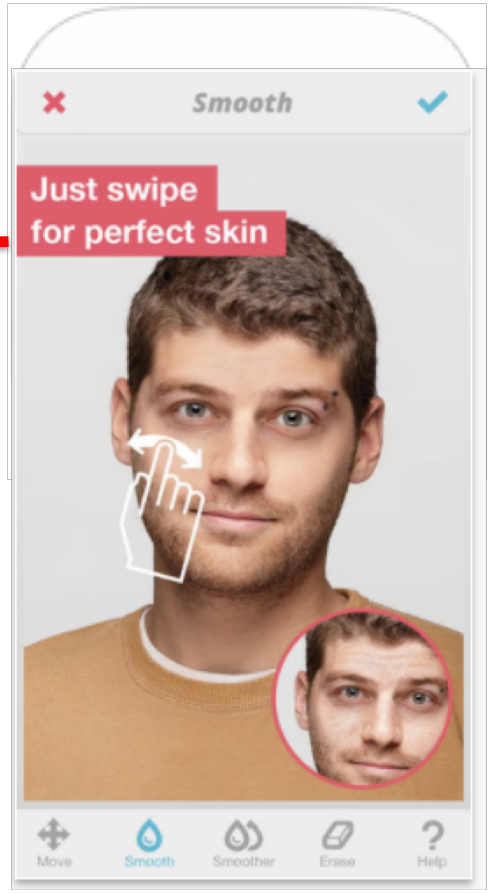

Most downloaded paid app on iOS 2017

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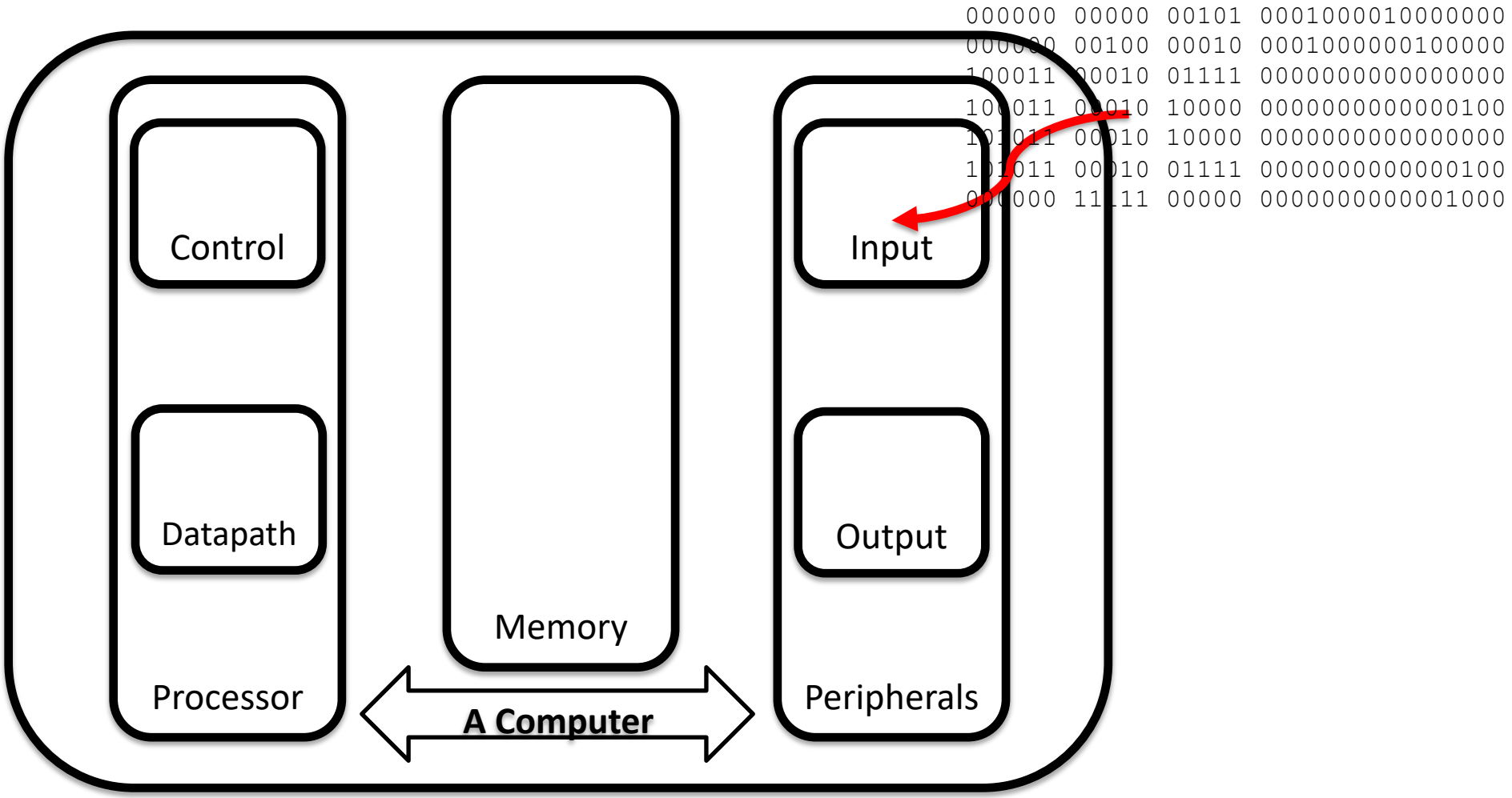

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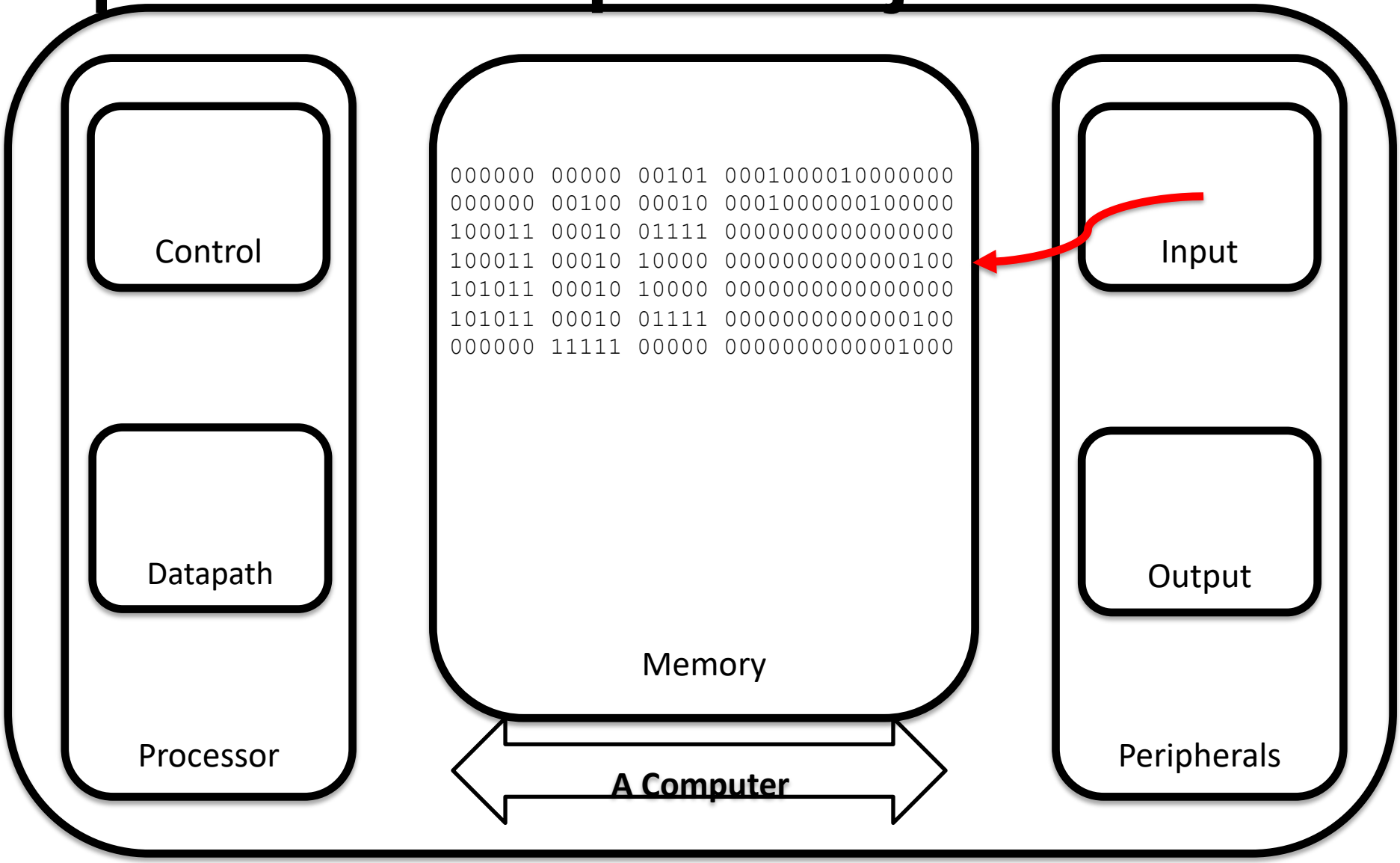

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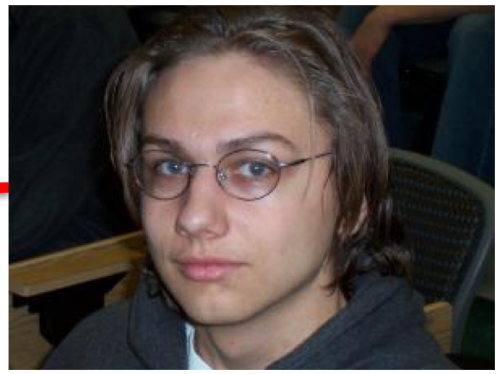

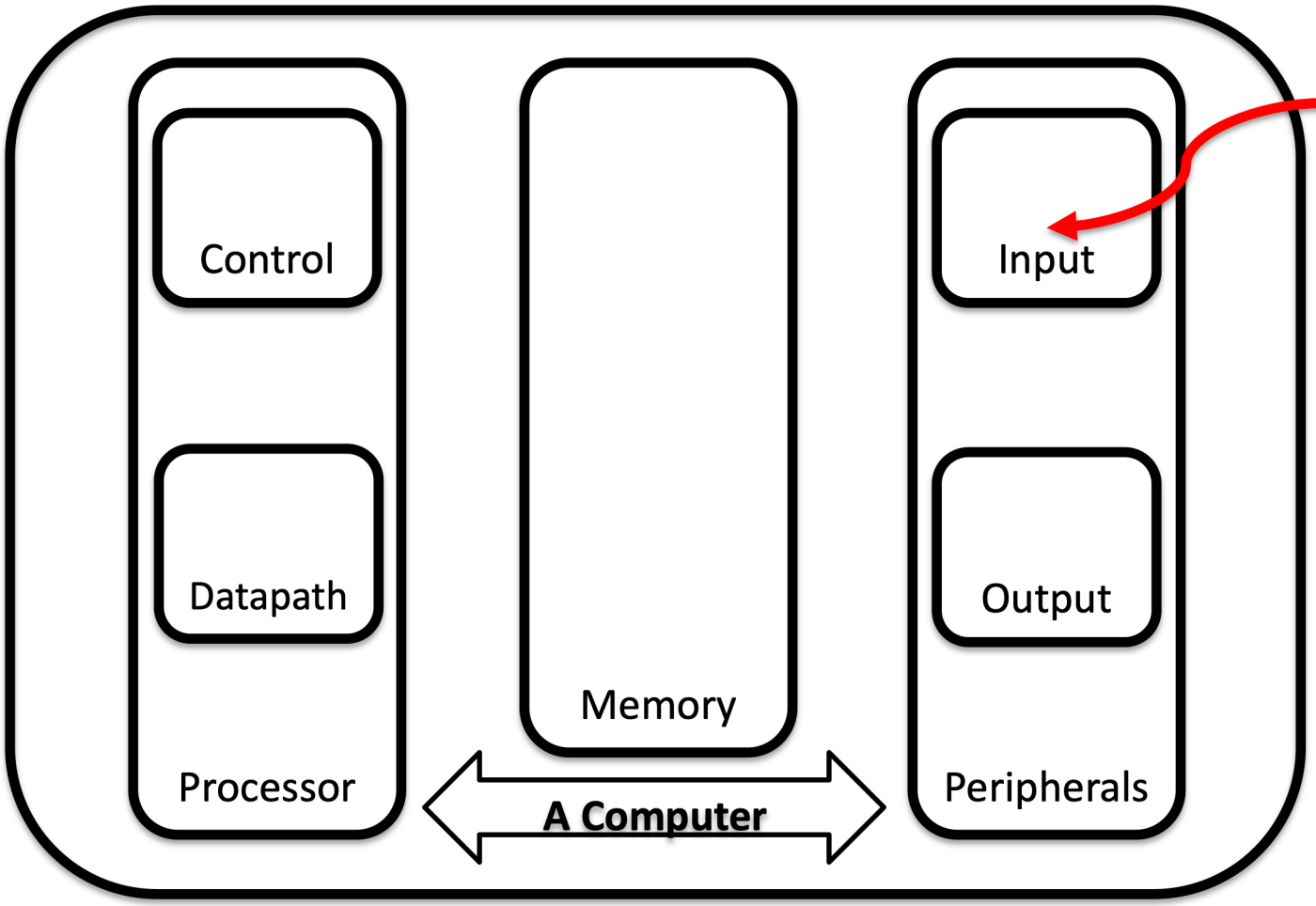

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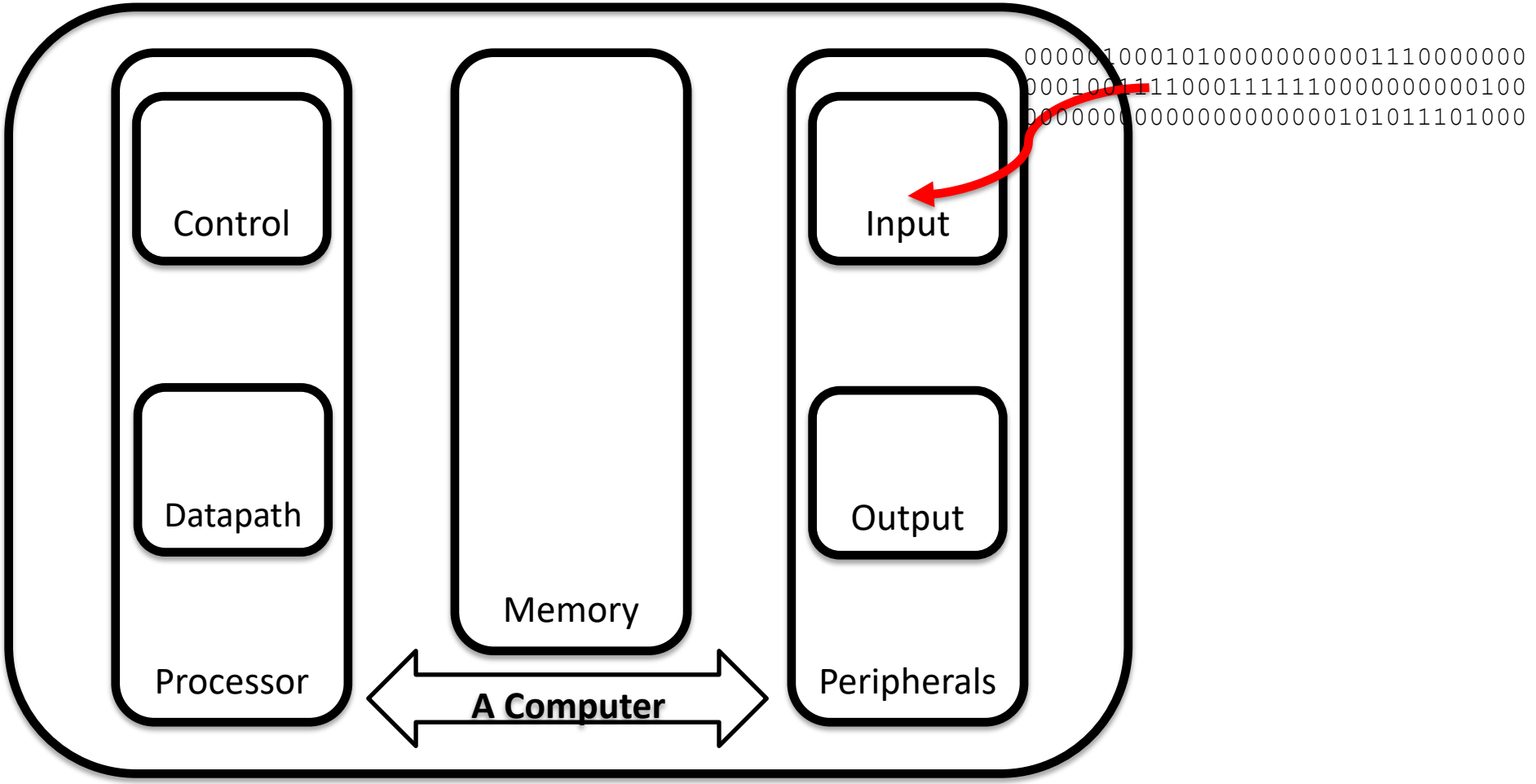

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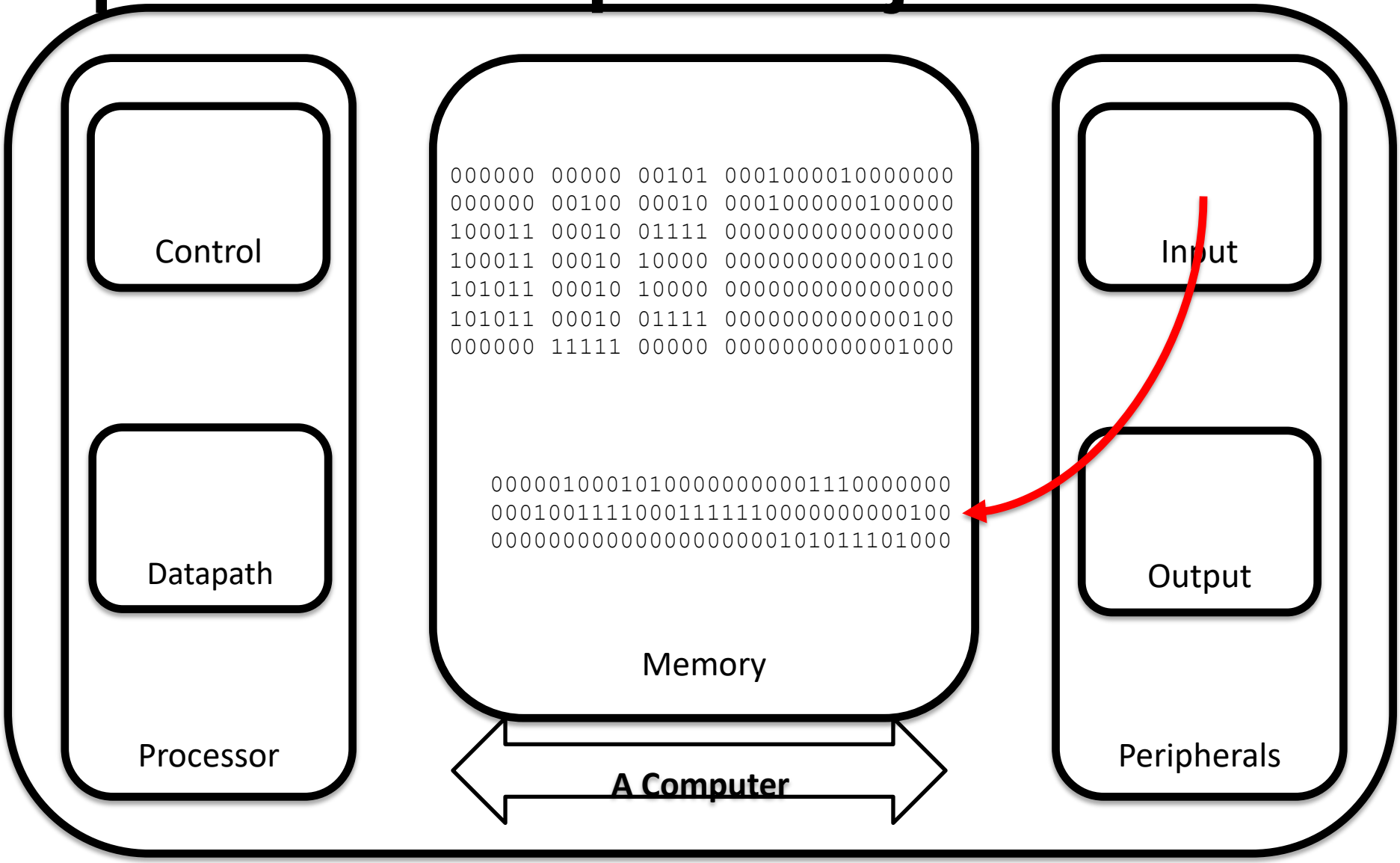
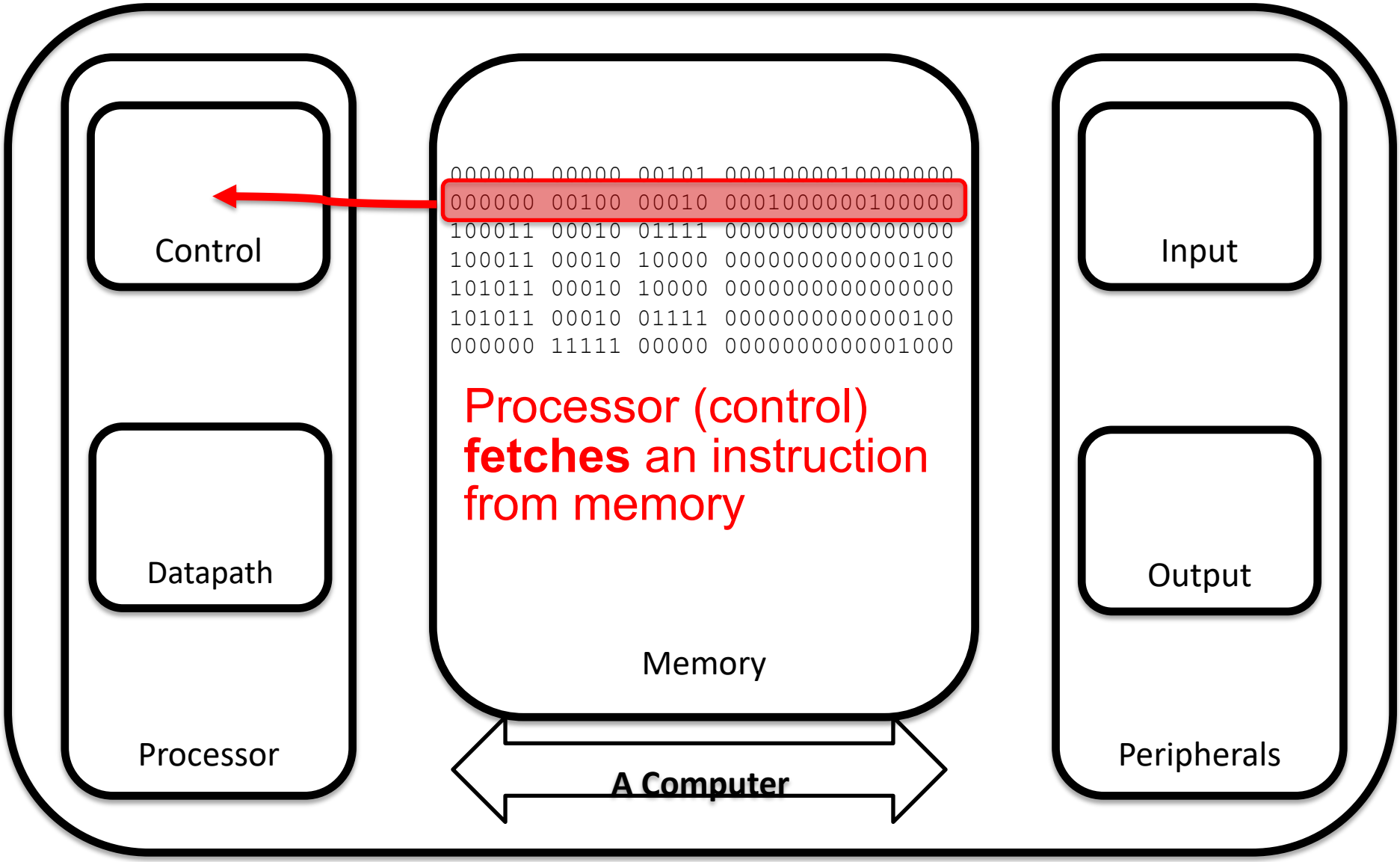
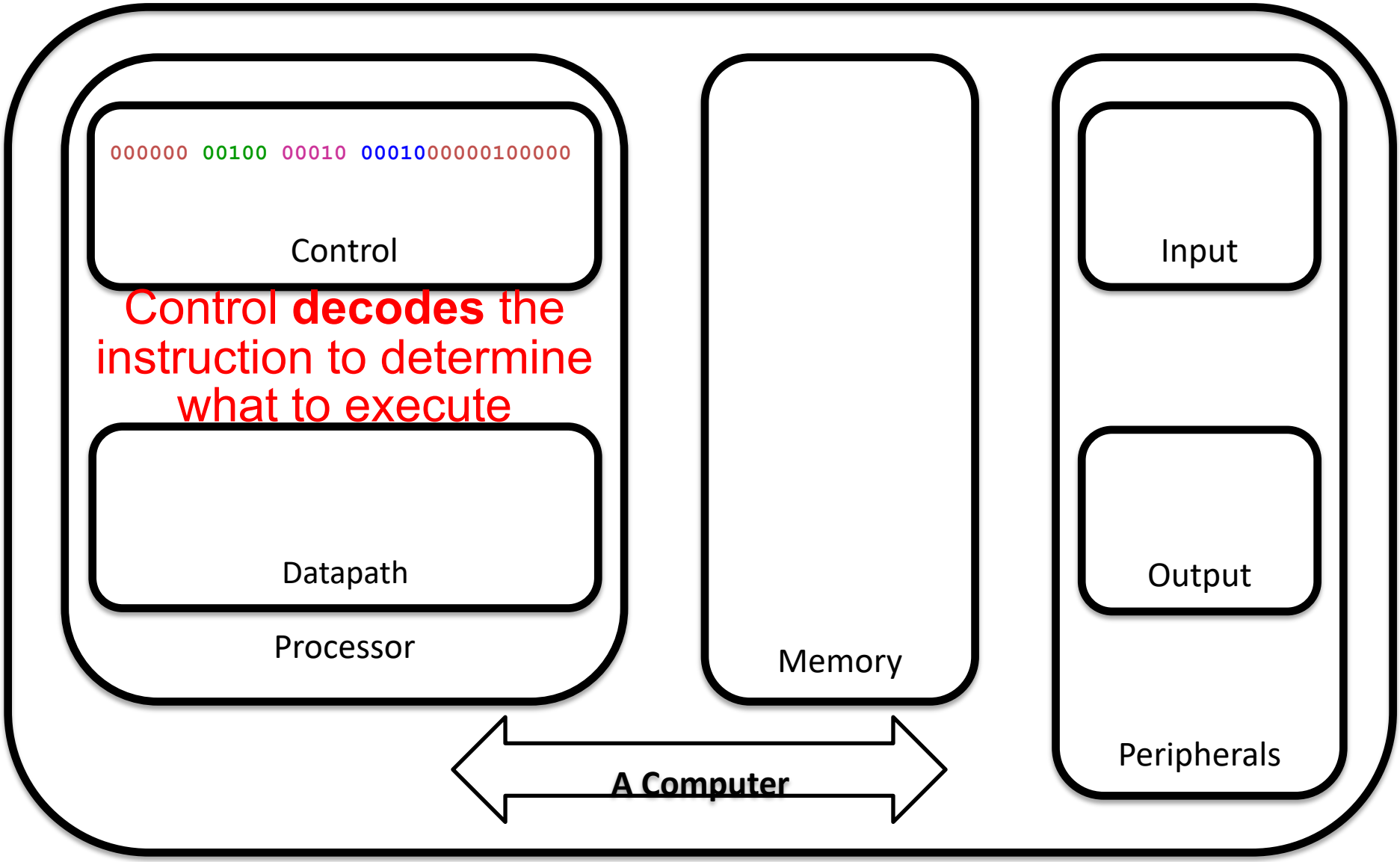


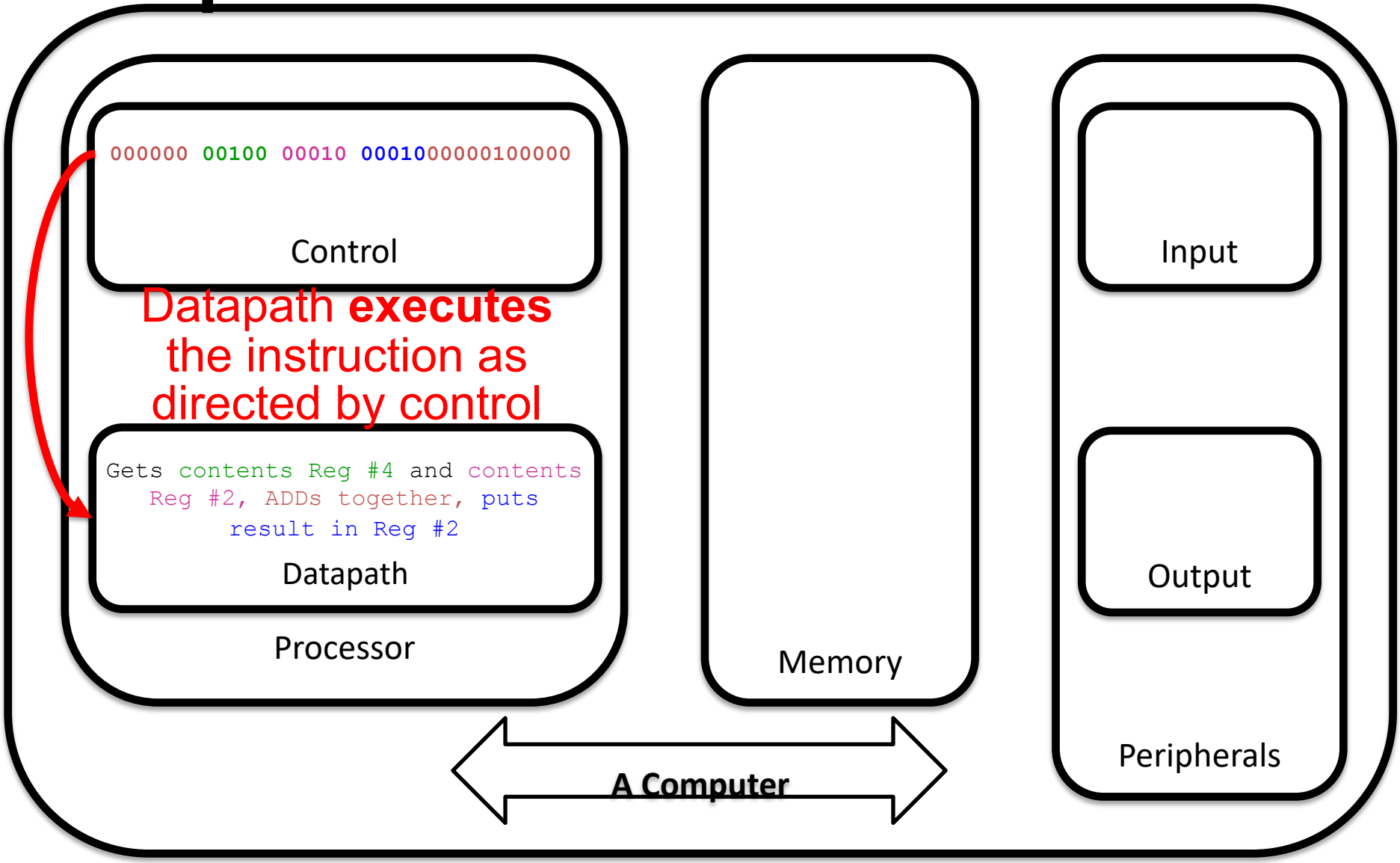
Instruction Fetch



Control Decodes the Instruction



Datapath Executes the Instruction



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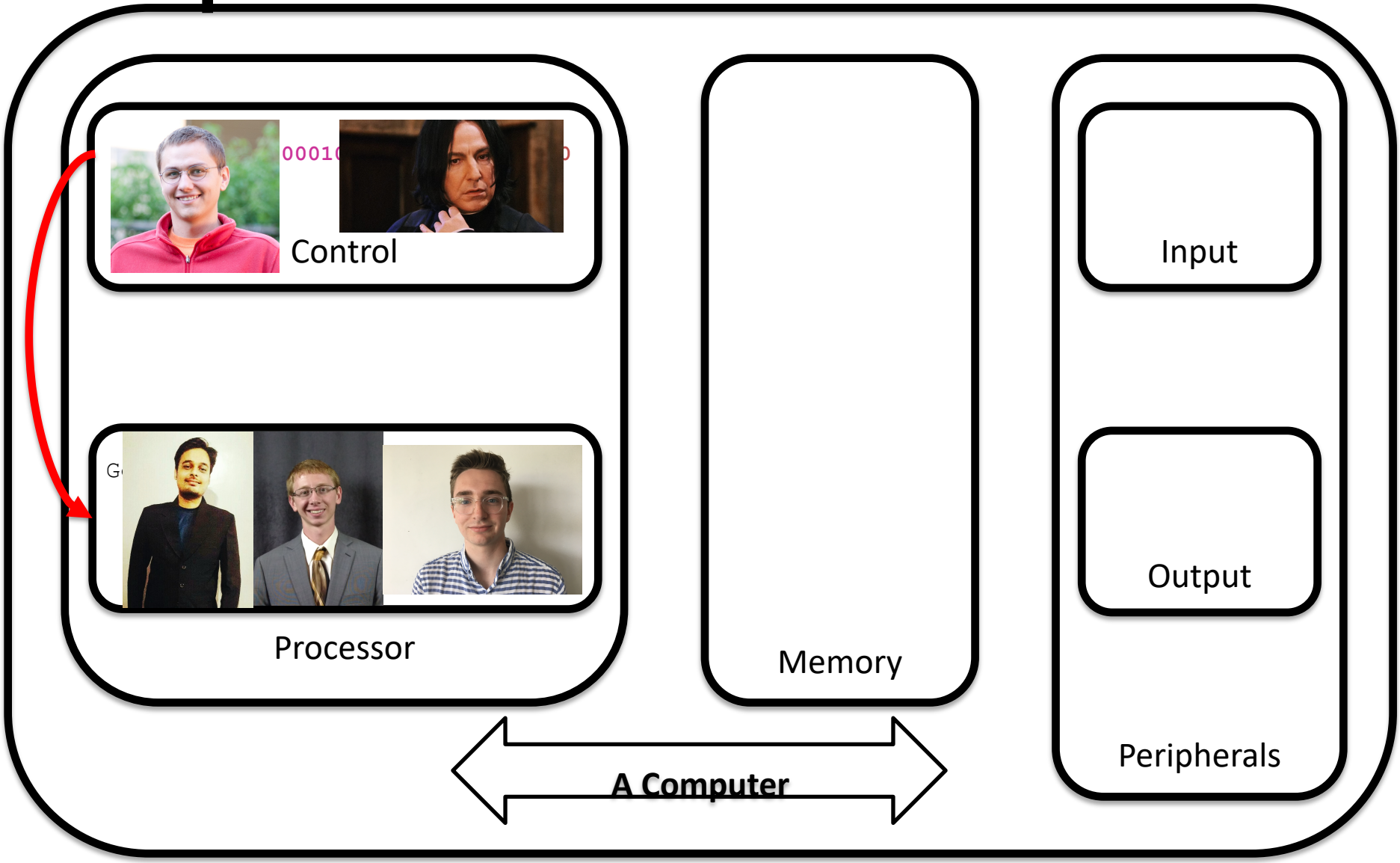
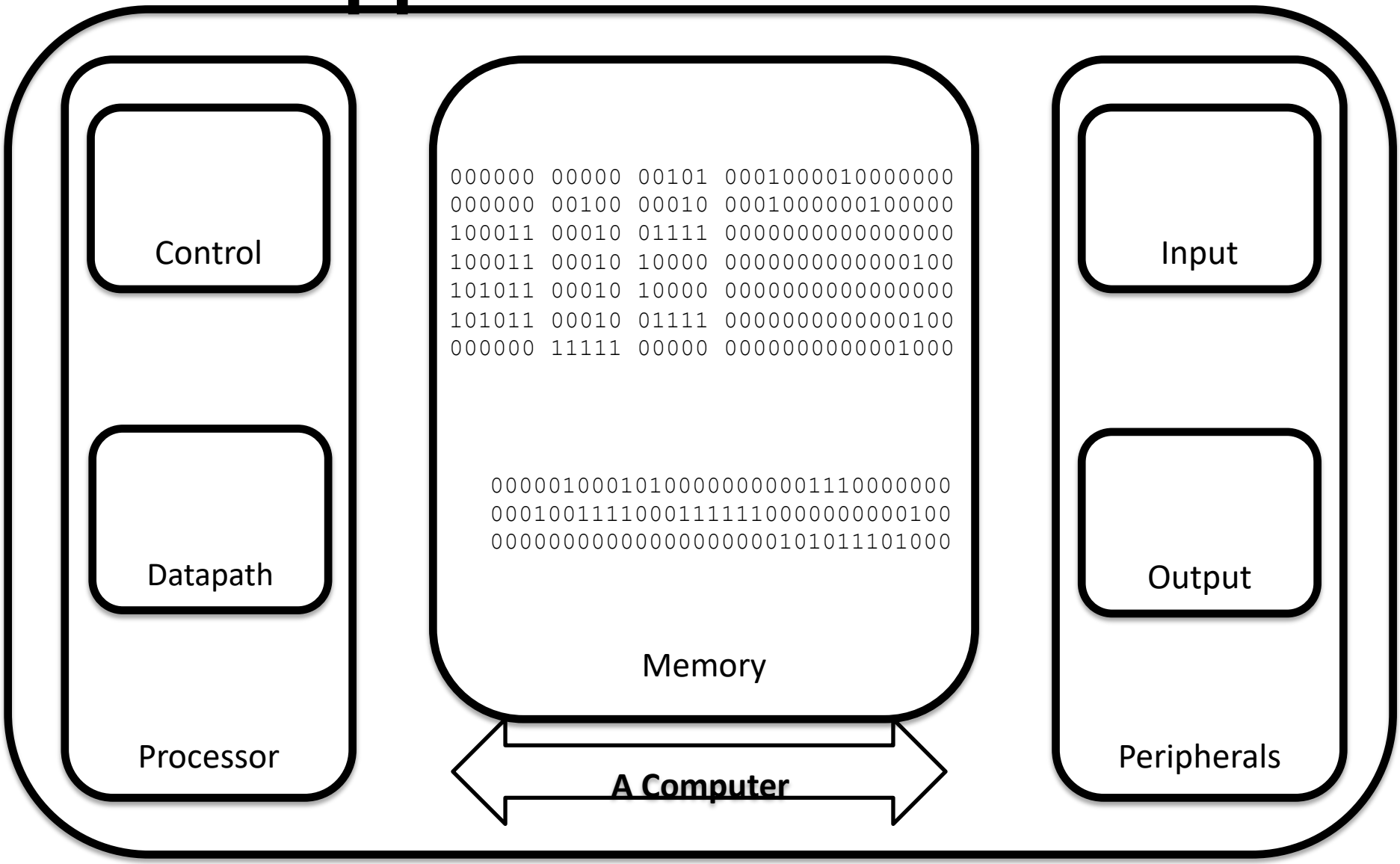


What Happens Next?



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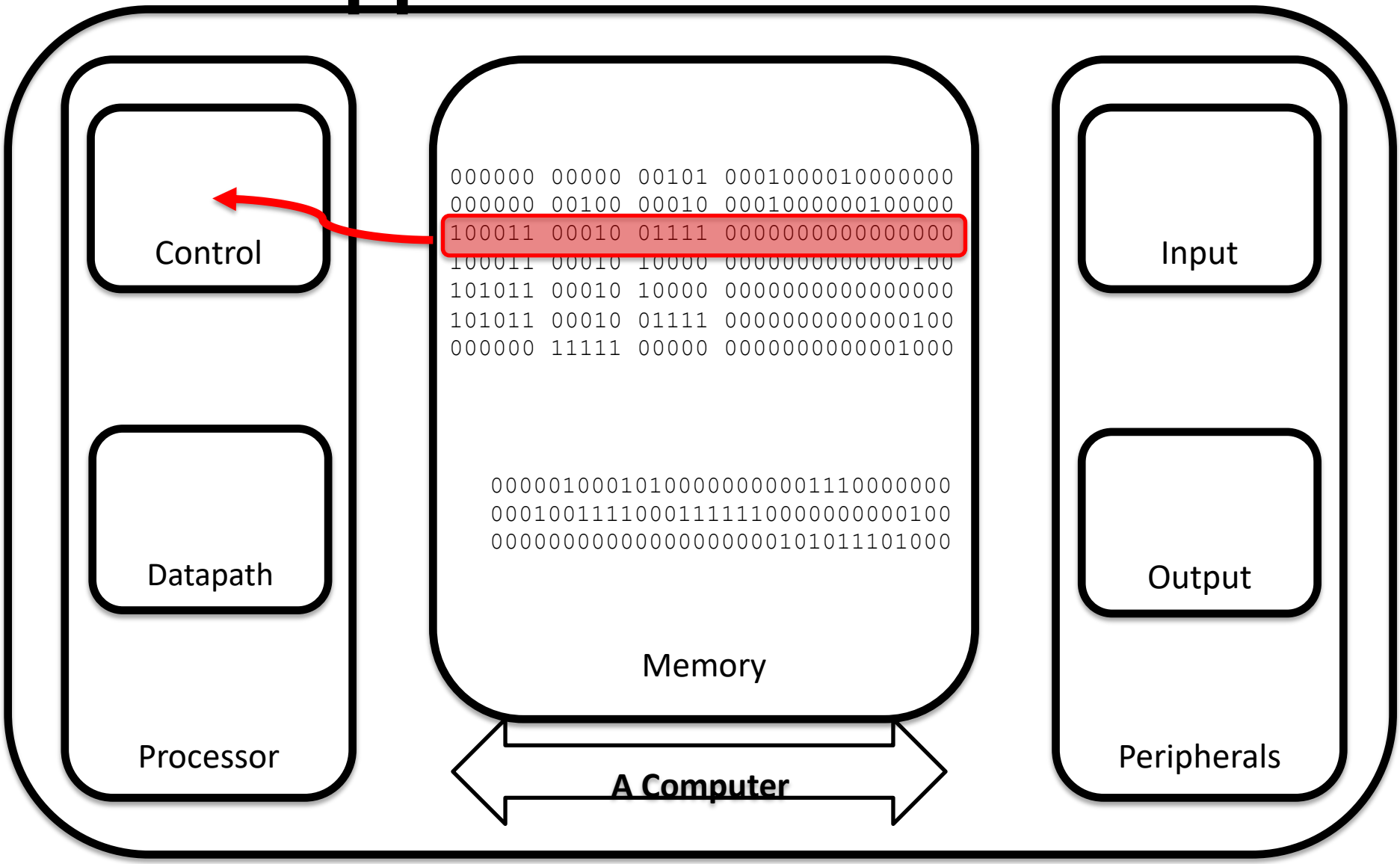

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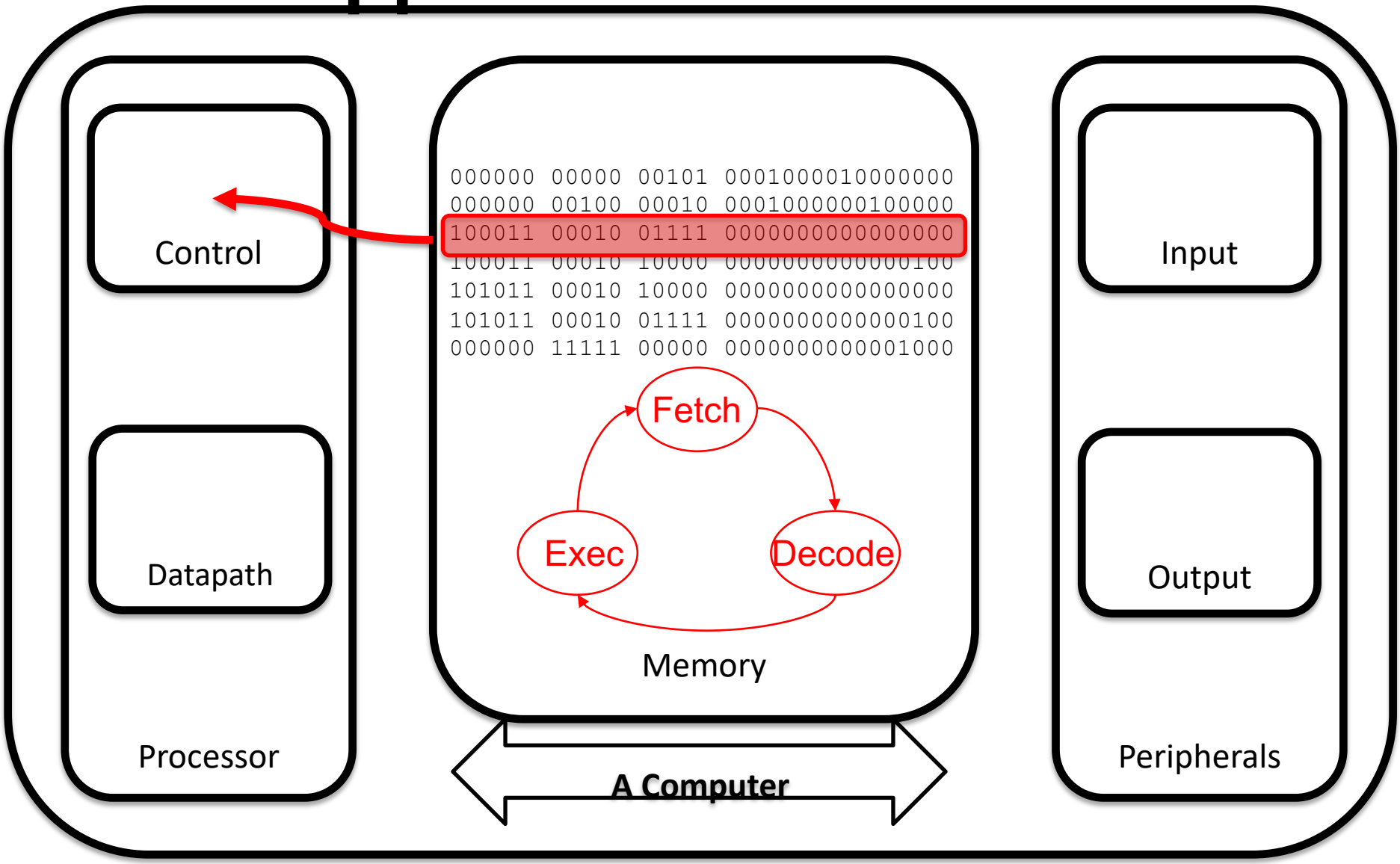

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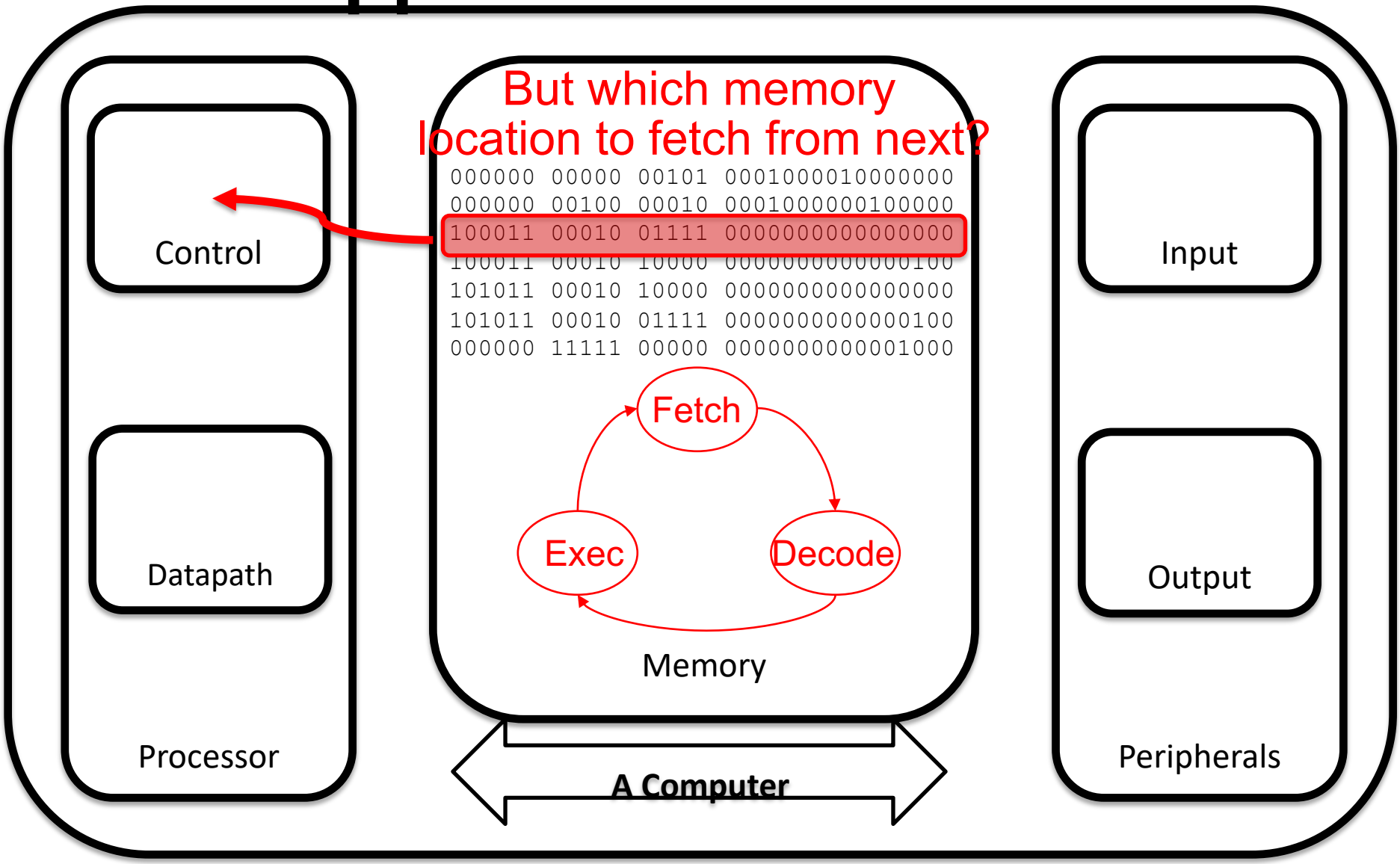
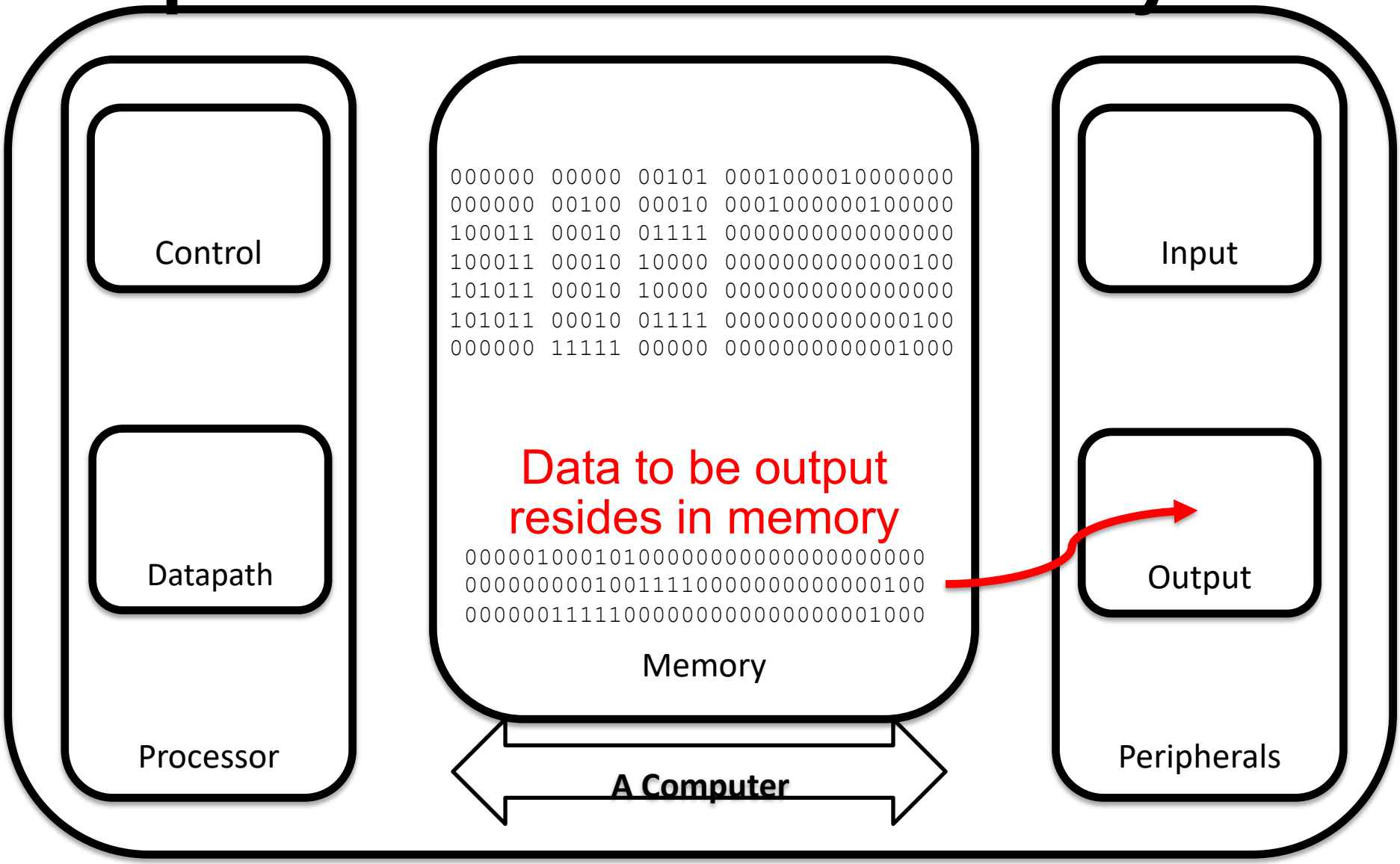


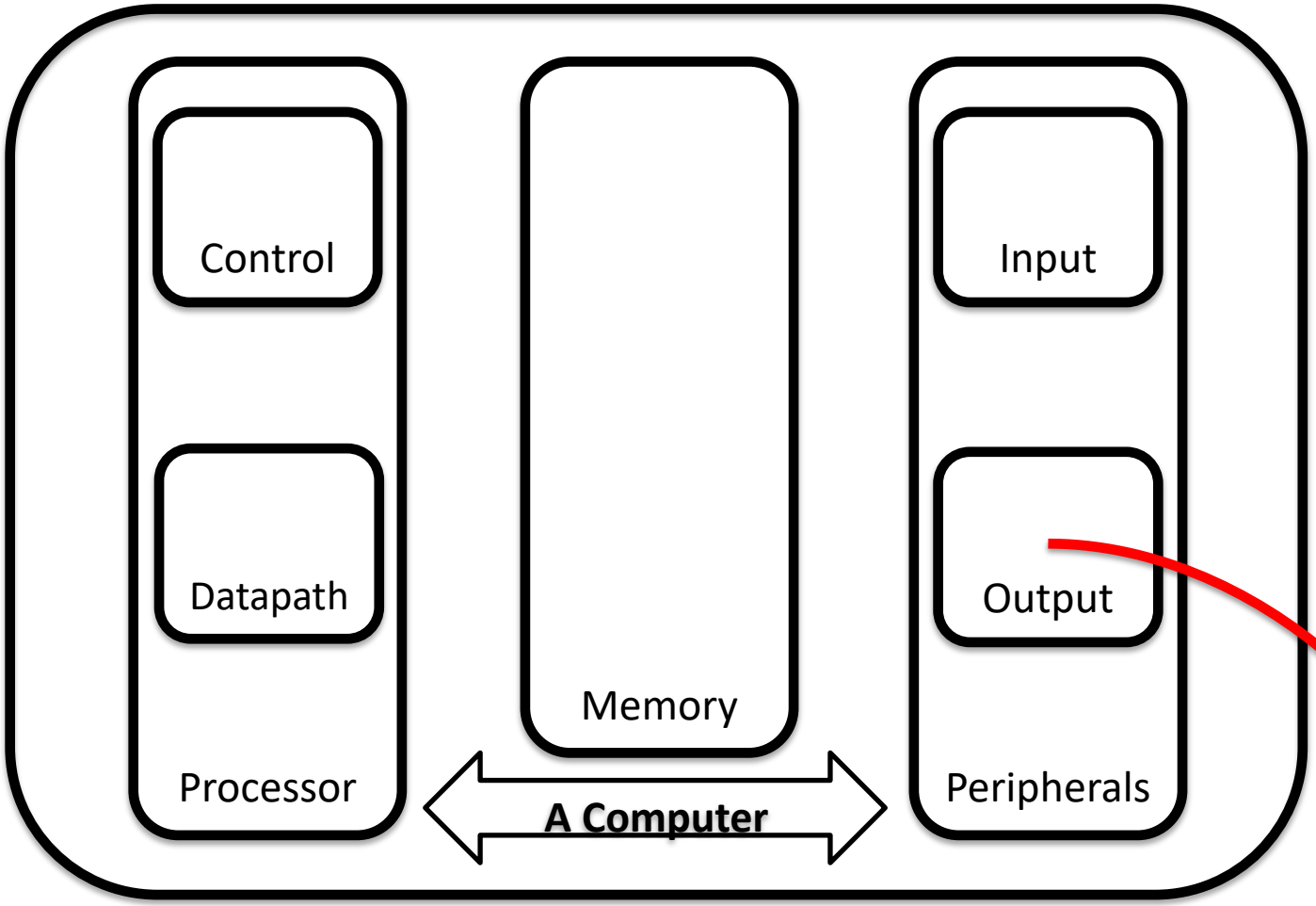
Processor Organization

- Control needs to have circuitry to
  - Decide which is the next instruction and input it from memory
  - Decode the instruction
  - Issue signals that control the way information flows between datapath components
  - Control what operations the datapath's functional units perform
- Datapath needs to have circuitry to
  - Execute instructions - functional units (e.g., adder) and storage locations (e.g., register file)
  - Interconnect the functional units so that the instructions can be executed as required
  - Load data from and store data to memory

Output Data Stored in Memory

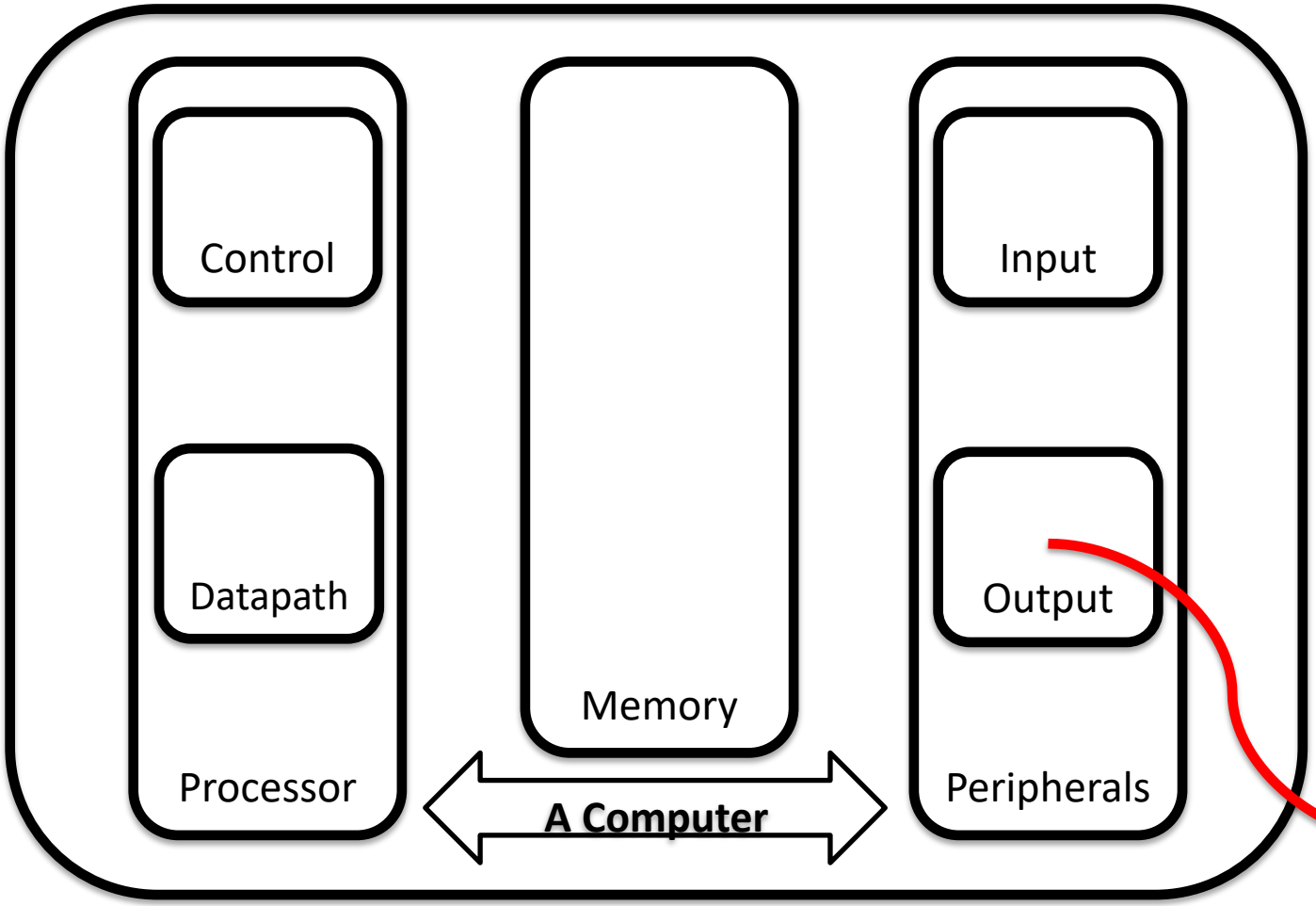


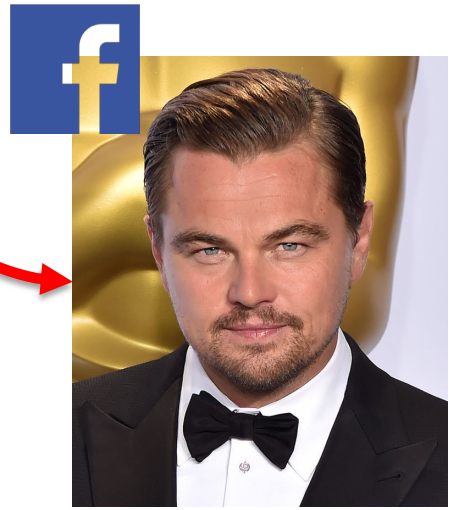
Output Device Outputs Data




```
00000100010100000000000000000000
00000000010011110000000000000100
00000011111000000000000000001000
```

Output Device Outputs Data





Machine Organization Summary

- Capabilities and performance characteristics of the principal Functional Units (FUs)
  - e.g., register file, ALU, multiplexors, memories, ...
- The ways those FUs are interconnected
  - e.g., buses
- Logic and means by which information flow between FUs is controlled
- **R**egister **T**ransfer **L**evel (**RTL**) machine description
- The machine's **I**nstruction **S**et **A**rchitecture (**ISA**)

Below the Program

- High-level language program (in C)

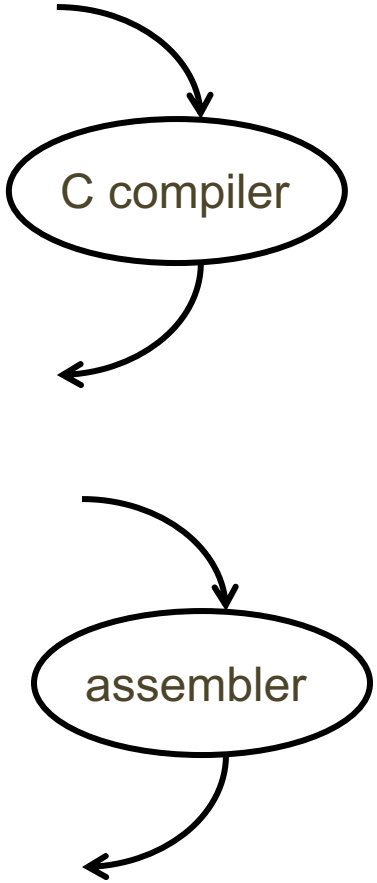
```
swap (int v[], int k)
. . .
```

- Assembly language program (for MIPS)

```
swap:   sll   $2, $5, 2
        add   $2, $4, $2
        lw    $15, 0($2)
        lw    $16, 4($2)
        sw    $16, 0($2)
        sw    $15, 4($2)
        jr    $31
```

- Machine (object) code (for MIPS)

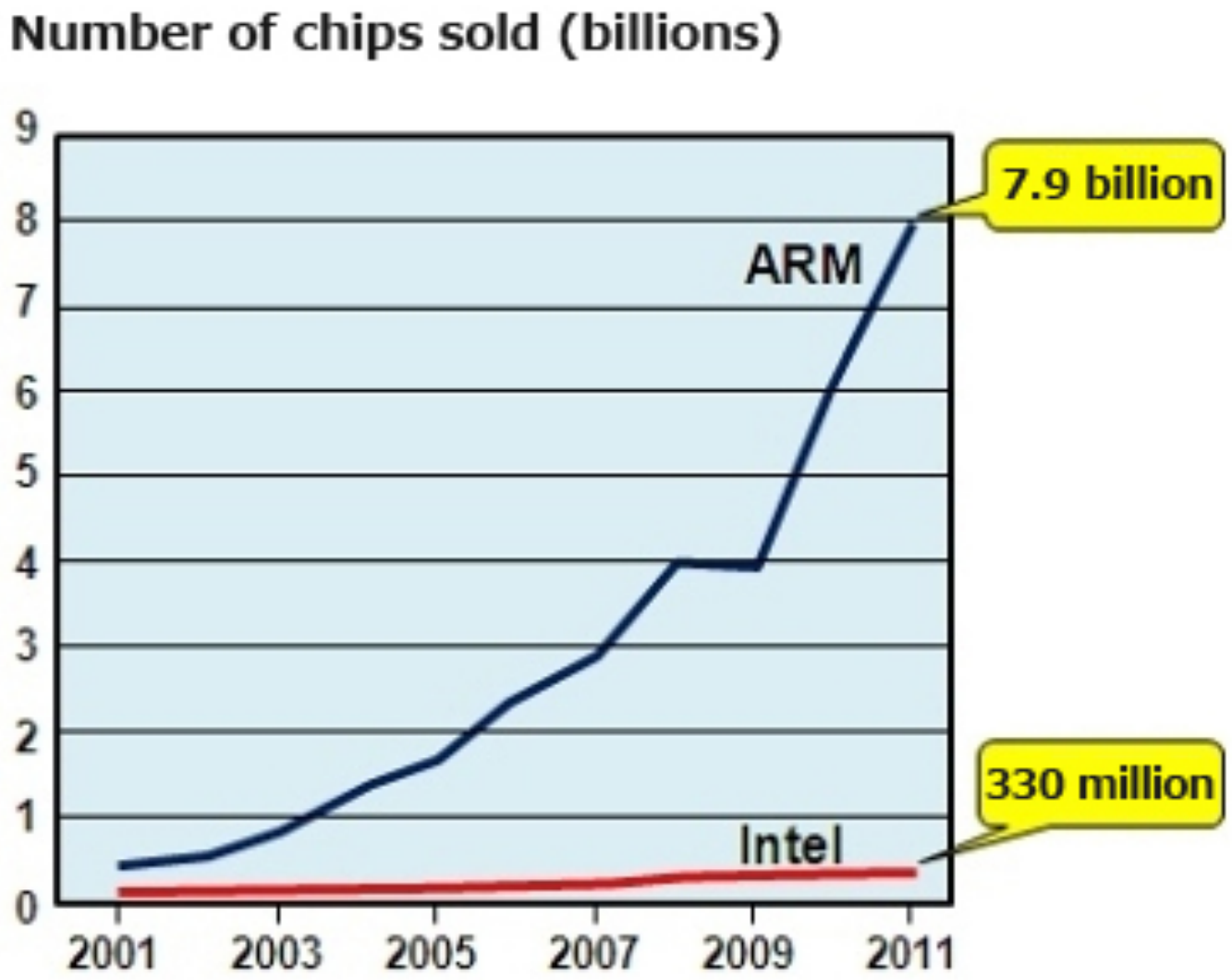
```
000000 00000 00101 00010000010000000
000000 00100 00010 00010000000100000
100011 00010 01111 00000000000000000
100011 00010 10000 00000000000000100
101011 00010 10000 00000000000000000
101011 00010 01111 00000000000000100
000000 11111 00000 00000000000001000
```



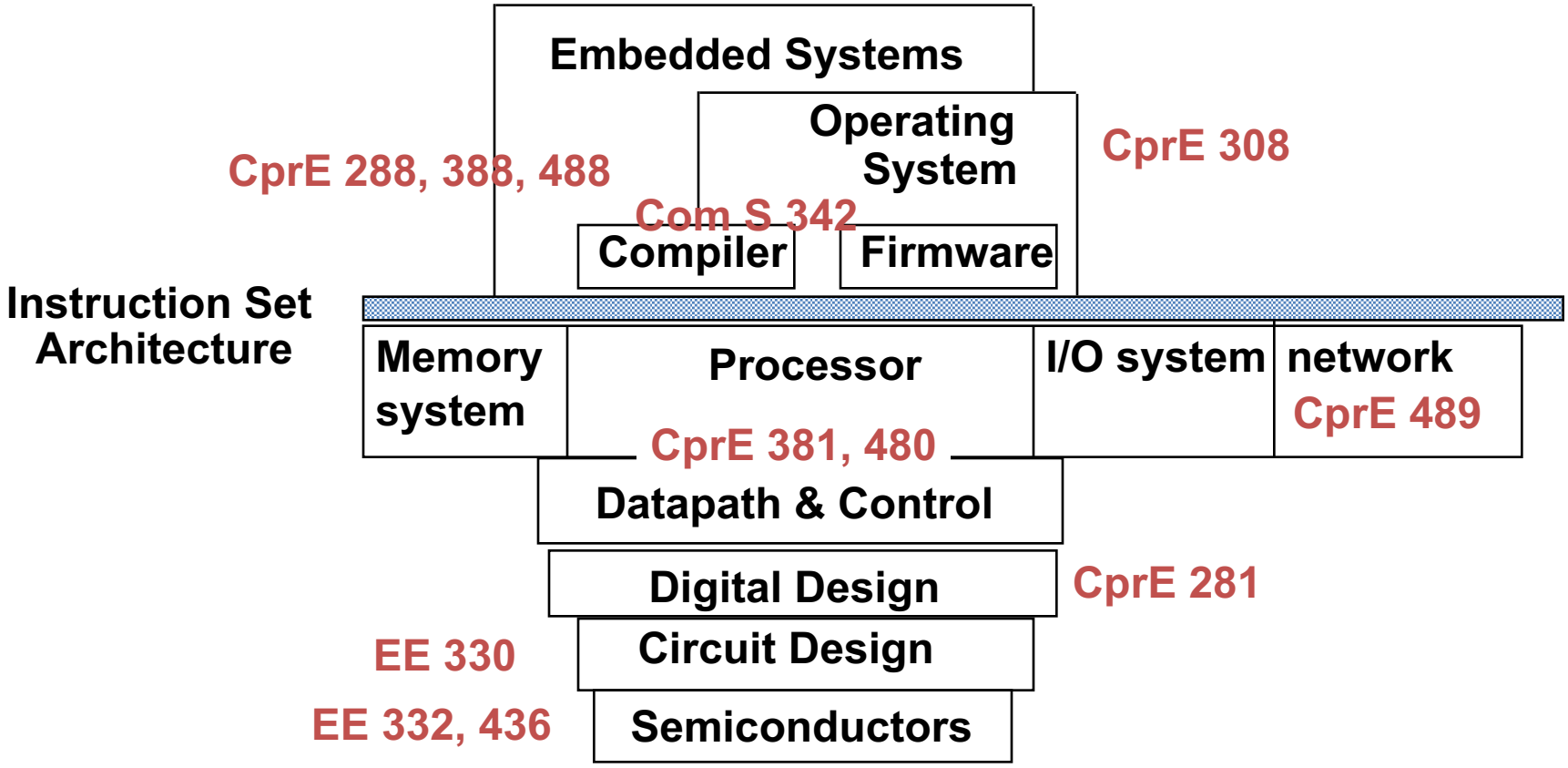
Advantages of Higher-Level Languages?

- Higher-level languages:
  - Allow the programmer to think in a **more natural language** and for their intended use (Fortran for scientific computation, C# for desktop GUI applications, Scheme for symbol manipulation, Javascript for web programming, …)
  - Improve **programmer productivity** – more understandable code that is easier to debug and validate
  - Improve **program maintainability**
  - Allow programs to be **independent of the computer** on which they are developed (compilers and assemblers can translate high-level language programs to the binary instructions of any machine)
  - Emergence of **optimizing compilers** that produce very efficient assembly code optimized for the target machine
- As a result, very little programming is done today at the assembler level

ISA Sales Trends

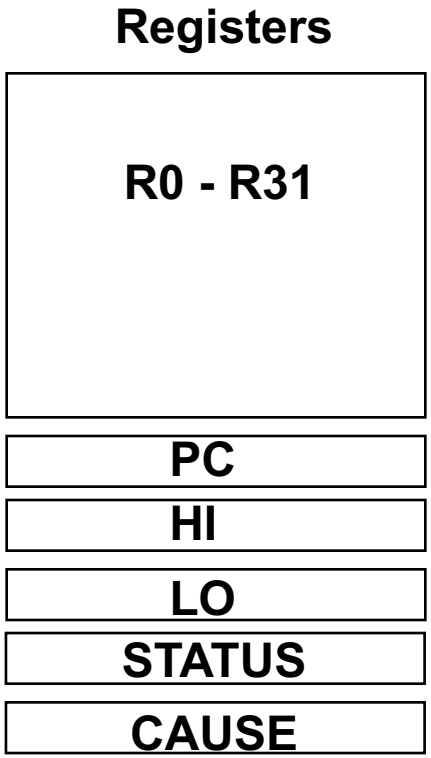


How do the Pieces Fit Together?

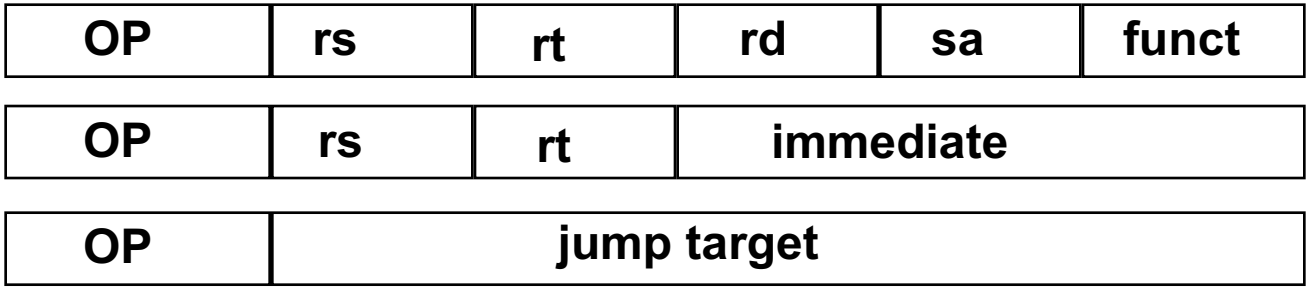


Preview: the MIPS ISA

- Instruction Categories
  - Load/Store
  - Computational
  - Jump and Branch
  - Floating Point
    - coprocessor
  - Memory Management
  - Special



3 Instruction Formats: all 32 bits wide



Acknowledgments

- These slides contain material developed and copyright by:
  - Joe Zambreno (Iowa State)
  - David Patterson (UC Berkeley)
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  - Krste Asanović (UC Berkeley)