Multiple Programs

How do programs communicate?
Multiple Programs

How do programs communicate? Files...
Multiple Programs

How do programs communicate? Files... Network...
Multiple Programs

How do programs communicate? Files... Network... Stdin...
Multiple Programs

How do programs communicate? Files... Network... Stdin... Etc.

But what’s in a file or sent over the network?
Byte Streams

Operating systems provide files, network connections, etc. as byte stream objects

A byte is a number between 0 and 255

A stream is a sequence with a counter and an operation: read-byte or write-byte

(read-byte in)
Byte Streams

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\begin{center}
\begin{tabular}{ccccccc}
104 & 101 & 108 & 108 & 111 & &
\end{tabular}
\end{center}

\texttt{(read-byte in)} $\rightarrow$ 104
Byte Streams

Operating systems provide files, network connections, etc. as *byte stream* objects

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```
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```

(read-byte in) $\rightarrow$ 104

(read-byte in) $\rightarrow$ 101
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(read-byte in) → 104  (read-byte in) → 108
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(read-byte in) → 104 (read-byte in) → 108
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(read-byte in) → 104         (read-byte in) → 108
(read-byte in) → 101         (read-byte in) → 111
(read-byte in) → 108         (read-byte in) → eof-object
Byte Streams

Operating systems provide files, network connections, etc. as **byte stream** objects

A **byte** is a number between 0 and **255**

A **stream** is a sequence with a counter and an operation: **read-byte** or **write-byte**

```
104 101 108 108 111
```

`fgetc(in)`
Byte Streams

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```
104 101 108 108 111

fgetc(in) → 104
fgetc(in) → 101
```
Byte Streams

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A **byte** is a number between 0 and 255

A **stream** is a sequence with a counter and an operation: **read-byte** or **write-byte**

```
104 101 108 108 111
```

fgets(in) → 104
fgets(in) → 101
fgets(in) → 108
Byte Streams

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A \textit{byte} is a number between 0 and 255.

A \textit{stream} is a sequence with a counter and an operation: \texttt{read-byte} or \texttt{write-byte}.

\begin{verbatim}
104 101 108 108 111
\end{verbatim}

\texttt{fgetc(in)} $\rightarrow$ 104 \quad \texttt{fgetc(in)} $\rightarrow$ 108
\texttt{fgetc(in)} $\rightarrow$ 101
\texttt{fgetc(in)} $\rightarrow$ 108
Byte Streams

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A \texttt{byte} is a number between 0 and 255

A \texttt{stream} is a sequence with a counter and an operation: \texttt{read-byte} or \texttt{write-byte}

\begin{verbatim}
104 101 108 108 111
\end{verbatim}

\begin{verbatim}
geticc(in) \rightarrow 104  \qquad  fgetc(in) \rightarrow 108  \\
geticc(in) \rightarrow 101  \qquad  fgetc(in) \rightarrow 111  \\
geticc(in) \rightarrow 108
\end{verbatim}
Byte Streams

Operating systems provide files, network connections, etc. as *byte stream* objects

A *byte* is a number between 0 and 255

A *stream* is a sequence with a counter and an operation: *read-byte* or *write-byte*

```
104 101 108 108 111
```

```
fgetc(in) → 104  fgetc(in) → 108
fgetc(in) → 101  fgetc(in) → 111
fgetc(in) → 108  fgetc(in) → -1
```
(write-byte 104 o)
→ (void)
(write-byte 104 o) → (void)

(write-byte 101 o) → (void)

Byte Streams
(write-byte 104 o)  →  (void)

(write-byte 101 o)  →  (void)

(read-byte i)   →  104
Byte Streams

\[(\text{write-byte } 104 \ 0)\]
\[\rightarrow (\text{void})\]

\[(\text{write-byte } 101 \ 0)\]
\[\rightarrow (\text{void})\]

\[(\text{read-byte } i)\]
\[\rightarrow 104\]

\[(\text{read-byte } i)\]
\[\rightarrow 101\]
Encoding

To communicate information other than small numbers, it must be **encoded**

To encode English text, map each **character** to a byte

\[
\begin{align*}
\#\backslash a & \Rightarrow 97 \\
\#\backslash b & \Rightarrow 98 \\
\#\backslash c & \Rightarrow 99 \\
& \cdots \\
\#\backslash A & \Rightarrow 65 \\
& \cdots \\
\#\backslash ( & \Rightarrow 40 \\
\#\backslash ) & \Rightarrow 41 \\
\#\backslash 1 & \Rightarrow 48 \\
& \cdots
\end{align*}
\]
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as *character streams*

```
#\h #\e #\l #\l #\o
```

(read-char in)
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as *character streams*

```scheme
(read-char in) → #\h
```

```
#\h #\e #\l #\l #\o
```
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as \textit{character streams}

\begin{itemize}
  \item \texttt{\textbackslash h} \\
  \item \texttt{\textbackslash e} \\
  \item \texttt{\textbackslash l} \\
  \item \texttt{\textbackslash l} \\
  \item \texttt{\textbackslash o}
\end{itemize}

\begin{itemize}
  \item \texttt{(read-char in)} \rightarrow \texttt{\textbackslash h}
  \item \texttt{(read-char in)} \rightarrow \texttt{\textbackslash e}
\end{itemize}
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as \textit{character streams}

\begin{verbatim}
\#\h \#\e \#\l \#\l \#\o
\end{verbatim}

(\texttt{read-char in}) \rightarrow \texttt{#\h}

(\texttt{read-char in}) \rightarrow \texttt{#\e}

...

(\texttt{read-char in}) \rightarrow \texttt{eof-object}
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as *character streams*

```
#\h #\e #\l #\l #\o
```

`fgetc(in)`
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as \textit{character streams}

\begin{verbatim}
\#h \#e \#l \#l \#o
\end{verbatim}

\texttt{fgetc(in)} $\rightarrow$ 'h' /* = 104 */
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as *character streams*

\[
\#\h \#\e \#\l \#\l \#\o
\]

\texttt{fgetc(in)} → 'h' /* = 104 */

\texttt{fgetc(in)} → 'e' /* = 101 */
Character Streams

This character encoding is so popular that byte streams are sometimes viewed as **character streams**

```
\#\h \#\e \#\l \#\l \#\0
```

fgetc(in) → 'h' /* = 104 */

fgetc(in) → 'e' /* = 101 */

...

fgetc(in) → -1
Accessing Streams

Stream types:

• Racket:
  ○ input port
  ○ output port

• Java:
  ○ InputStream
  ○ PrintStream

• C:
  ○ FILE*
Accessing Streams

Getting standard input, output, and error-output:

- **Racket:**
  - `(current-input-port)`
  - `(current-output-port)`
  - `(current-error-port)`

- **Java:**
  - `System.out`
  - `System.in`
  - `System.err`

- **C with `#include <stdio.h>`:**
  - `stdin`
  - `stdout`
  - `stderr`
Accessing Streams

Reading or writing a file:

• Racket:
  ○ `(open-input-file filename)`
  ○ `(open-output-file filename)`

• Java:
  ○ `new BufferedReader(new FileReader(filename))`
  ○ `new BufferedWriter(new FileWriter(filename))`

• C with `#include <stdio.h>`:
  ○ `fopen(filename, "rb")`
  ○ `fopen(filename, "wb")`
Character Streams in Racket

(define o (open-output-file "ex1"))
(write-char \h o)
(write-char \e o)
...
(close-output-port o)

(define i (open-input-file "ex1"))
(check-expect (read-char i) \h)
(check-expect (read-char i) \e)
...
(close-input-port i)

Note: Racket term for stream is port
Encoding: Characters in Racket

In Racket, characters are actually encoded in multiple bytes, sometimes

```
97 206 187 98
```

↑
Encoding: Characters in Racket

In Racket, characters are actually encoded in multiple bytes, sometimes

\[
\begin{array}{c}
97 & 206 & 187 & 98 \\
\end{array}
\]

\((\text{read-char in}) \rightarrow \#\backslash a\)
Encoding: Characters in Racket

In Racket, characters are actually encoded in multiple bytes, sometimes

\begin{center}
\begin{tabular}{cccc}
97 & 206 & 187 & 98 \\
\end{tabular}
\end{center}

(read-char in) → \#\a

(read-char in) → \#\\lambda
Encoding: Characters in Racket

In Racket, characters are actually encoded in multiple bytes, sometimes

\[
\begin{array}{cccc}
97 & 206 & 187 & 98
\end{array}
\]

\[(\text{read-char in}) \rightarrow \#\a\]

\[(\text{read-char in}) \rightarrow \#\lambda\]

\[(\text{read-char in}) \rightarrow \#\b\]
Encoding: Characters in C

In C, char just means “byte”
Encoding: Characters in C

In C, `char` just means “byte”

\[
\begin{array}{cccc}
97 & 206 & 187 & 98 \\
\end{array}
\]

`fgetc(in) \rightarrow 'a'`
Encoding: Characters in C

In C, `char` just means “byte”

\[
\begin{array}{cccc}
97 & 206 & 187 & 98 \\
\end{array}
\]

\[
\text{fgetc}(\text{in}) \rightarrow 'a' \\
\text{fgetc}(\text{in}) \rightarrow 'î'
\]
Encoding: Characters in C

In C, `char` just means “byte”

\[
\begin{array}{c}
97 & 206 & 187 & 98 \\
\end{array}
\]

\[
fgetc(in) \rightarrow 'a'
\]

\[
fgetc(in) \rightarrow 'î'
\]

\[
fgetc(in) \rightarrow '≫'
\]
Encoding: Characters in C

In C, `char` just means “byte”

```
97 206 187 98
```

- `fgetc(in) → 'a'`
- `fgetc(in) → 'î'`
- `fgetc(in) → '»'`
- `fgetc(in) → 'b'`
Some Character Encoding Standards

• ASCII
  ○ “Characters” 0 to 127
  ○ A kind of English plus computer creole

• Latin-1
  ○ “Characters” 0 to 255
  ○ A kind of Western Europe plus computer creole
  ○ A superset of ASCII

• UTF-8
  ○ “Characters” 0 to 917999 or so
  ○ Roughly covers all languages on Earth
  ○ A superset of ASCII

• UTF-16
  ○ Same coverage as UTF-8
  ○ Uses 2 or 4 bytes for each character

• ...

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Communicating Strings

One string: encode as a sequence of characters

Multiple strings: need a way to mark the end of one string
Communicating Strings

One string: encode as a sequence of characters

Multiple strings: need a way to mark the end of one string

The most popular encoding is **line-based**:

- Use a newline (encoded as 10) to separate strings
  - `\newline` or `'\n'`

- Works for strings that don’t contain newlines

- Racket:
  - `(read-line input-port)`

- C:
  - `fgets(buffer, len, stream)`
CRLF versus LF

Sometimes, lines are separated by two characters (CRLF: 13 then 10) instead of one (LF: 10):

"one\ntwo\n" versus "one\nr\ntwo\nr\n"

The encoding convention depends on the platform

Opening a file in “text mode” reads CRLF or LF as newline, as appropriate for a given platform

• Racket:
  - (open-input-file #:mode 'text filename)
  - (open-output-file #:mode 'text filename)

• C:
  - fopen(filename, "r")
  - fopen(filename, "w")
Communicating More Than Characters

To read and write aquariums, we need to communicate lists of (large) numbers
Communicating More Than Characters

To read and write aquariums, we need to communicate lists of (large) numbers

Again, we must encode:

- empty \( \Rightarrow \) \#'\.  
- '10000' \( \Rightarrow \) \#'1 #\0 #\0 #\0 #\space #\.'  
- '1 2' \( \Rightarrow \) \#'1 #\space #\2 #\space #\.'  
- ...
Number List Serialization

A `<numlist>` is either

```
  
  <num> \space <numlist>
```

A `<num>` is either

```
  <digit>
  <num> <digit>
```

A `<digit>` is either

```
  \0
  \1
  ...
  \9
```
Number List Writer

; write-numlist : list-of-num output-port -> void
(define (write-numlist l p)
  (cond
   [(empty? l) (write-char #\ . p)]
   [else (begin
            (write-num (first l) p)
            (write-char #\ space p)
            (write-numlist (rest l) p))]))

; write-num : num output-port -> void
(define (write-num n p)
  (cond
   [(< n 10) (write-digit n p)]
   [else (begin
            (write-num (quotient n 10) p)
            (write-digit (remainder n 10) p))]))

; write-digit : num [0-9] output-port -> void
(define (write-digit n p)
  (cond
   [(= n 0) (write-char #\0 p)]
   ...[
   [(= n 9) (write-char #\9 p)]]))
Number List Parsing

**Parse** using an equivalent but more convenient form:

A `<numlist>` is either

- `#\.`
- `<num> \space <numlist>`

A `<num>` is either

- `<digit>`
  - `<num> <digit>`

A `<digit>` is either

- `#\0`
- `#\1`
- ...  
- `#\9`
Number List Reader

; read-numlist : input-port -> list-of-num
(define (read-numlist p)
  (local [(define c (read-char p))]
    (cond
      [(char=? #\ . c) empty]
      [(char-digit? c) (cons (read-number p (digit-val c))
                               (read-numlist p))]))
)

; read-number : input-port num -> num
(define (read-number p n)
  (local [(define c (read-char p))]
    (cond
      [(char=? #\space c) n]
      [(char-digit? c)
       (read-number p (+ (* n 10) (digit-val c)))])))

; char-digit? : char -> bool
... 

; digit-val : char -> num
...
I/O Libraries

You don’t always have to start from scratch

• Racket:
  ○ `read` and `write`
  ○ `read-line` and `displayln`
  ○ `read-xml` and `write-xml`
  ○ ...

• C:
  ○ `fscanf` and `fprintf`
  ○ ...

Buffers

Dear Sir: ...
Buffers

A *buffer* is why you see no output from

```c
int main() {
    printf("hello");
    crash();
}
```
Buffers

A **buffer** is why you see no output from

```c
int main() {
    printf("hello");
    crash();
}
```

**Line-buffering** is why you do see output from

```c
int main() {
    printf("hello\n");
    crash();
}
```

... unless you redirect to an output file
Buffers

Flushing buffers:

- Racket:
  - `(flush-output output-port)`

- C:
  - `fflush(stream)`