Computer Organization and Architecture

Chapter 7

Instruction Sets: Characteristics and Functions

What is an Instruction Set?

- The complete collection of instructions that are understood by a CPU
- Machine Code
- Binary
- Usually represented by assembly codes

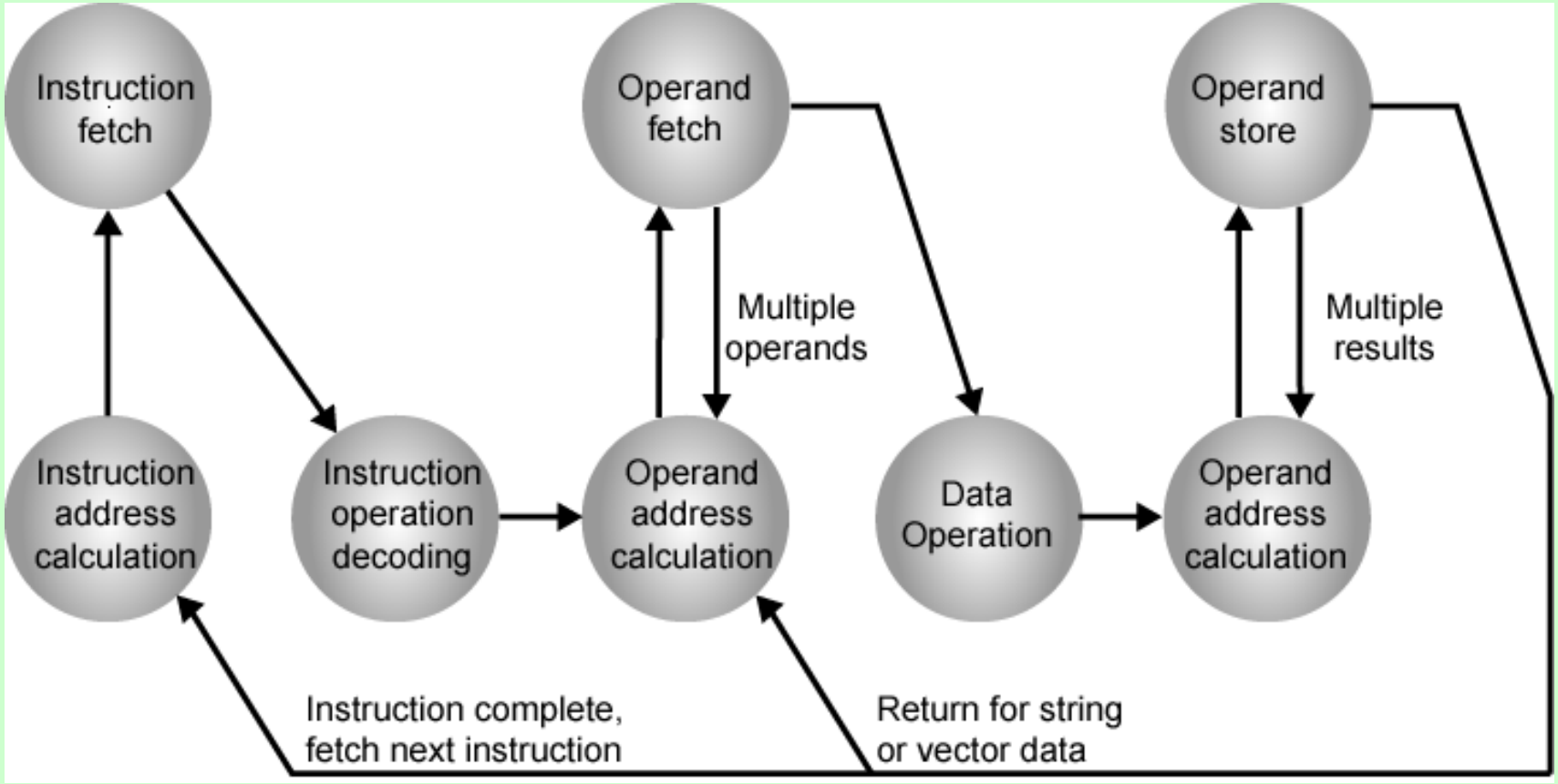
Elements of an Instruction

- Operation code (Op code)
  - —Do this
- Source Operand reference
  - —To this
- Result Operand reference
  - —Put the answer here
- Next Instruction Reference
  - —When you have done that, do this...

Where have all the Operands Gone?

- Long time passing….
- (If you don’t understand, you’re too young!)
- Main memory (or virtual memory or cache)
- CPU register
- I/O device

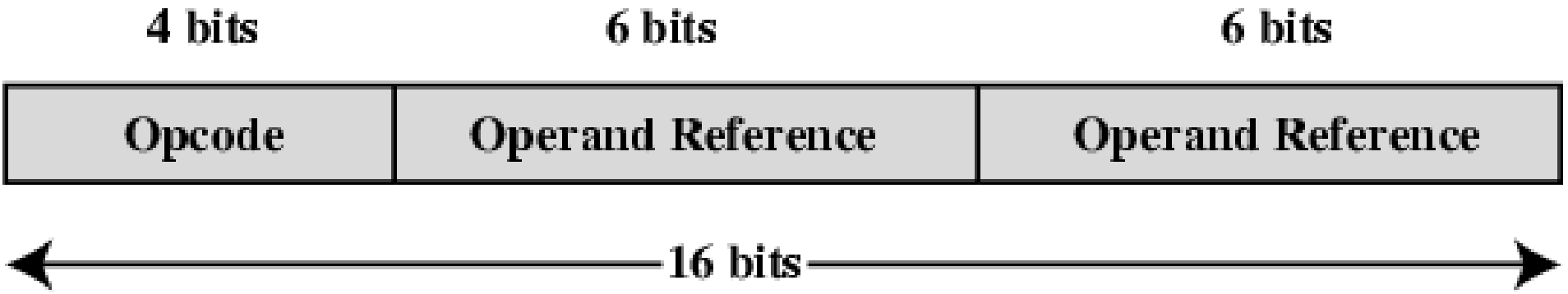
Instruction Cycle State Diagram



Instruction Representation

- In machine code each instruction has a unique bit pattern
- For human consumption (well, programmers anyway) a symbolic representation is used
  - —e.g. ADD, SUB, LOAD
- Operands can also be represented in this way
  - —ADD A,B

Simple Instruction Format



Instruction Types

- Data processing
- Data storage (main memory)
- Data movement (I/O)
- Program flow control

Number of Addresses (a)

- 3 addresses
  - —Operand 1, Operand 2, Result
  - —a = b + c;
  - —May be a forth - next instruction (usually implicit)
  - —Not common
  - —Needs very long words to hold everything

Number of Addresses (b)

- 2 addresses
  - —One address doubles as operand and result
  - —a = a + b
  - —Reduces length of instruction
  - —Requires some extra work
    - – Temporary storage to hold some results

Number of Addresses (c)

- 1 address
  - —Implicit second address
  - —Usually a register (accumulator)
  - —Common on early machines

Number of Addresses (d)

- 0 (zero) addresses
  - —All addresses implicit
  - —Uses a stack
  - —e.g. push a
  - — push b
  - — add
  - — pop c
  - —c = a + b

How Many Addresses

- More addresses
  - More complex (powerful?) instructions
  - More registers
    - Inter-register operations are quicker
  - Fewer instructions per program
- Fewer addresses
  - Less complex (powerful?) instructions
  - More instructions per program
  - Faster fetch/execution of instructions

Design Decisions (1)

- Operation repertoire
  - How many ops?
  - What can they do?
  - How complex are they?
- Data types
- Instruction formats
  - Length of op code field
  - Number of addresses

Design Decisions (2)

- Registers
  - Number of CPU registers available
  - Which operations can be performed on which registers?
- Addressing modes (later…)
- RISC v CISC

Types of Operand

- Addresses
- Numbers
  - —Integer/floating point
- Characters
  - —ASCII etc.
- Logical Data
  - —Bits or flags
- (Aside: Is there any difference between numbers and characters? Ask a C programmer!)

Types of Operation

- Data Transfer
- Arithmetic
- Logical
- Conversion
- I/O
- System Control
- Transfer of Control

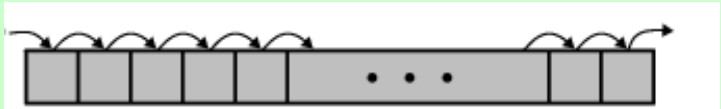
Data Transfer

- Specify
  - —Source
  - —Destination
  - —Amount of data
- May be different instructions for different movements
  - —e.g. IBM 370
- Or one instruction and different addresses
  - —e.g. VAX

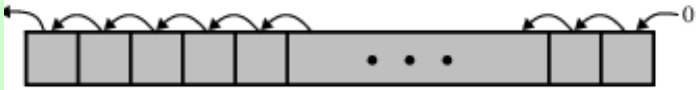
Arithmetic

- Add, Subtract, Multiply, Divide
- Signed Integer
- Floating point ?
- May include
  - Increment (a++)
  - Decrement (a--)
  - Negate (-a)

Shift and Rotate Operations

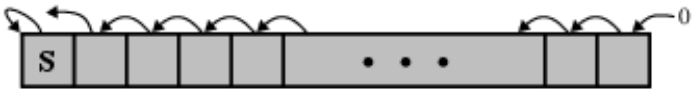


(a) Logical right shift

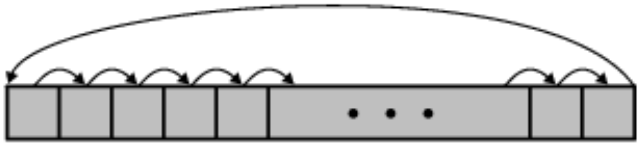


(b) Logical left shift

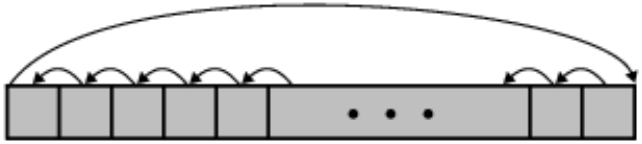
(c) Arithmetic right shift



(d) Arithmetic left shift



(e) Right rotate



(f) Left rotate

Logical

- Bitwise operations
- AND, OR, NOT

Conversion

- E.g. Binary to Decimal

Input/Output

- May be specific instructions
- May be done using data movement instructions (memory mapped)
- May be done by a separate controller (DMA)

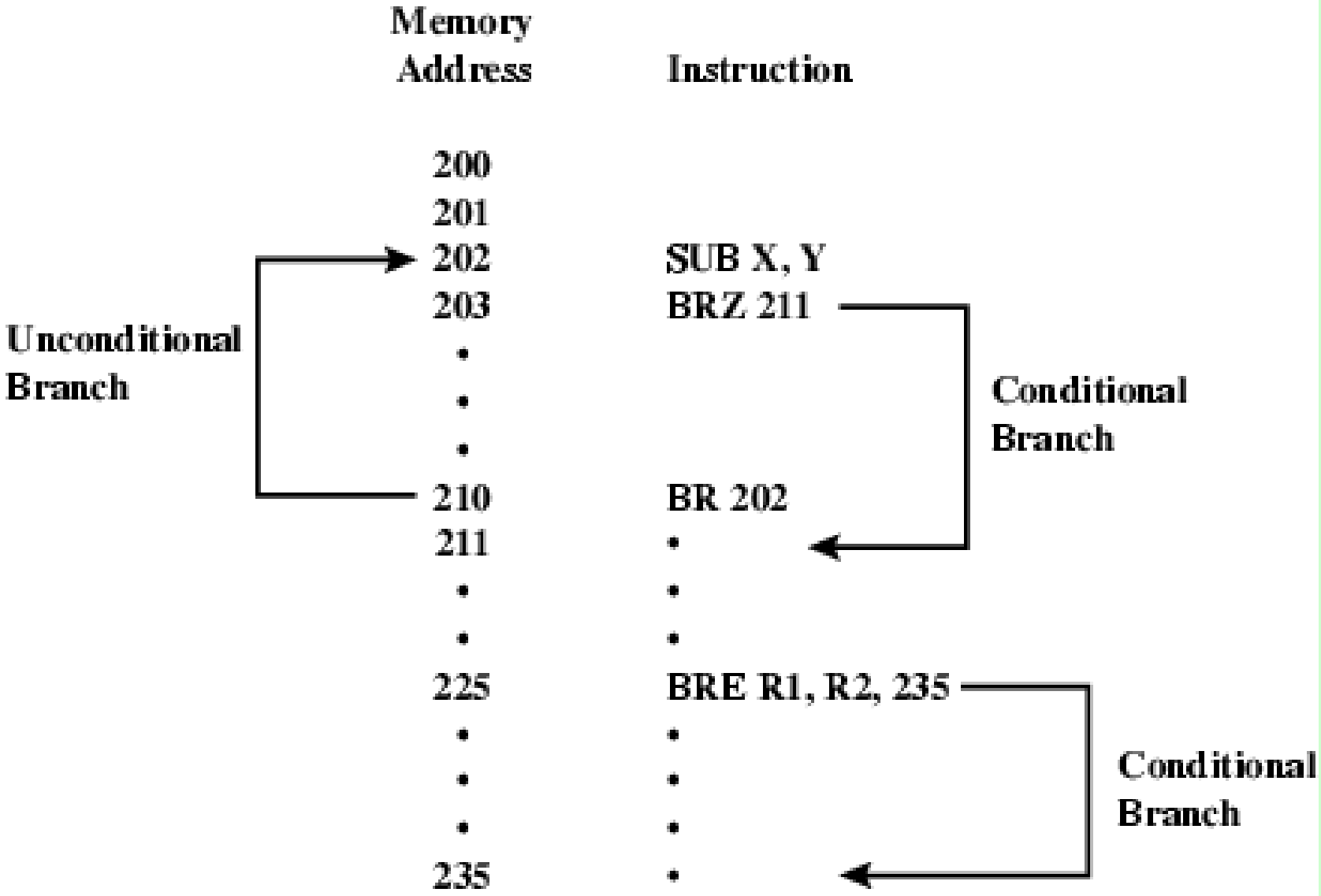
Systems Control

- Privileged instructions
- CPU needs to be in specific state
  - Ring 0 on 80386+
  - Kernel mode
- For operating systems use

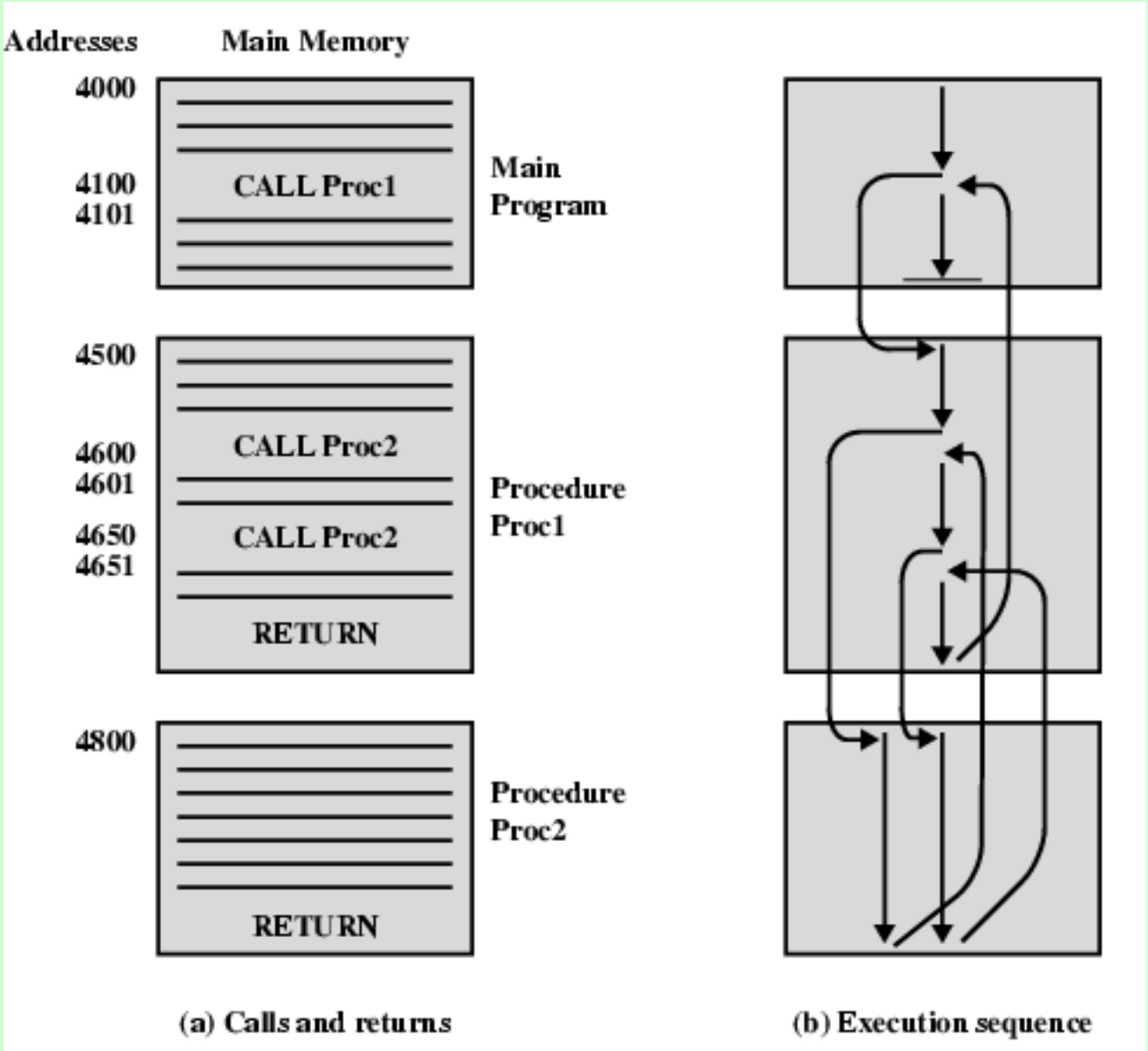
Transfer of Control

- Branch
  - e.g. branch to x if result is zero
- Skip
  - e.g. increment and skip if zero
  - ISZ Register1
  - Branch xxxx
  - ADD A
- Subroutine call
  - c.f. interrupt call

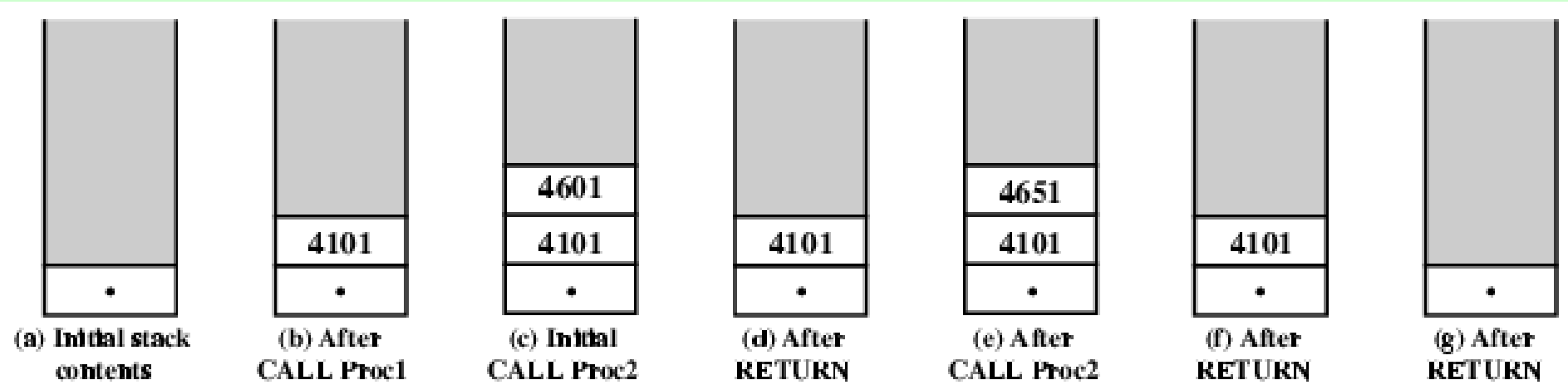
Branch Instruction



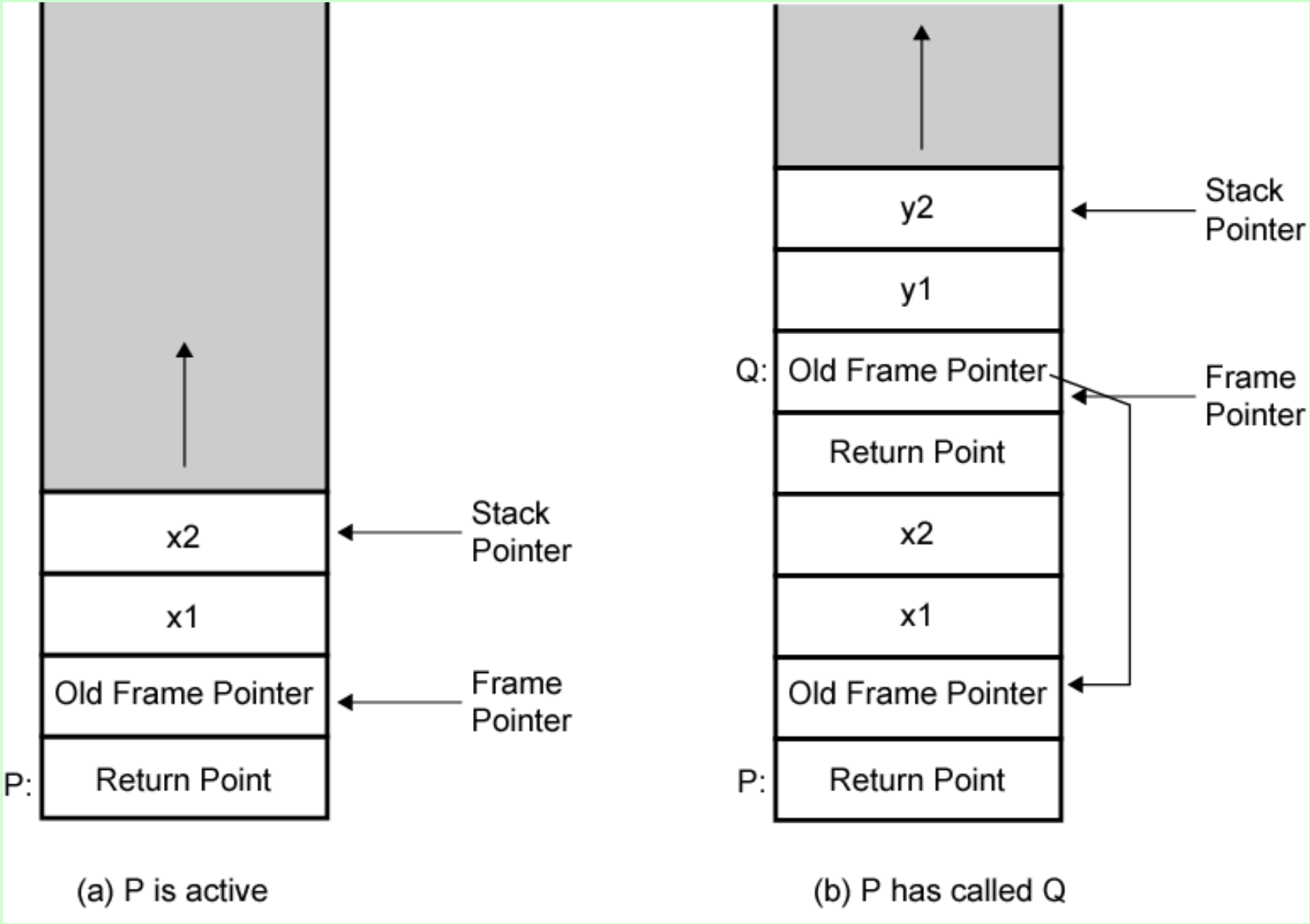
Nested Procedure Calls



Use of Stack


4101
4601
4101
4101
4651
4101
4101
(a) Initial stack contents
(b) After CALL Proc1
(c) Initial CALL Proc2
(d) After RETURN
(e) After CALL Proc2
(f) After RETURN
(g) After RETURN

Stack Frame Growth Using Sample Procedures P and Q



Byte Order
(A portion of chips?)

- What order do we read numbers that occupy more than one byte
- e.g. (numbers in hex to make it easy to read)
- 12345678 can be stored in 4x8bit locations as follows

Byte Order (example)

Address	Value (1)	Value(2)
184	12	78
185	34	56
186	56	34
186	78	12

- i.e. read top down or bottom up?

Byte Order Names

- The problem is called Endian
- The system on the left has the least significant byte in the lowest address
- This is called big-endian
- The system on the right has the least significant byte in the highest address
- This is called little-endian