

ICOM 4036

Structure and Properties of Programming Languages

Lecture 1

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Outline

- Motivation
- Programming Domains
- Language Evaluation Criteria
- Influences on Language Design
- Language Categories
- Language Design Trade-Offs
- Implementation Methods
- Milestones on PL Design

What is a Programming Language?

- A Programming Language ...
 - ... provides an encoding for algorithms
 - ...should express all possible algorithms
 - ... must be decodable by an algorithm
 - ... should support complex software
 - ...should be easy to read and understand
 - ... should support efficient algorithms
 - ...should support rapid software development

Motivation:

Why Study Programming Languages?

- Increased ability to express ideas
- Improved background for choosing appropriate languages
- Greater ability to learn new languages
- Understand significance of implementation
- Ability to design new languages
- Overall advancement of computing

Programming Domains

- Scientific applications
 - Large number of floating point computations
- Business applications
 - Produce reports, use decimal numbers and characters
- Artificial intelligence
 - Symbols rather than numbers manipulated. Code = Data.
- Systems programming
 - Need efficiency because of continuous use. Low-level control.
- Scripting languages
 - Put a list of commands in a file to be executed. Glue apps.
- Special-purpose languages
 - Simplest/fastest solution for a particular task.

Language Evaluation Criteria

- Readability
- Write-ability
- Reliability
- Cost
- Others

The key to good language design consists of crafting the best possible compromise among these criteria

Language Evaluation Criteria

Readability

- Overall simplicity
 - Too many features is bad
 - Multiplicity of features is bad
- Orthogonality
 - Makes the language easy to learn and read
 - Meaning is context independent
 - A relatively small set of primitive constructs can be combined in a relatively small number of ways
 - Every possible combination is legal
 - Lack of orthogonality leads to exceptions to rules

Language Evaluation Criteria

Write-ability

- Simplicity and orthogonality
- Support for abstraction
- Support for alternative paradigms
- Expressiveness

Language Evaluation Criteria

Reliability

Some PL features that impact reliability:

- Type checking
- Exception handling
- Aliasing

Language Evaluation Criteria

Cost

What is the cost involved in:

- Training programmers to use language
- Writing programs
- Compiling programs
- Executing programs
- Using the language implementation system
- Risk involved in using unreliable language
- Maintaining programs

Language Evaluation Criteria

Other

- Portability
- Generality
- Well-definedness
- Elegance
- Availability
- ...

Some Language Design Trade-Offs

- Reliability vs. cost of execution
- Readability vs. writability
- Flexibility vs. safety

Influences on Language Design Through the Years

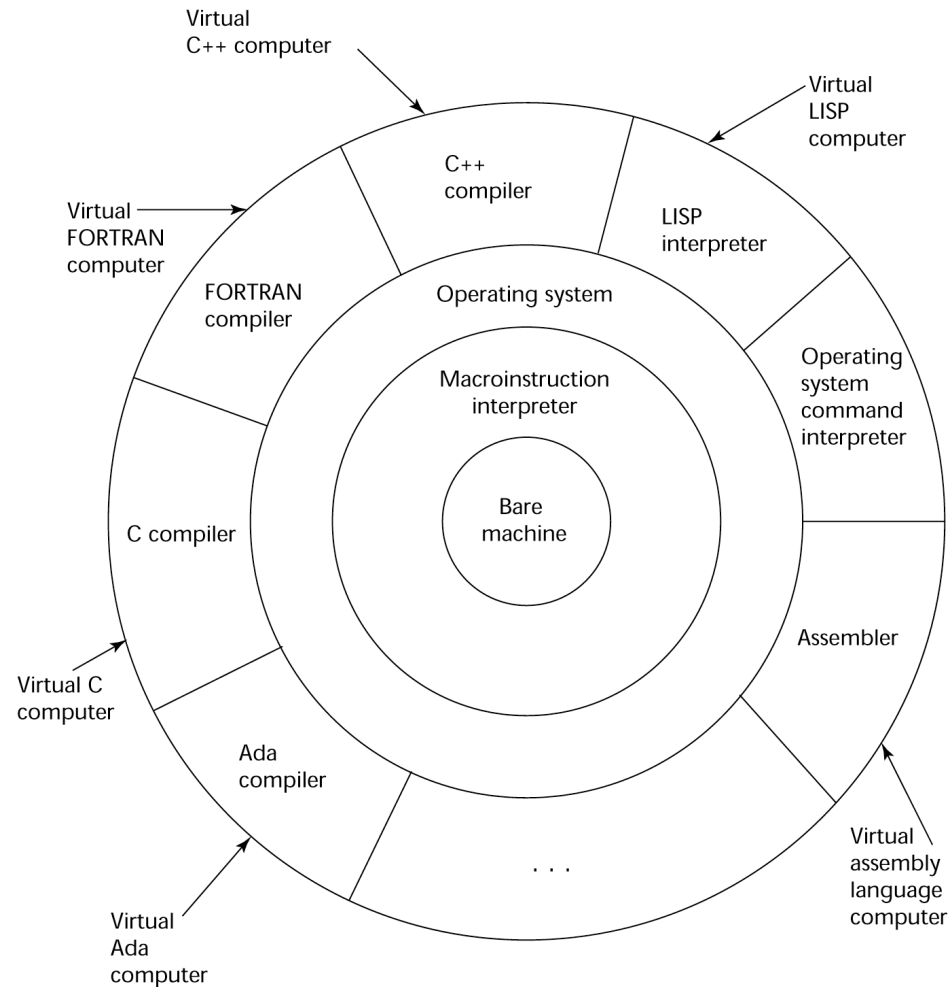
- Programming methodologies thru time:
 - 1950s and early 1960s:
 - Simple applications; worry about machine efficiency
 - Late 1960s:
 - People efficiency became important;
 - readability, better control structures
 - Structured programming
 - Top-down design and step-wise refinement
 - Late 1970s: Process-oriented to data-oriented
 - data abstraction
 - Middle 1980s: Re-use, Modularity
 - Object-oriented programming
 - Late 1990s: Portability, reliability, security
 - Java, C#

Some Programming Paradigms

- Imperative
 - Central features are variables, assignment statements, and iteration
 - Examples: FORTRAN, C, Pascal
- Functional
 - Main means of making computations is by applying functions to given parameters
 - Examples: LISP, Scheme
- Logic
 - Rule-based
 - Rules are specified in no special order
 - Examples: Prolog
- Object-oriented
 - Encapsulate data objects with processing
 - Inheritance and dynamic type binding
 - Grew out of imperative languages
 - Examples: C++, Java

Languages typically support more than one paradigm although not equally well

Layered View of Computer

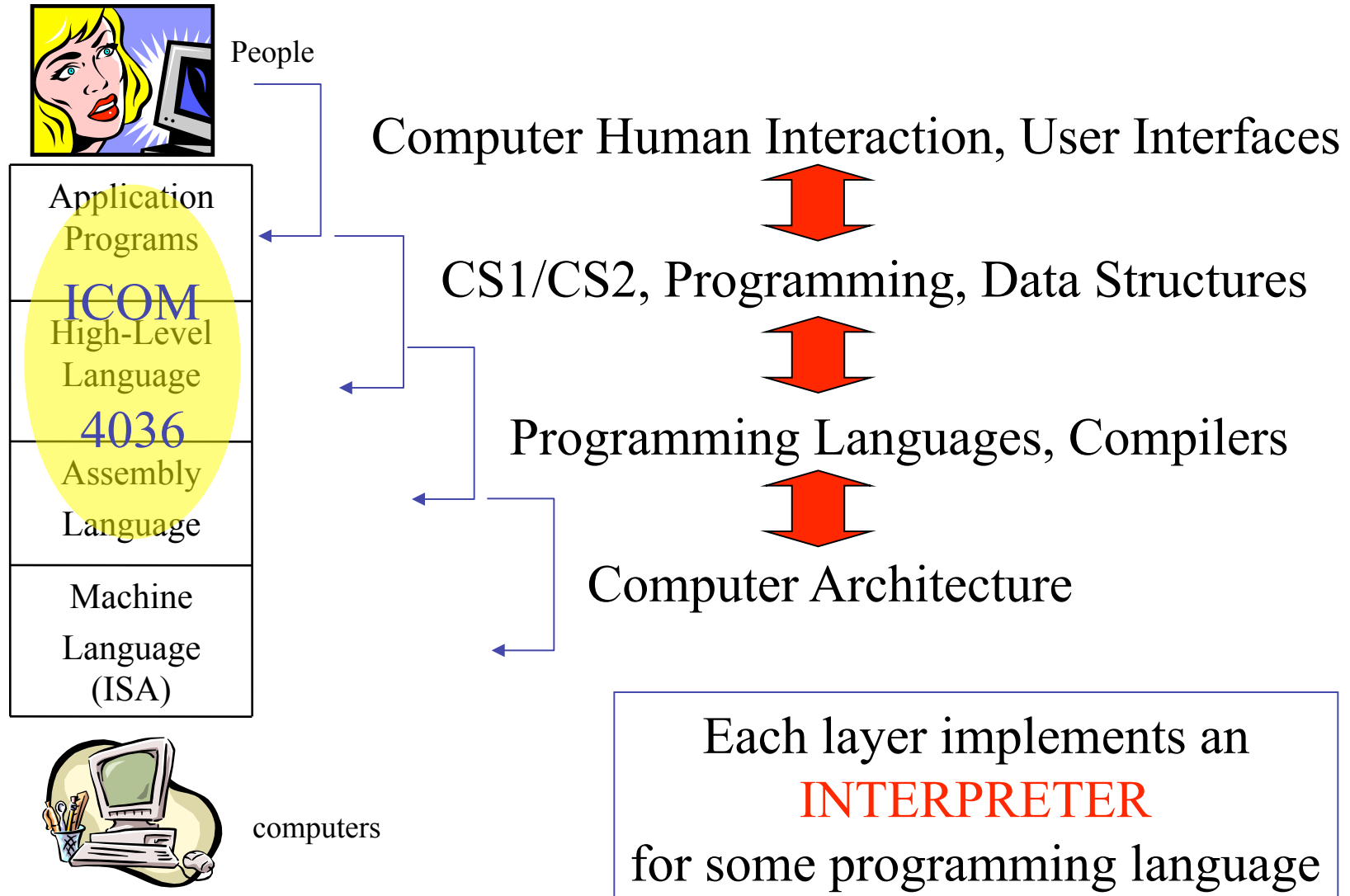


Each Layer Implements a **Virtual Machine**
with its own Programming Language

Virtual Machines (VM's)

Type of Virtual Machine	Examples	Instruction Elements	Data Elements	Comments
Application Programs	Spreadsheet, Word Processor	Drag & Drop, GUI ops, macros	cells, paragraphs, sections	Visual, Graphical, Interactive Application Specific Abstractions Easy for Humans Hides HLL Level
High-Level Language	C, C++, Java, FORTRAN, Pascal	if-then-else, procedures, loops	arrays, structures	Modular, Structured, Model Human Language/ Thought General Purpose Abstractions Hides Lower Levels
Assembly-Level	SPIM, MASM	directives, pseudo-instructions, macros	registers, labelled memory cells	Symbolic Instructions/Data Hides some machine details like alignment, address calculations Exposes Machine ISA
Machine-Level (ISA)	MIPS, Intel 80x86	load, store, add, branch	bits, binary addresses	Numeric, Binary Difficult for Humans

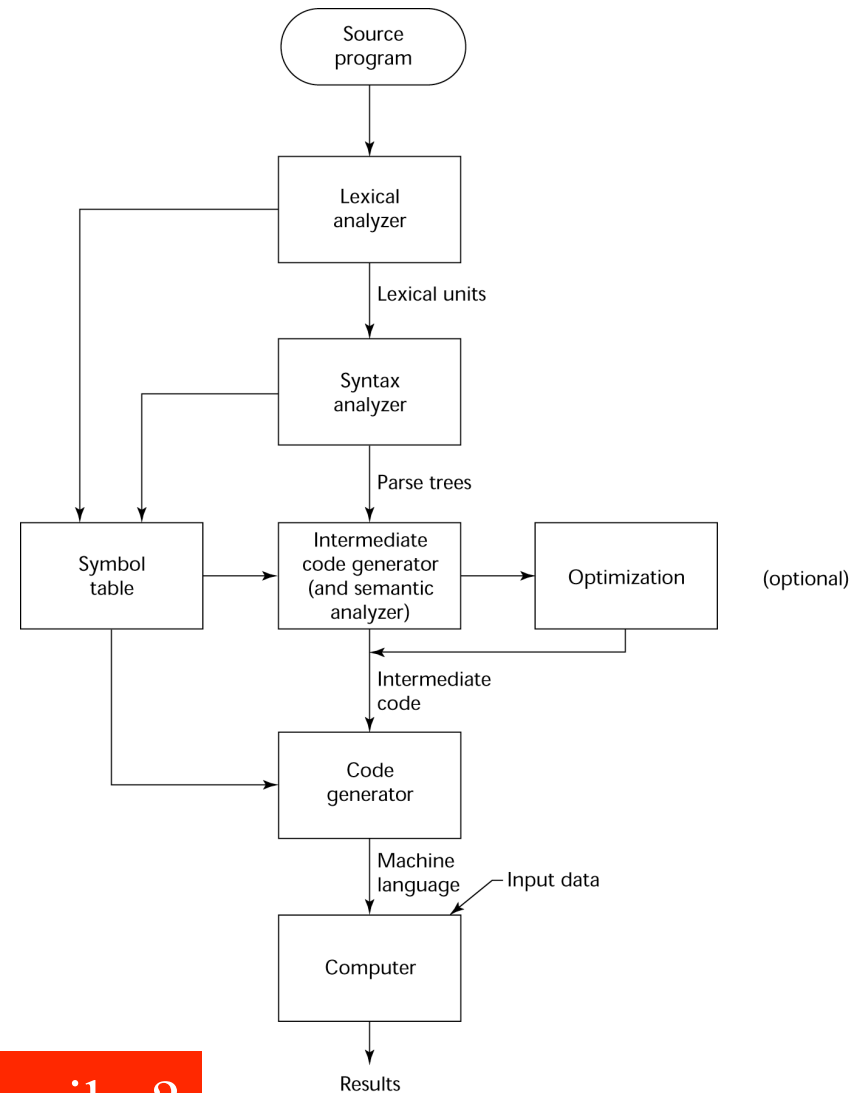
Computing in Perspective



Implementation Methods

Compilation

- Translate high-level program to machine code
- Slow translation
- Fast execution



Trivia: Who developed the first compiler?

Answer: Computing Pioneer Grace Murray Hopper developed the first compiler ever



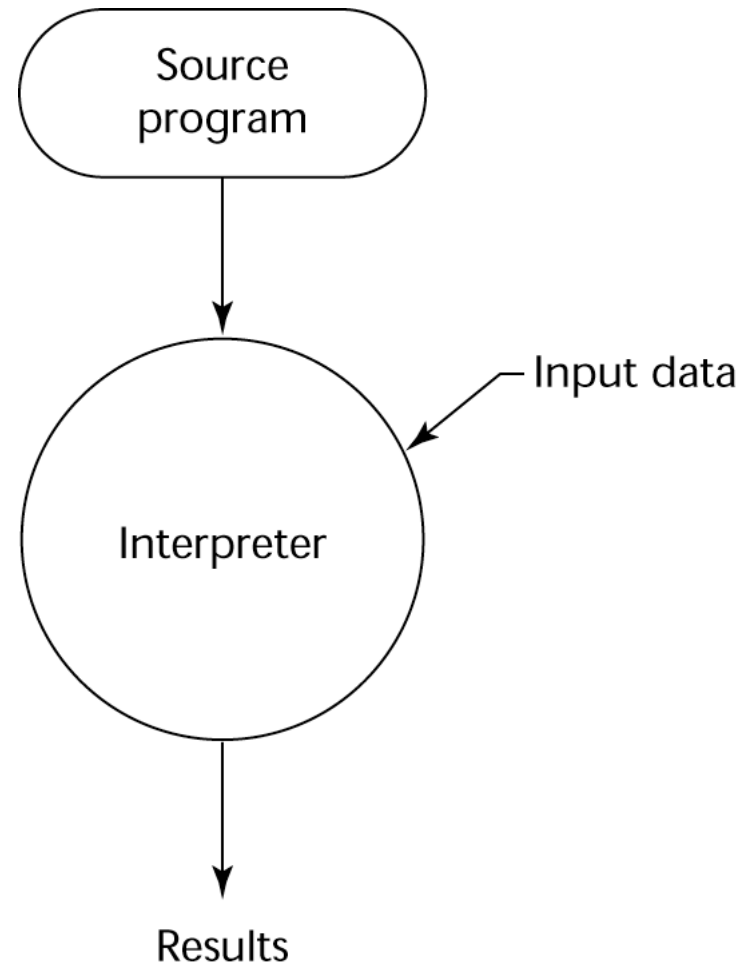
1984 picture

Learn more about Grace Murray Hopper @ [wikipedia.org](https://en.wikipedia.org/wiki/Grace_Murray_Hopper)

Implementation Methods

Interpretation

- No translation
- Slow execution
- Common in Scripting Languages



Implementation Methods

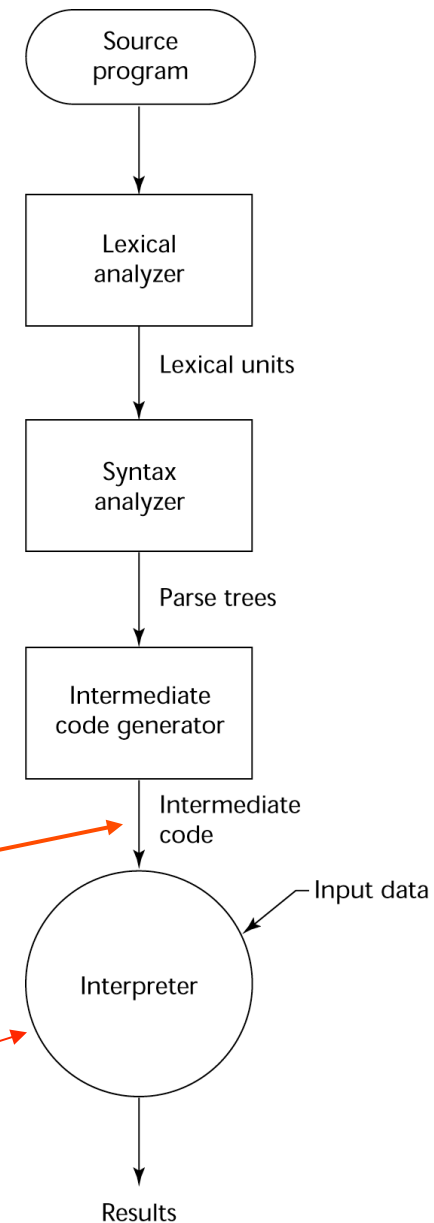
Hybrid Approaches

- Small translation cost
- Medium execution speed
- Portability

Examples of Intermediate Languages:

- Java Bytecodes
- .NET MSIL

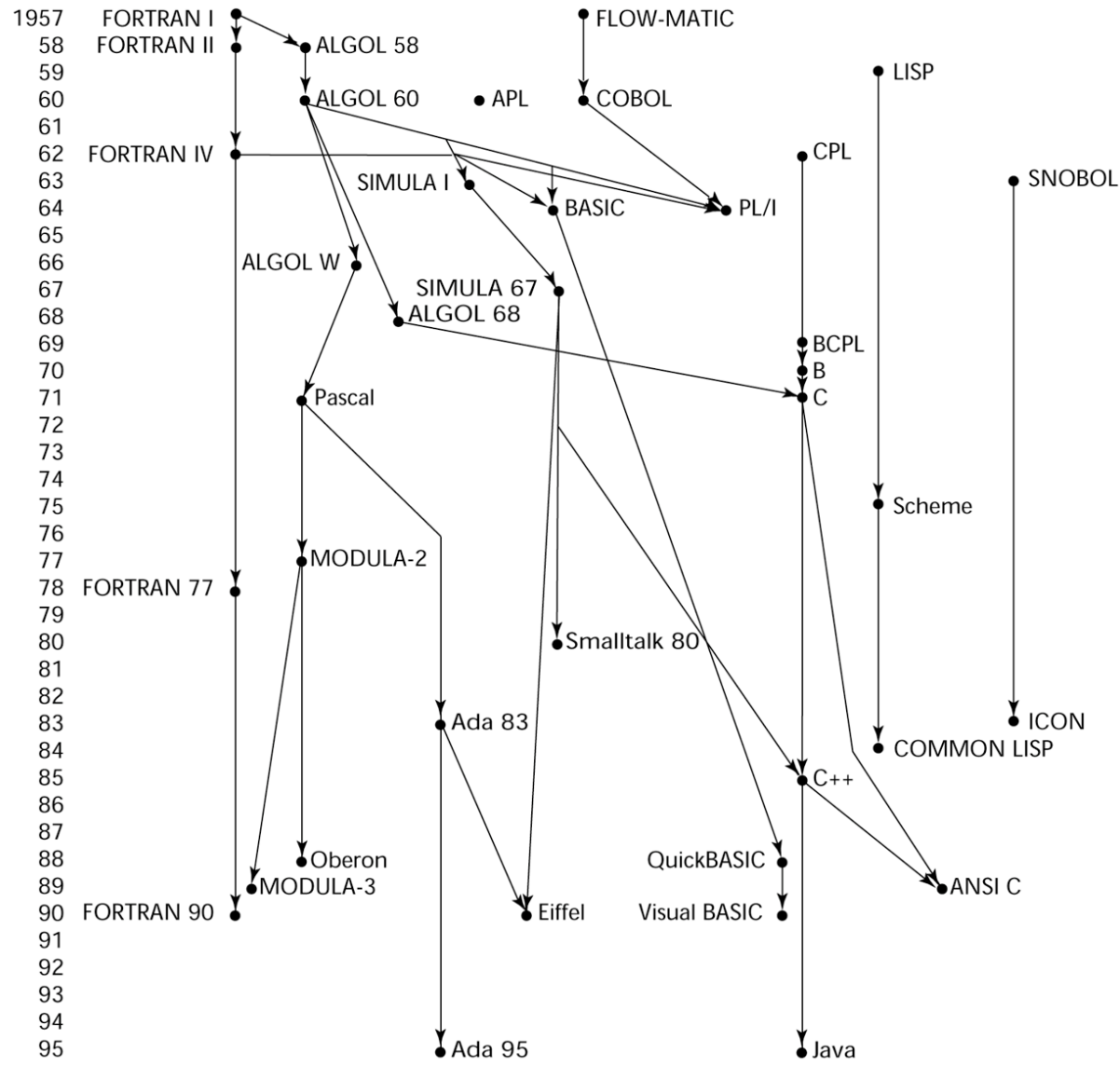
Java VM



Software Development Environments (SDE's)

- The collection of tools used in software development
- GNU/FSF Tools
 - Emacs, GCC, GDB, Make
- Eclipse
 - An integrated development environment for Java
- Microsoft Visual Studio.NET
 - A large, complex visual environment
 - Used to program in C#, Visual BASIC.NET, Jscript, J#, or C++
- IBM WebSphere Studio
 - Specialized with many wizards to support webapp development

Genealogy of High-Level Languages



Machine Code – Computer's Native Language

- Binary encoded instruction sequence
- Architecture specific
- Interpreted by the processor
- Hard to read and debug

```
int a = 12;
int b = 4;
int result = 0;
main () {
    if (a >= b) {
        while (a > 0) {
            a = a - b;
            result ++;
        }
    }
}
```

Address	I Bit	Opcode (binary)	X (base 10)
0	0	00 110	0
2	0	00 111	12
4	0	00 100	1000
6	0	00 110	0
8			4
10			1004
12			0
14	0	00 100	1008
16	0	00 101	1004
18	0	00 000	unused
20	0	00 111	1
22	1	00 111	1000
24	0	00 010	46
26	0	00 101	1000
28	0	00 010	46
30	0	00 101	1004
32	0	00 000	unused
34	0	00 111	1
36	0	00 100	1000
38	0	00 101	1008
40	0	00 111	1
42	0	00 100	1008
44	0	00 011	26

Machine Code Instruction:

0001110000001100₂

1C0C₁₆

Assembly Language

Improvements

- Symbolic names for each machine instruction
- Symbolic addresses
- Macros

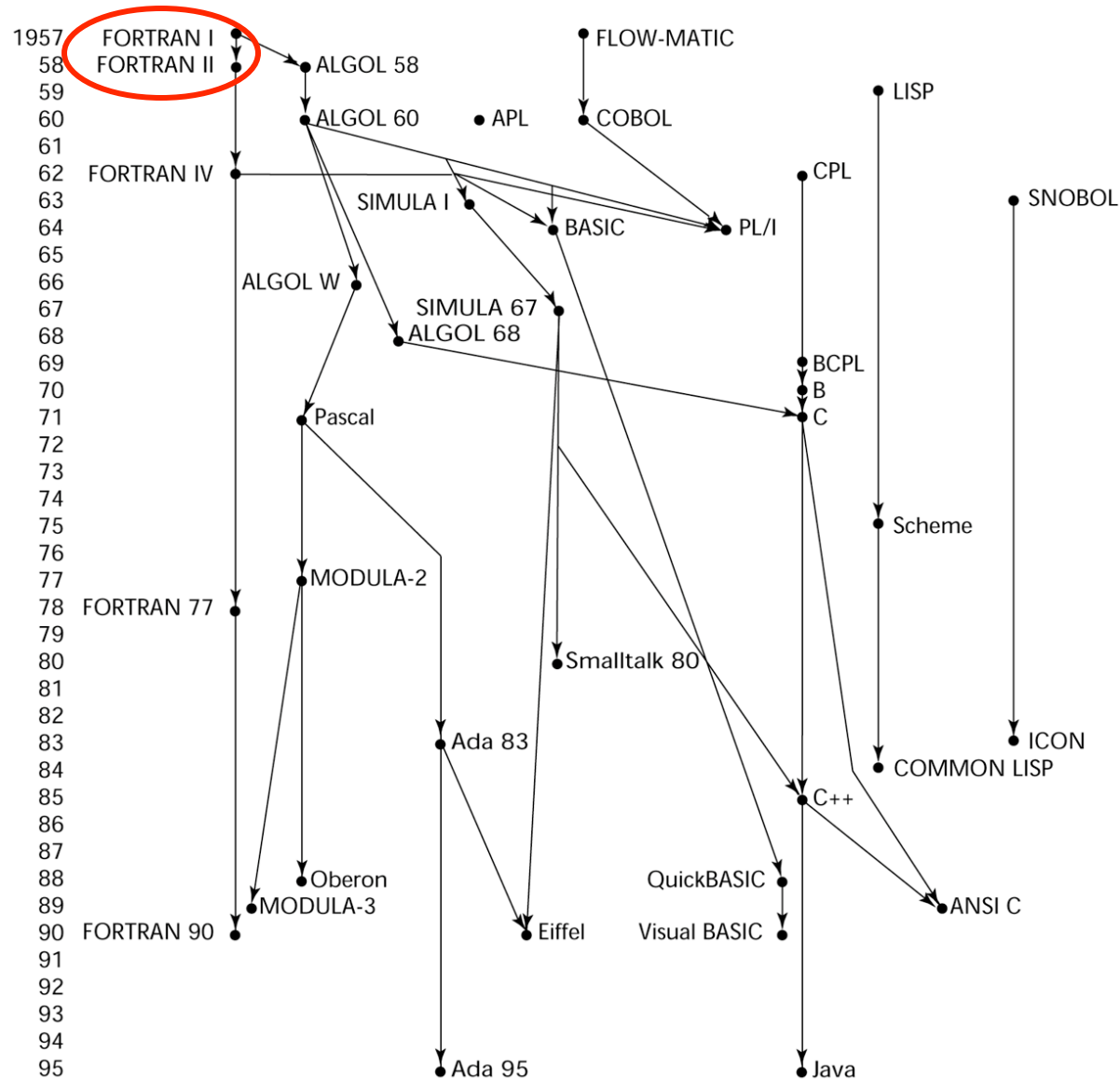
But

- Requires translation step
- Still architecture specific

```
int a = 12;
int b = 4;
int result = 0;
main () {
    if (a >= b) {
        while (a > 0) {
            a = a - b;
            result ++;
        }
    }
}
```

```
0:      andi    0           # AC = 0
      addi    12
      storei  1000        # a = 12 (a stored @ 1000)
      andi    0           # AC = 0
      addi    4
      storei  1004        # b = 4 (b stored @ 1004)
      andi    0           # AC = 0
      storei  1008        # result = 0 (result @ 1008)
main:   loadi   1004        # compute a - b in AC
      comp
      addi    1           # using 2's complement add
      add     1000
      brni    exit        # exit if AC negative
loop:   loadi   1000
      brni    endloop
      loadi   1004        # compute a - b in AC
      comp
      addi    1           # using 2's complement add
      add     1000        # Uses indirect bit I = 1
      storei  1000
      loadi   1008        # result = result + 1
      addi    1
      storei  1008
      jumpi   loop
endloop:
exit:
```

Genealogy of High-Level Languages



IBM 704 and the FORMula TRANslation Language

- State of computing technology at the time
 - Computers were resource limited and unreliable
 - Applications were scientific
 - No programming methodology or tools
 - Machine efficiency was most important
 - Programs written in key-punched cards
- As a consequence
 - Little need for dynamic storage
 - Need good array handling and counting loops
 - No string handling, decimal arithmetic, or powerful input/output (commercial stuff)
 - Inflexible lexical/syntactic structure

FORTRAN

Example

Some Improvements:

- Architecture independence
- Static Checking
- Algebraic syntax
- Functions/Procedures
- Arrays
- Better support for Structured Programming
- Device Independent I/O
- Formatted I/O

```

subroutine checksum(buffer,length,sum32)

C      Calculate a 32-bit 1's complement checksum of the input buffer, adding
C      it to the value of sum32.  This algorithm assumes that the buffer
C      length is a multiple of 4 bytes.

C      a double precision value (which has at least 48 bits of precision)
C      is used to accumulate the checksum because standard Fortran does not
C      support an unsigned integer datatype.

C      buffer - integer buffer to be summed
C      length - number of bytes in the buffer (must be multiple of 4)
C      sum32  - double precision checksum value (The calculated checksum
C              is added to the input value of sum32 to produce the
C              output value of sum32)

      integer buffer(*),length,i,hibits
      double precision sum32,word32
      parameter (word32=4.294967296D+09)
C          (word32 is equal to 2**32)

C      LENGTH must be less than 2**15, otherwise precision may be lost
C      in the sum
      if (length .gt. 32768)then
          print *, 'Error: size of block to sum is too large'
          return
      end if

      do i=1,length/4
          if (buffer(i) .ge. 0)then
              sum32=sum32+buffer(i)
          else
C              sign bit is set, so add the equivalent unsigned value
              sum32=sum32+(word32+buffer(i))
          end if
      end do

C      fold any overflow bits beyond 32 back into the word
10    hibits=sum32/word32
      if (hibits .gt. 0)then
          sum32=sum32-(hibits*word32)+hibits
          go to 10
      end if

      end

```

FORTRAN I (1957)

- First implemented version of FORTRAN
- Compiler released in April 1957 (18 worker-years of effort)
- Language Highlights
 - Names could have up to six characters
 - Post-test counting loop (**DO**)
 - Formatted I/O
 - User-defined subprograms
 - Three-way selection statement (arithmetic **IF**)
 - No data typing statements
 - No separate compilation
 - Code was very fast
 - Quickly became widely used



John W. Backus

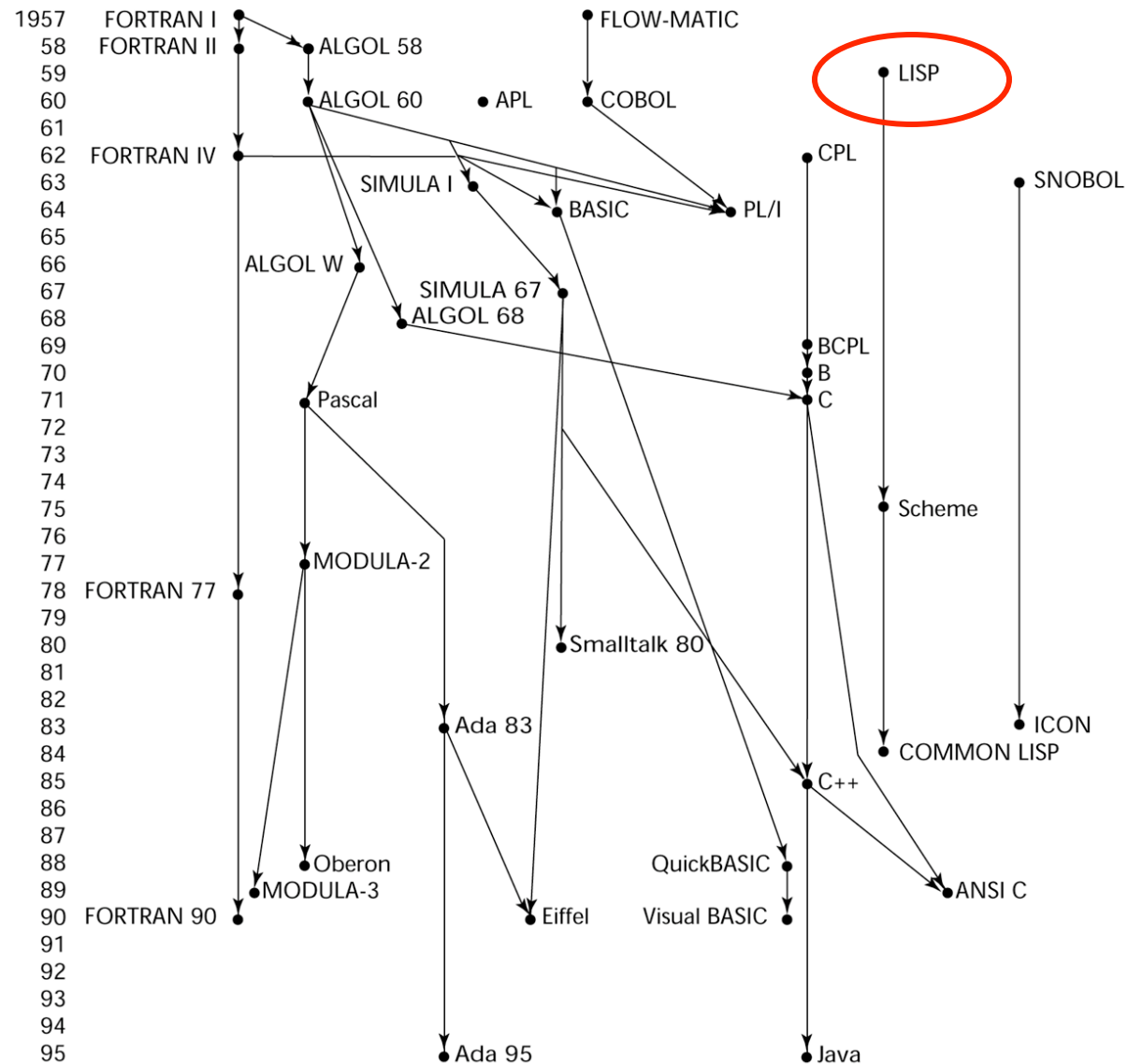
Many of these features are still dominant in current PLs

All Languages Evolve

**Fifty years and still one of
the most widely used
languages in the planet!**

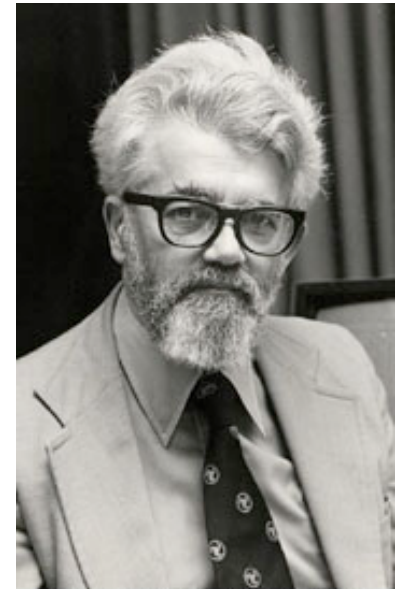
- FORTRAN 0 (1954)
- FORTRAN I (1957)
- FORTRAN II (1958)
 - Independent or separate compilation
 - Fixed compiler bugs
- FORTRAN IV (1960-62)
 - Explicit type declarations
 - Logical selection statement
 - Subprogram names could be parameters
 - ANSI standard in 1966
- FORTRAN 77 (1978)
 - Character string handling
 - Logical loop control statement
 - **IF-THEN-ELSE** statement
 - Still no recursion
- FORTRAN 90 (1990)
 - Modules
 - Dynamic arrays
 - Pointers
 - Recursion
 - **CASE** statement
 - Parameter type checking

Genealogy of High-Level Languages



LISP - 1959

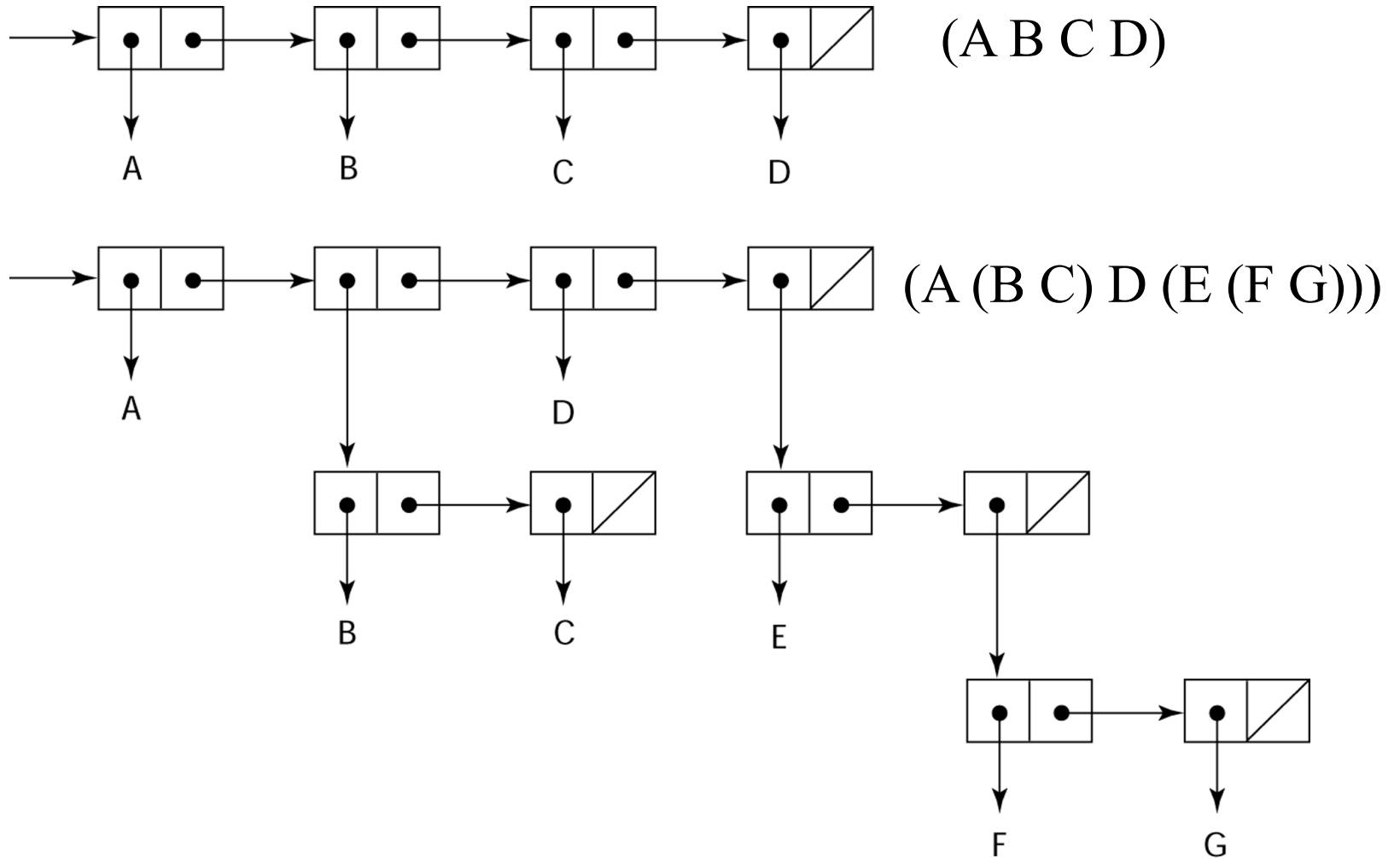
- LISt Processing language
(Designed at MIT by McCarthy)
- AI research needed a language that:
 - Process data in lists (rather than arrays)
 - Symbolic computation (rather than numeric)
- Only two data types: atoms and lists
- Syntax is based on lambda calculus
- Pioneered functional programming
 - No need for variables or assignment
 - Control via recursion and conditional expressions
- Same syntax for data and code



●Lisp 研究の権威、John McCarthy 氏

The original LISP paper is [here](#)

Representation of Two LISP Lists



Scheme Example

```
;;; From: Structure and Interpretation of Computer Programs
;;; (Harold Abelson and Gerald Jay Sussman with Julie Sussman)
```

```
;;; Added by Bjoern Hoefling (for usage with MIT-Scheme)
```

```
(define (atom? x)
  (or (number? x)
      (string? x)
      (symbol? x)
      (null? x)
      (eq? x #t)))
```

```
;;; Section 2.2.4 -- Symbolic differentiation
```

```
(define (deriv exp var)
  (cond ((constant? exp) 0)
        ((variable? exp)
         (if (same-variable? exp var) 1 0))
        ((sum? exp)
         (make-sum (deriv (addend exp) var)
                     (deriv (augend exp) var)))
        ((product? exp)
         (make-sum
          (make-product (multiplier exp)
                        (deriv (multiplicand exp) var))
          (make-product (deriv (multiplier exp) var)
                        (multiplicand exp))))))
```

```
(define (constant? x) (number? x))
```

```
(define (variable? x) (symbol? x))
```

```
(define (same-variable? v1 v2)
  (and (variable? v1) (variable? v2) (eq? v1 v2)))
```

```
(define (make-sum a1 a2) (list '+ a1 a2))
```

```
(define (make-product m1 m2) (list '* m1 m2))
```

```
(define (sum? x)
  (if (not (atom? x)) (eq? (car x) '+) nil))
```

```
(define (addend s) (cadr s))
```

```
(define (augend s) (caddr s))
```

```
(define (product? x)
  (if (not (atom? x)) (eq? (car x) '*) nil))
```

```
(define (multiplier p) (cadr p))
```

```
(define (multiplicand p) (caddr p))
```

```
;;; examples from the textbook
```

```
(deriv '(+ x 3) 'x)
;Value 1: (+ 1 0)
(deriv '(* x y) 'y)
;Value 2: (+ (* x 1) (* 0 y))
(deriv '(* (* x y) (+ x 3)) 'x)
;Value 3: (+ (* (* x y) (+ 1 0)) (* (+ (* x 0) (* 1 y)) (+ x 3)))
```

```
;;; Better versions of make-sum and make-product
```

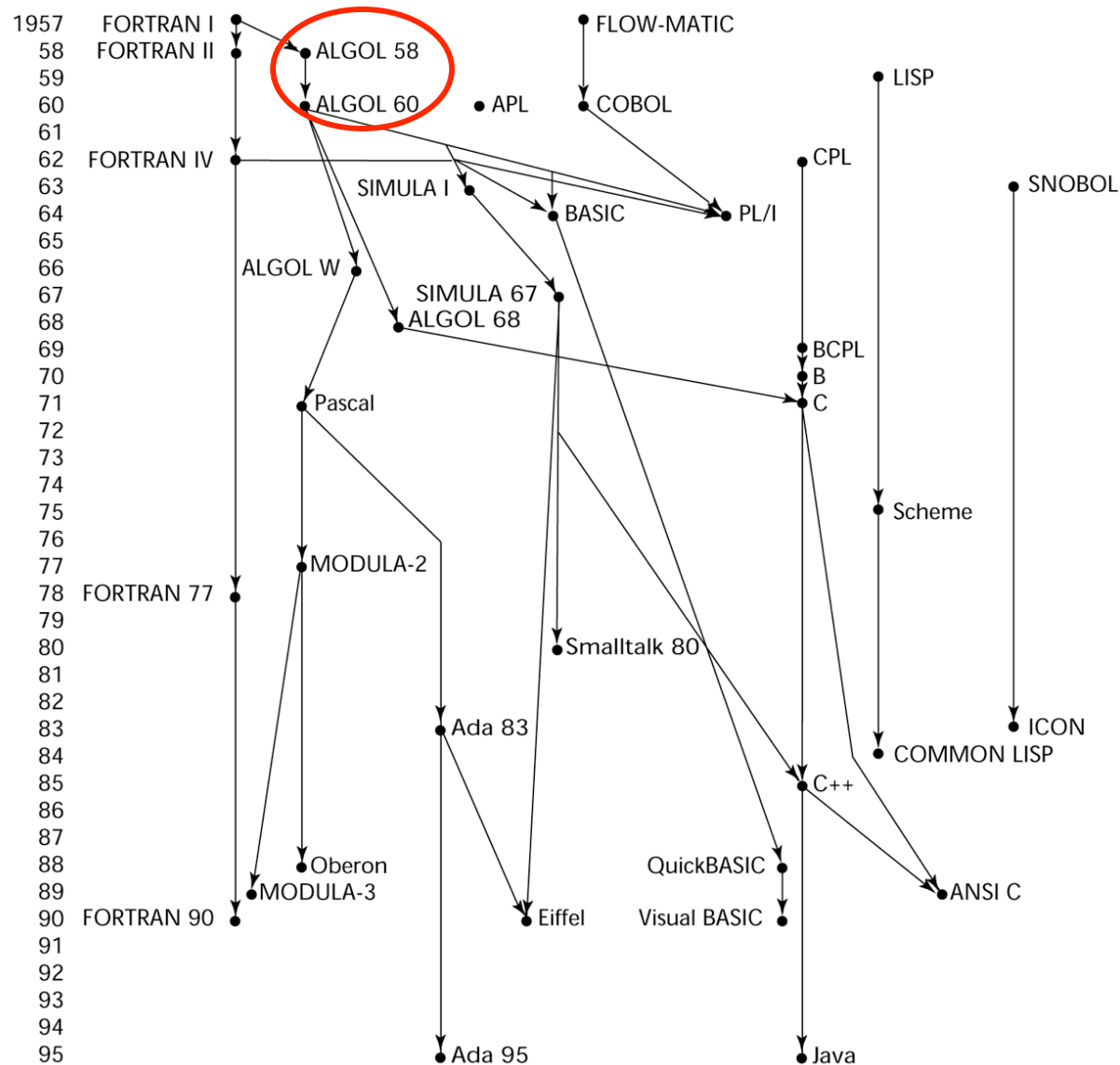
```
(define (make-sum a1 a2)
  (cond ((and (number? a1) (number? a2)) (+ a1 a2))
        ((number? a1) (if (= a1 0) a2 (list '+ a1 a2)))
        ((number? a2) (if (= a2 0) a1 (list '+ a1 a2)))
        (else (list '+ a1 a2))))
```

```
(define (make-product m1 m2)
  (cond ((and (number? m1) (number? m2)) (* m1 m2))
        ((number? m1)
         (cond ((= m1 0) 0)
               ((= m1 1) m2)
               (else (list '* m1 m2))))
        ((number? m2)
         (cond ((= m2 0) 0)
               ((= m2 1) m1)
               (else (list '* m1 m2))))
        (else (list '* m1 m2))))
```

```
;;; same examples as above
```

```
(deriv '(+ x 3) 'x)
;Value: 1
(deriv '(* x y) 'y)
;Value: x
(deriv '(* (* x y) (+ x 3)) 'x)
;Value 4: (+ (* x y) (* y (+ x 3)))
```

Genealogy of High-Level Languages



ALGOL 58 and 60

- State of Affairs
 - FORTRAN had (barely) arrived for IBM 70x
 - Many other languages were being developed, all for specific machines
 - No portable language; all were machine-dependent
 - No universal language for communicating algorithms
- ACM and GAMM met for four days for design
- Goals of the language:
 - Close to mathematical notation
 - Good for describing algorithms
 - Must be translatable to machine code

ALGOL 58

- New language features:
 - Concept of type was formalized
 - Names could have any length
 - Arrays could have any number of subscripts
 - Parameters were separated by mode (in & out)
 - Subscripts were placed in brackets
 - Compound statements (**begin** ... **end**)
 - Semicolon as a statement separator. Free format syntax.
 - Assignment operator was :=
 - **if** had an **else-if** clause
 - No I/O - “would make it machine dependent”

ALGOL 60

- Modified ALGOL 58 at 6-day meeting in Paris
- New language features:
 - Block structure (local scope)
 - Two parameter passing methods
 - Subprogram recursion
 - Stack-dynamic arrays
 - Still no I/O and no string handling
- Successes:
 - It was the standard way to publish algorithms for over 20 years
 - All subsequent imperative languages are based on it
 - First machine-independent language
 - First language whose syntax was formally defined (BNF)

ALGOL 60

- Failure:
 - Never widely used, especially in U.S.
- Possible Reasons:
 - No I/O and the character set made programs non-portable
 - Too flexible--hard to implement
 - Entrenchment of FORTRAN
 - Formal syntax description
 - Lack of support of IBM

Good isn't always popular

Algol 60 Example

```
'begin'
  'comment'
    create some random numbers, print them and
    print the average.
  ;

  'integer' NN;

  NN := 20;

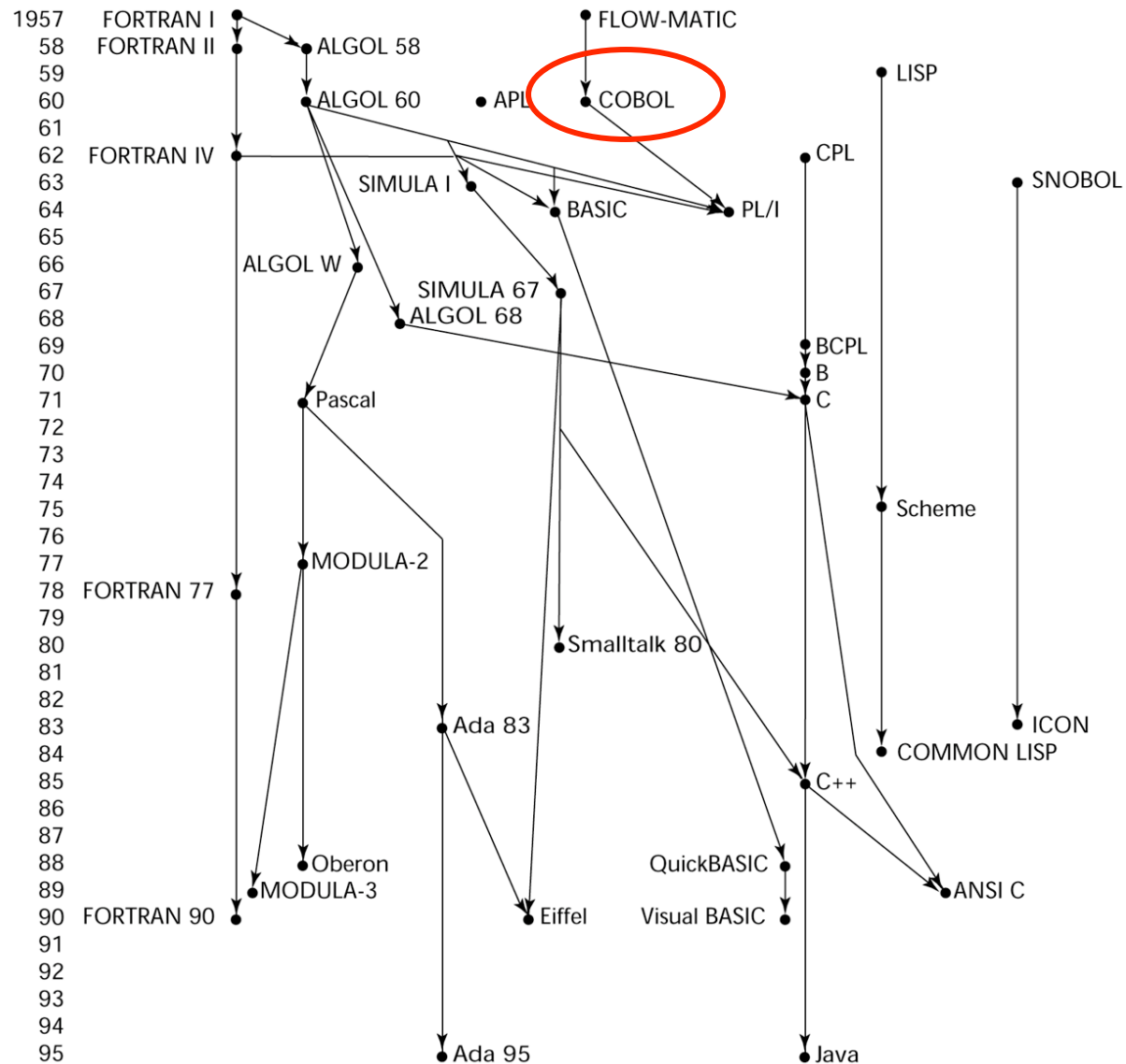
  'begin'
    'integer' i;
    'real' sum;

    vprint ("random numbers:");

    sum := 0;
    'for' i := 1 'step' 1 'until' NN 'do' 'begin'
      'real' x;
      x := rand;
      sum := sum + x;
      vprint (i, x)
    'end';

    vprint ("average is:", sum / NN)
  'end'
'end'
```


Genealogy of High-Level Languages



COBOL

- Contributions:
 - First macro facility in a high-level language
 - Hierarchical data structures (records)
 - Nested selection statements
 - Long names (up to 30 characters), with hyphens
 - Separate data division
- Comments:
 - First language required by DoD
 - Still the most widely used business applications language

Cobol Example

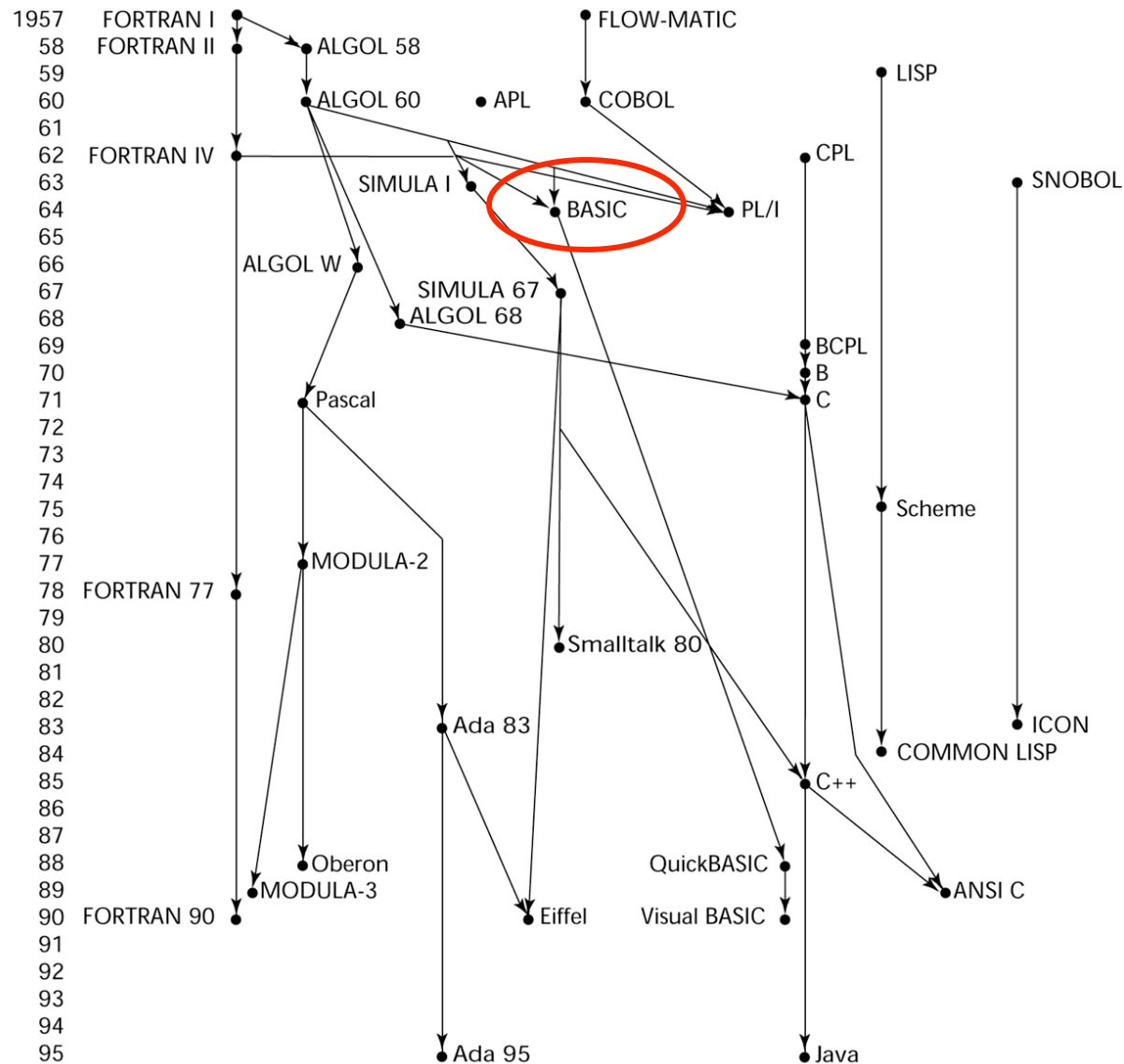
```
$ SET SOURCEFORMAT"FREE"

IDENTIFICATION DIVISION.
PROGRAM-ID. Iteration-If.
AUTHOR. Michael Coughlan.

DATA DIVISION.
WORKING-STORAGE SECTION.
01 Num1      PIC 9  VALUE ZEROS.
01 Num2      PIC 9  VALUE ZEROS.
01 Result    PIC 99 VALUE ZEROS.
01 Operator  PIC X  VALUE SPACE.

PROCEDURE DIVISION.
Calculator.
    PERFORM 3 TIMES
        DISPLAY "Enter First Number   : " WITH NO ADVANCING
        ACCEPT Num1
        DISPLAY "Enter Second Number  : " WITH NO ADVANCING
        ACCEPT Num2
        DISPLAY "Enter operator (+ or *) : " WITH NO ADVANCING
        ACCEPT Operator
        IF Operator = "+" THEN
            ADD Num1, Num2 GIVING Result
        END-IF
        IF Operator = "*" THEN
            MULTIPLY Num1 BY Num2 GIVING Result
        END-IF
        DISPLAY "Result is = ", Result
    END-PERFORM.
STOP RUN.
```

Genealogy of High-Level Languages



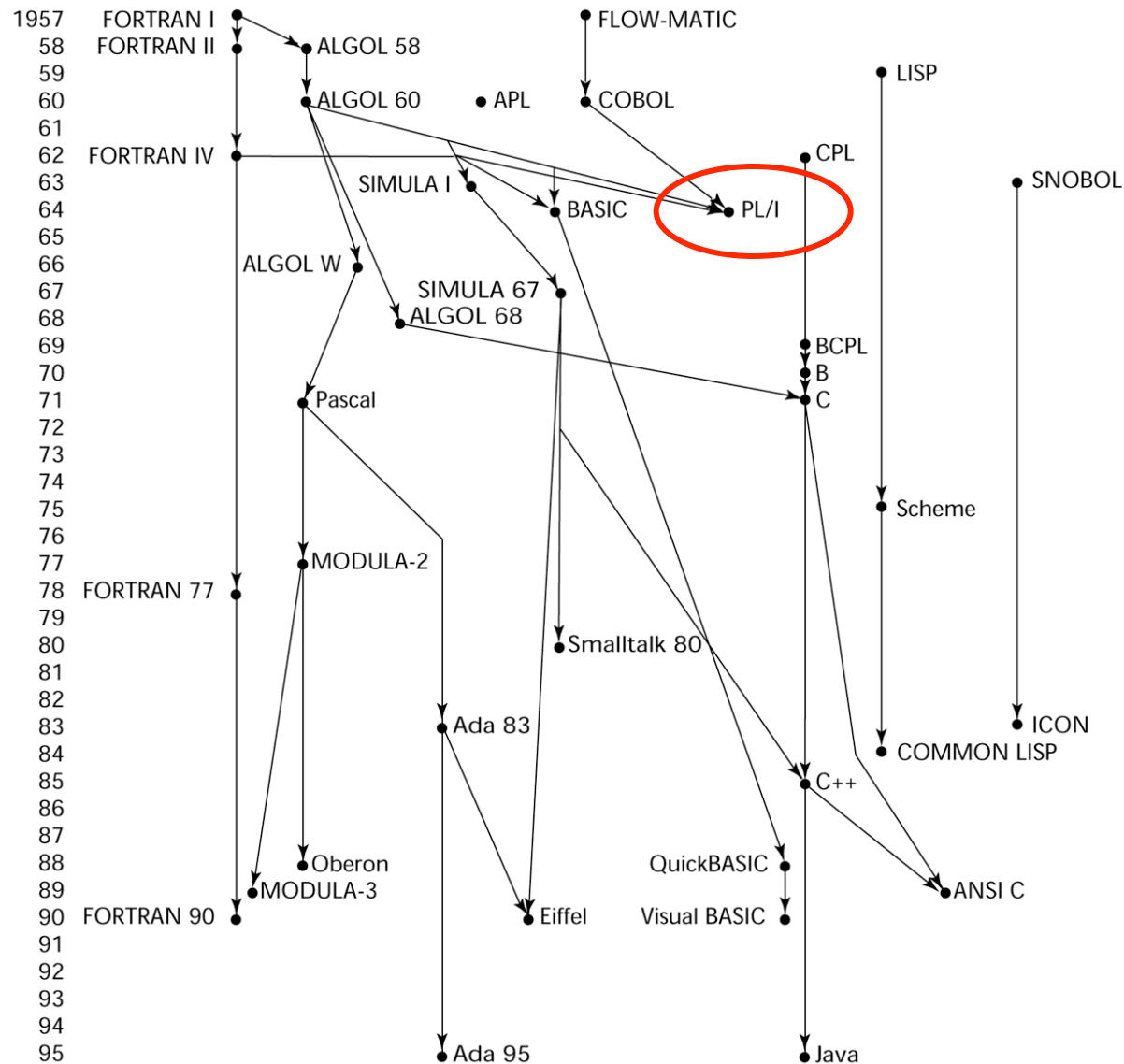
BASIC - 1964

- Designed by Kemeny & Kurtz at Dartmouth
- Design Goals:
 - Easy to learn and use for non-science students
 - Must be “pleasant and friendly”
 - Fast turnaround for homework
 - Free and private access
 - User time is more important than computer time
- Current popular dialect: Visual BASIC
- First widely used language with time sharing

Basic Example

```
1 DIM A(9)
10 PRINT "          TIC-TAC-TOE"
20 PRINT
30 PRINT "WE NUMBER THE SQUARES LIKE THIS:"
40 PRINT
50 PRINT 1,2,3
55 PRINT: PRINT
60 PRINT 4,5,6
70 PRINT 7,8,9
75 PRINT
80 FOR I=1 TO 9
90 A(I)=0
95 NEXT I
97 C=0
100 IF RND (2)=1 THEN 150           (flip a coin for first move)
110 PRINT "I'LL GO FIRST THIS TIME"
120 C=1
125 A(5)=1                         (computer always takes
130 PRINT                          the center)
135 GOSUB 1000
140 goto 170
150 print "YOU MOVE FIRST"
160 PRINT
170 INPUT "WHICH SPACE DO YOU WANT",B
180 IF A(B)=0 THEN 195
185 PRINT "ILLEGAL MOVE"
190 GOTO 170
195 C=C+1                           (C is the move counter)
200 A(B)=1
205 GOSUB 1700
209 IF G=0 THEN 270                (G is the flag signaling
211 IF C=9 THEN 260                 a win)
213 GOSUB 1500
215 C=C+1
220 GOSUB 1000
230 GOSUB 1700
235 IF G=0 THEN 270
250 IF C<9 THEN 170
260 PRINT "TIE GAME!!!"
265 PRINT
270 INPUT "PLAY AGAIN (Y OR N)",A$
275 IF A$="Y" THEN 80               (No need to Dimension a string
280 PRINT "SO LONG"                 with length of one)
285 END
995 REM *PRINT THE BOARD*
1000 FOR J=1 TO 3
1010 TAB 6
1020 PRINT "*";
1030 TAB 12
```

Genealogy of High-Level Languages



PL/I - 1965

- Designed by IBM and SHARE
- Computing situation in 1964 (IBM's point of view)
 - Scientific computing
 - IBM 1620 and 7090 computers
 - FORTRAN
 - SHARE user group
 - Business computing
 - IBM 1401, 7080 computers
 - COBOL
 - GUIDE user group
 - Compilers expensive and hard to maintain

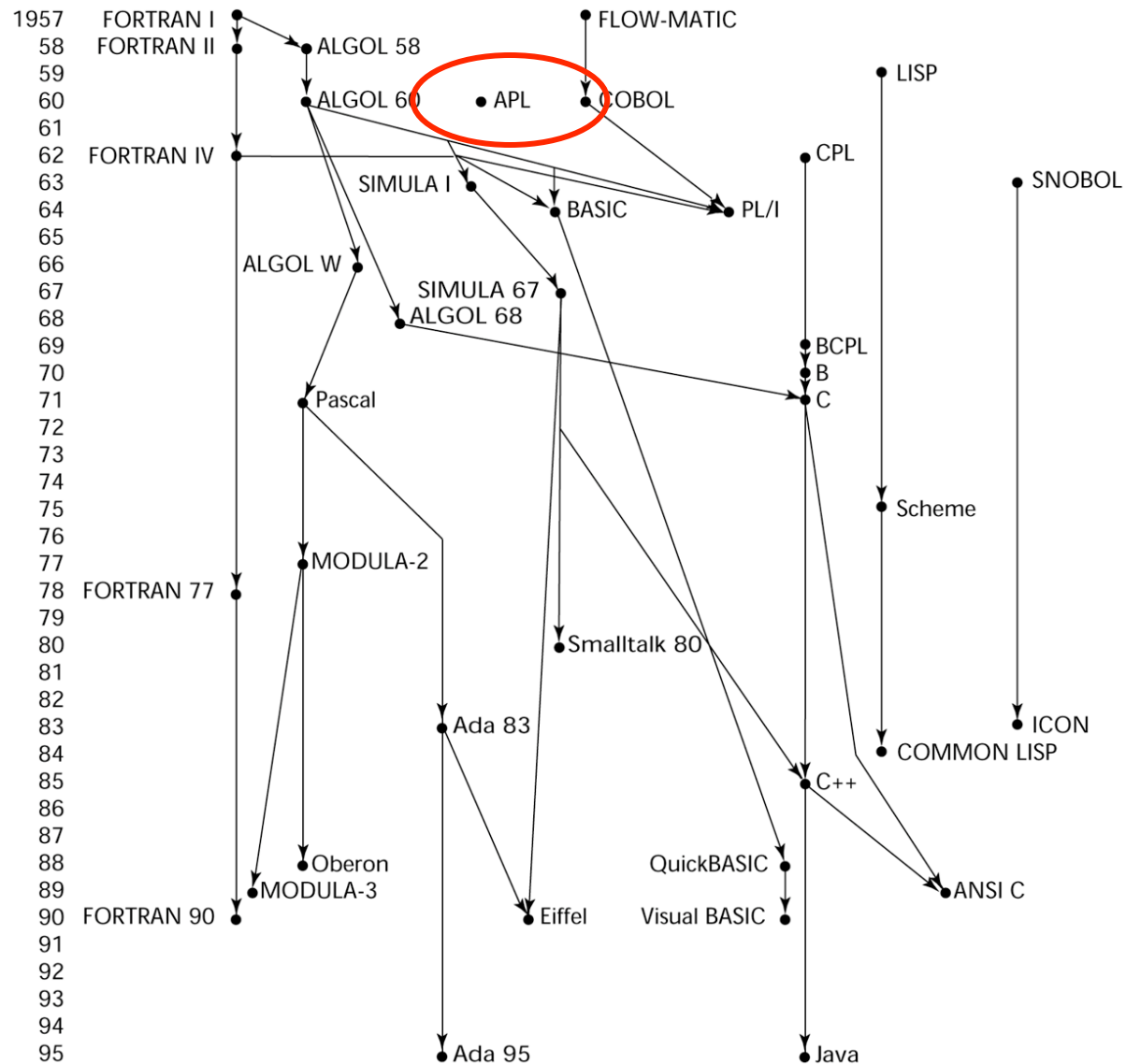
PL/I

- By 1963, however,
 - Scientific users began to need more elaborate I/O, like COBOL had; Business users began to need floating point and arrays (MIS)
 - It looked like many shops would begin to need two kinds of computers, languages, and support staff-- too costly
- The obvious solution:
 - Build a new computer to do both kinds of applications
 - Design a new language to do both kinds of applications

PL/I

- Designed in five months by the 3 X 3 Committee
- PL/I contributions:
 - First unit-level concurrency
 - First exception handling
 - Switch-selectable recursion
 - First pointer data type
 - First array cross sections
- Comments:
 - Many new features were poorly designed
 - Too large and too complex
 - Was (and still is) actually used for both scientific and business applications

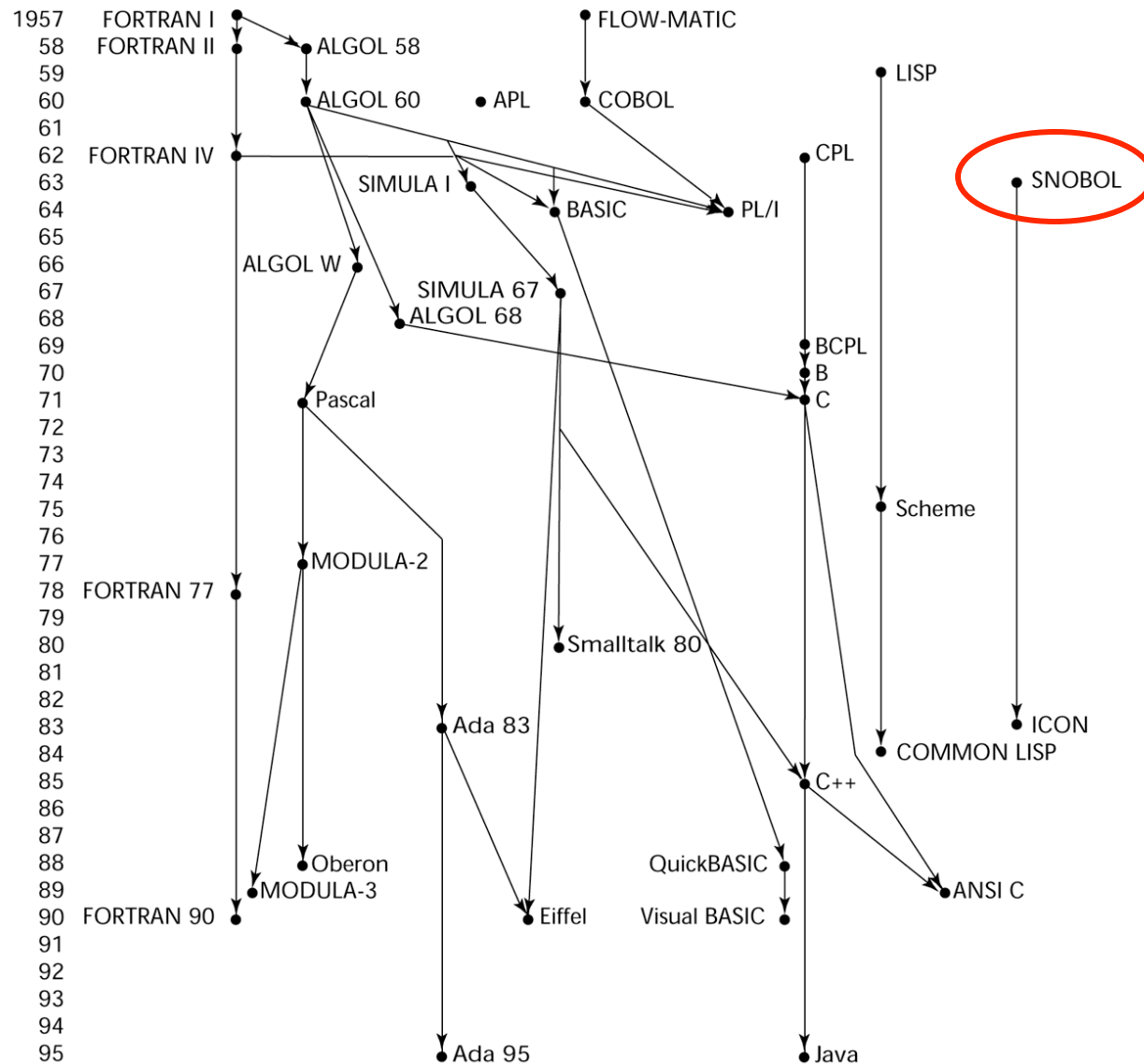
Genealogy of High-Level Languages



APL (1962)

- Characterized by dynamic typing and dynamic storage allocation
- APL (A Programming Language) 1962
 - Designed as a hardware description language (at IBM by Ken Iverson)
 - Highly expressive (many operators, for both scalars and arrays of various dimensions)
 - Programs are very difficult to read

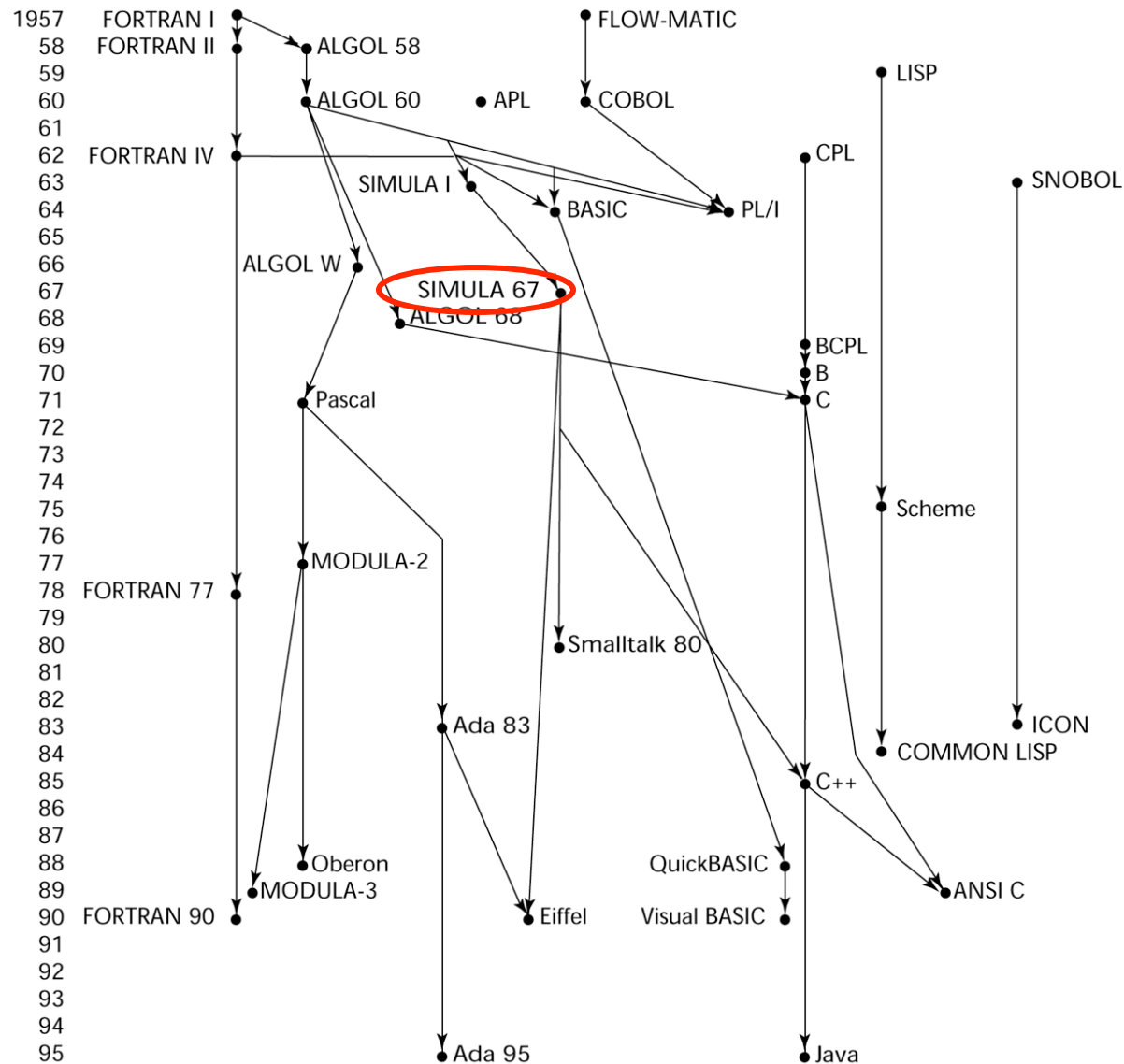
Genealogy of High-Level Languages



SNOBOL (1964)

- A string manipulation special purpose language
- Designed as language at Bell Labs by Farber, Griswold, and Polensky
- Powerful operators for string pattern matching

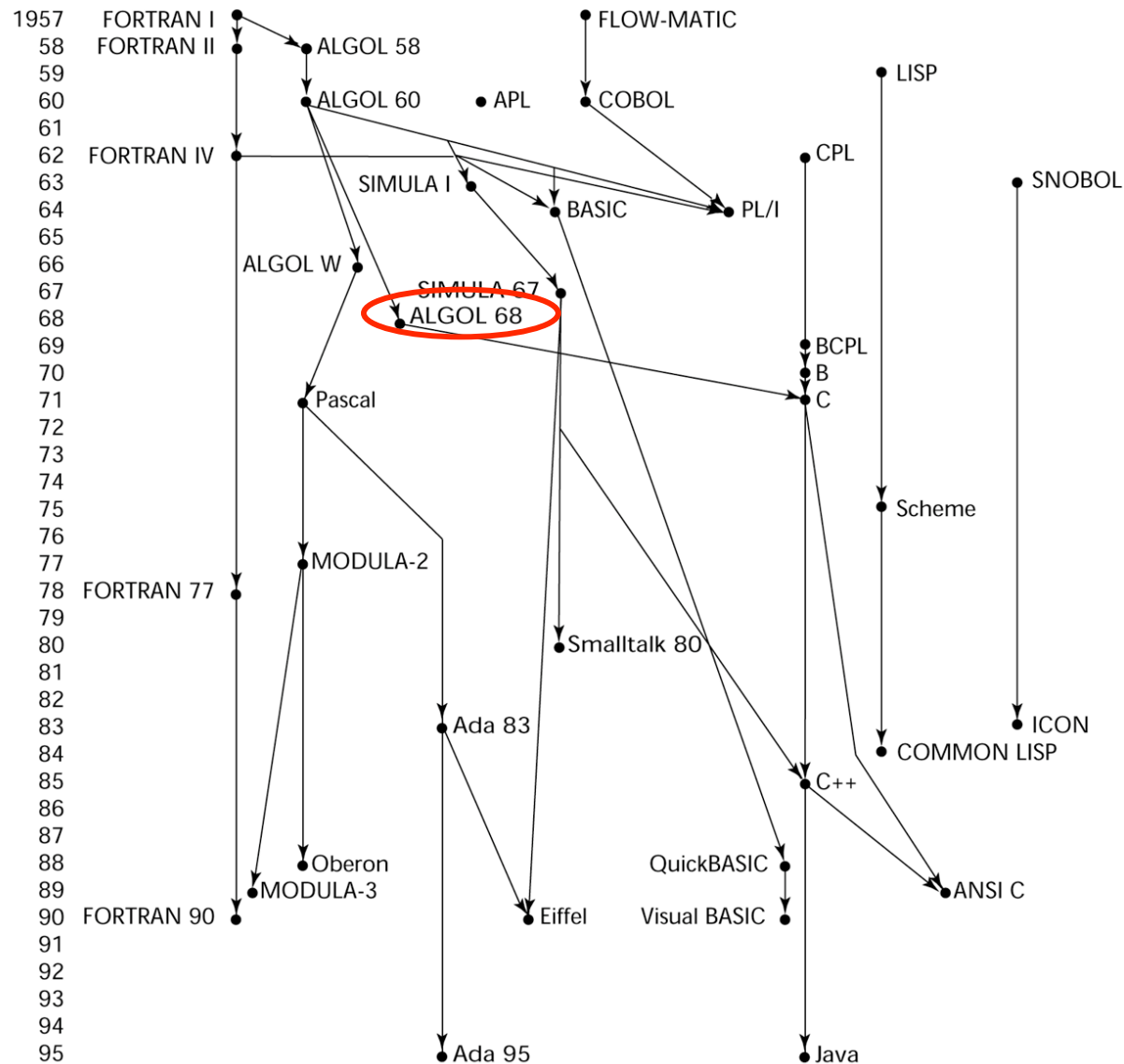
Genealogy of High-Level Languages



SIMULA 67 (1967)

- Designed primarily for system simulation (in Norway by Nygaard and Dahl)
- Based on ALGOL 60 and SIMULA I
- Primary Contribution:
 - Co-routines - a kind of subprogram
 - Implemented in a structure called a class
 - Classes are the basis for data abstraction
 - Classes are structures that include both local data and functionality
 - Supported objects and inheritance

Genealogy of High-Level Languages



ALGOL 68 (1968)

- Derived from, but not a superset of Algol 60
- Design goal is orthogonality
- Contributions:
 - User-defined data structures
 - Reference types
 - Dynamic arrays (called flex arrays)
- Comments:
 - Had even less usage than ALGOL 60
 - Had strong influence on subsequent languages, especially Pascal, C, and Ada

Important ALGOL Descendants I

- Pascal - 1971 (Wirth)
 - Designed by Wirth, who quit the ALGOL 68 committee (didn't like the direction of that work)
 - Designed for teaching structured programming
 - Small, simple, nothing really new
 - From mid-1970s until the late 1990s, it was the most widely used language for teaching programming in colleges
- C – 1972 (Dennis Richie)
 - Designed for systems programming
 - Evolved primarily from B, but also ALGOL 68
 - Powerful set of operators, but poor type checking
 - Initially spread through UNIX



Important ALGOL Descendants II

- Modula-2 - mid-1970s (Wirth)
 - Pascal plus modules and some low-level features designed for systems programming
- Modula-3 - late 1980s (Digital & Olivetti)
 - Modula-2 plus classes, exception handling, garbage collection, and concurrency
- Oberon - late 1980s (Wirth)
 - Adds support for OOP to Modula-2
 - Many Modula-2 features were deleted (e.g., **for** statement, enumeration types, **with** statement, noninteger array indices)

Prolog - 1972

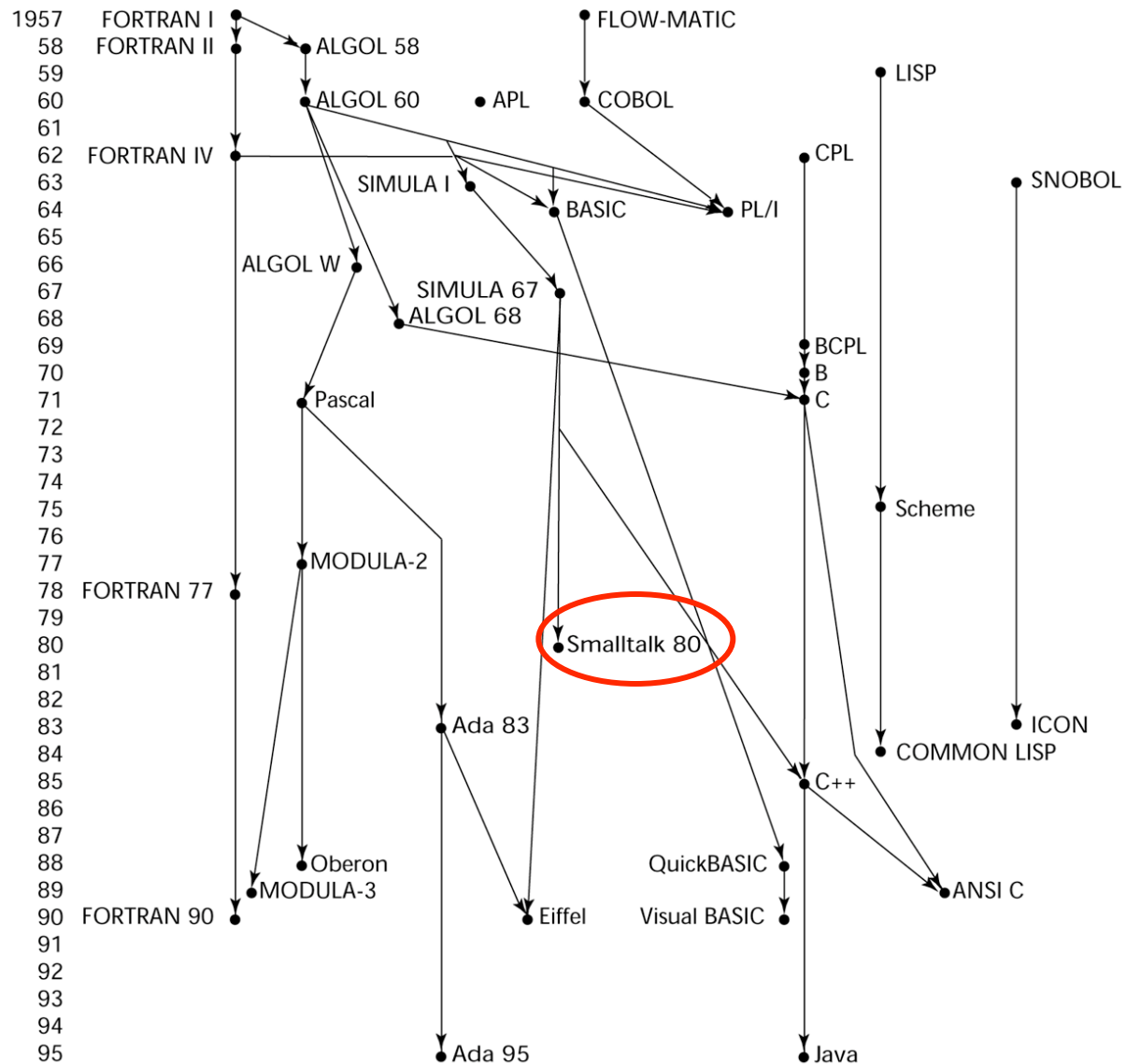


- Developed at the University of Aix-Marseille, by Comerauer and Roussel, with some help from Kowalski at the University of Edinburgh
- Based on formal logic
- Non-procedural
- Can be summarized as being an intelligent database system that uses an inference process to infer the truth of given queries

Prolog Examples

```
fac1(0,1).  
fac1(M,N) :- M1 is M-1, fac1(M1,N1), N is M*N1.  
  
fac2(M,1) :- M =<0.  
fac2(M,N) :- M1 is M-1, fac2(M1,N1), N is M*N1.  
  
fac3(M,1) :- M =<0, !.  
fac3(M,N) :- M1 is M-1, fac3(M1,N1), N is M*N1.
```

Genealogy of High-Level Languages

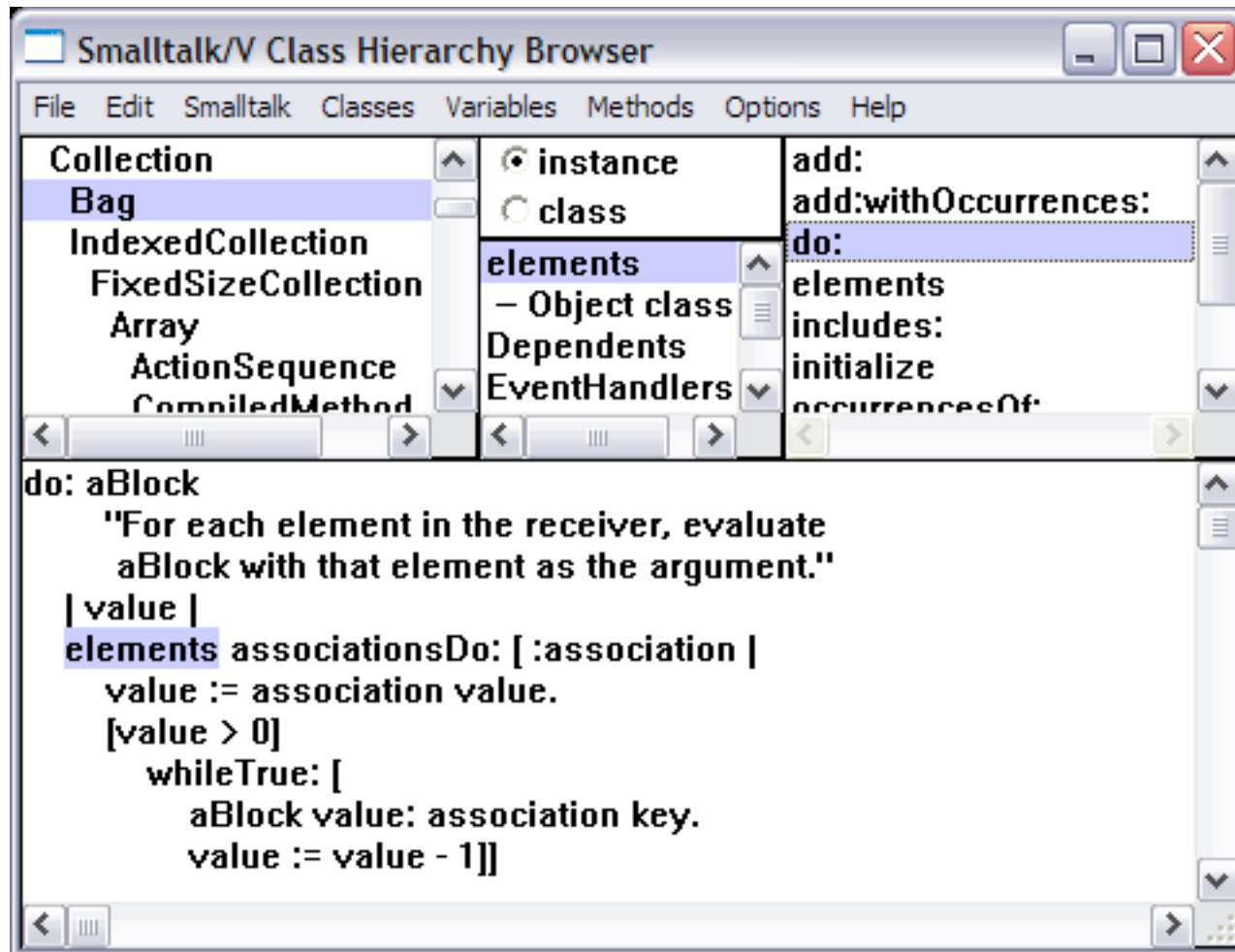


Smalltalk - 1972-1980

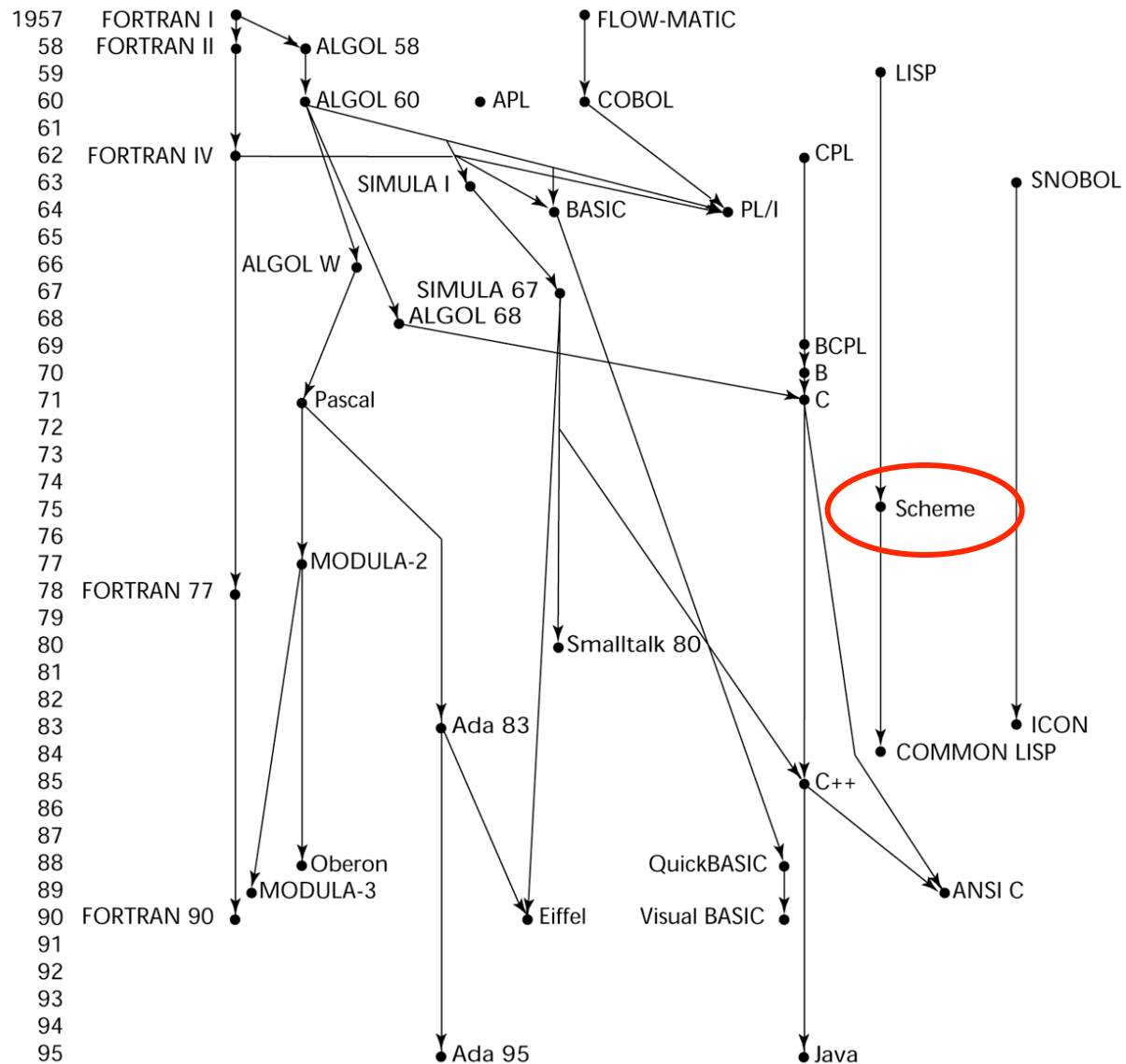
- Developed at Xerox PARC, initially by Alan Kay, later by Adele Goldberg
- First full implementation of an object-oriented language (data abstraction, inheritance, and dynamic type binding)
- Pioneered the graphical user interface everyone now uses



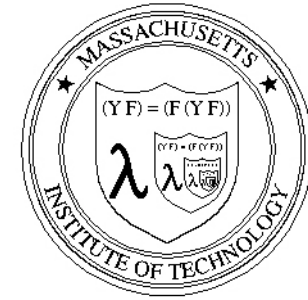
Smalltalk - 1972-1980



Genealogy of High-Level Languages



Scheme (1970's)



- MIT's dear programming language
- Designed by Gerald J. Sussman and Guy Steele Jr
- LISP with static scoping and closures
- Compiled code coexists with interpreted code
- Garbage collection
- Tail recursion
- Explicit Continuations

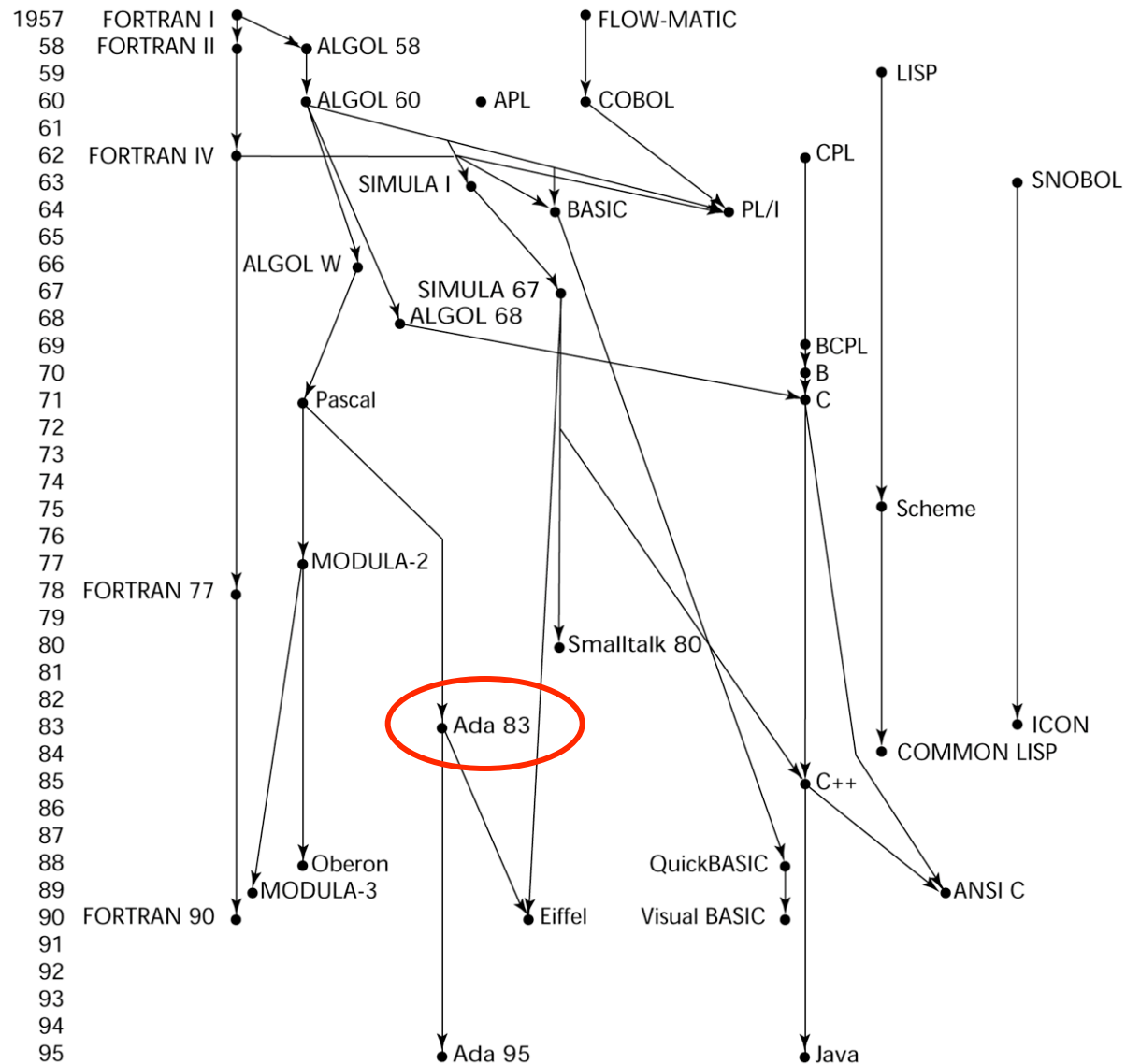


Sussman



Steele

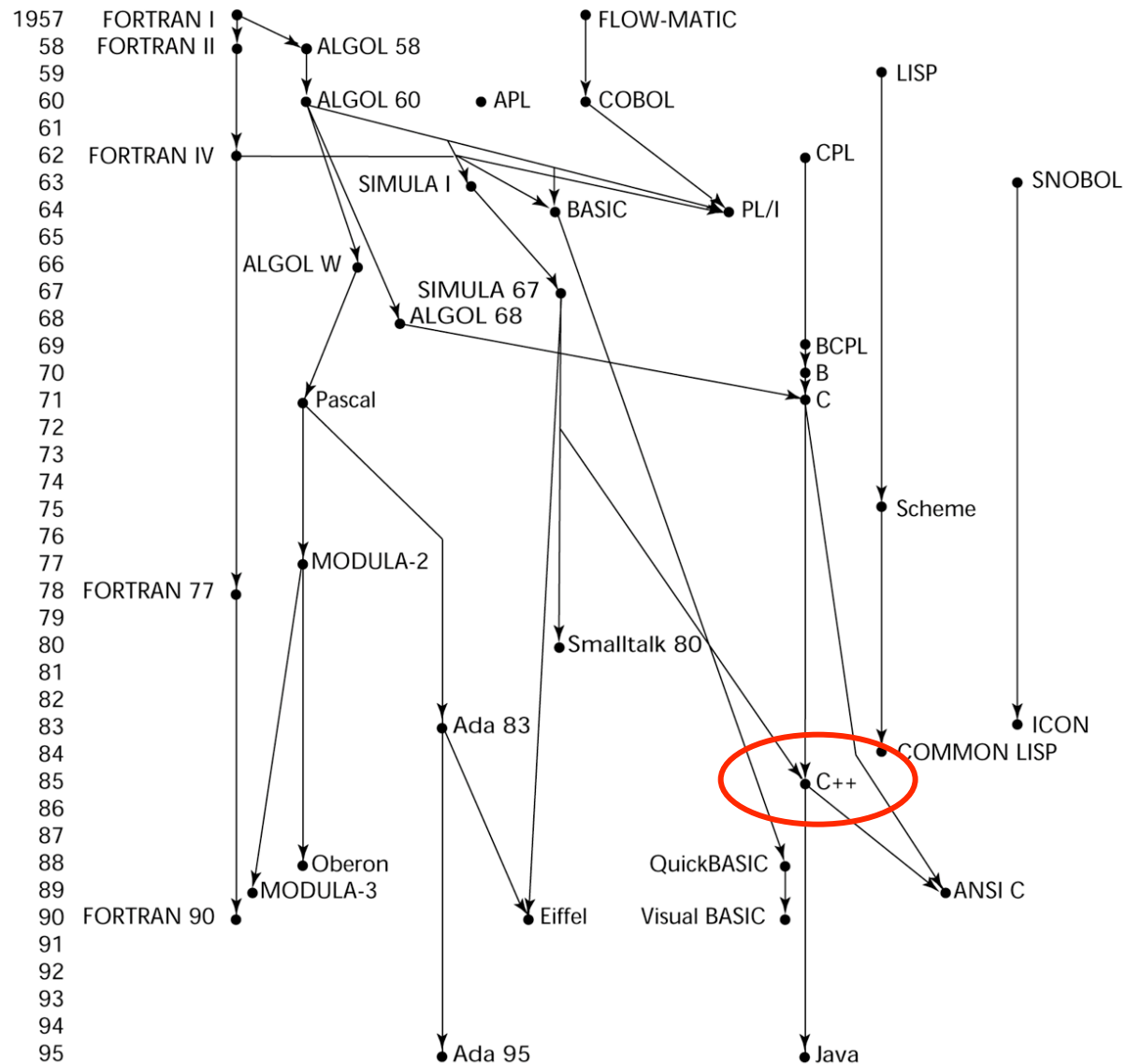
Genealogy of High-Level Languages



Ada - 1983 (began in mid-1970s)

- Huge design effort, involving hundreds of people, much money, and about eight years
- Environment: More than 450 different languages being used for DOD embedded systems (no software reuse and no development tools)
- Contributions:
 - Packages - support for data abstraction
 - Exception handling - elaborate
 - Generic program units
 - Concurrency - through the tasking model
- Comments:
 - Competitive design
 - Included all that was then known about software engineering and language design
 - First compilers were very difficult; the first really usable compiler came nearly five years after the language design was completed

Genealogy of High-Level Languages



C++ (1985)

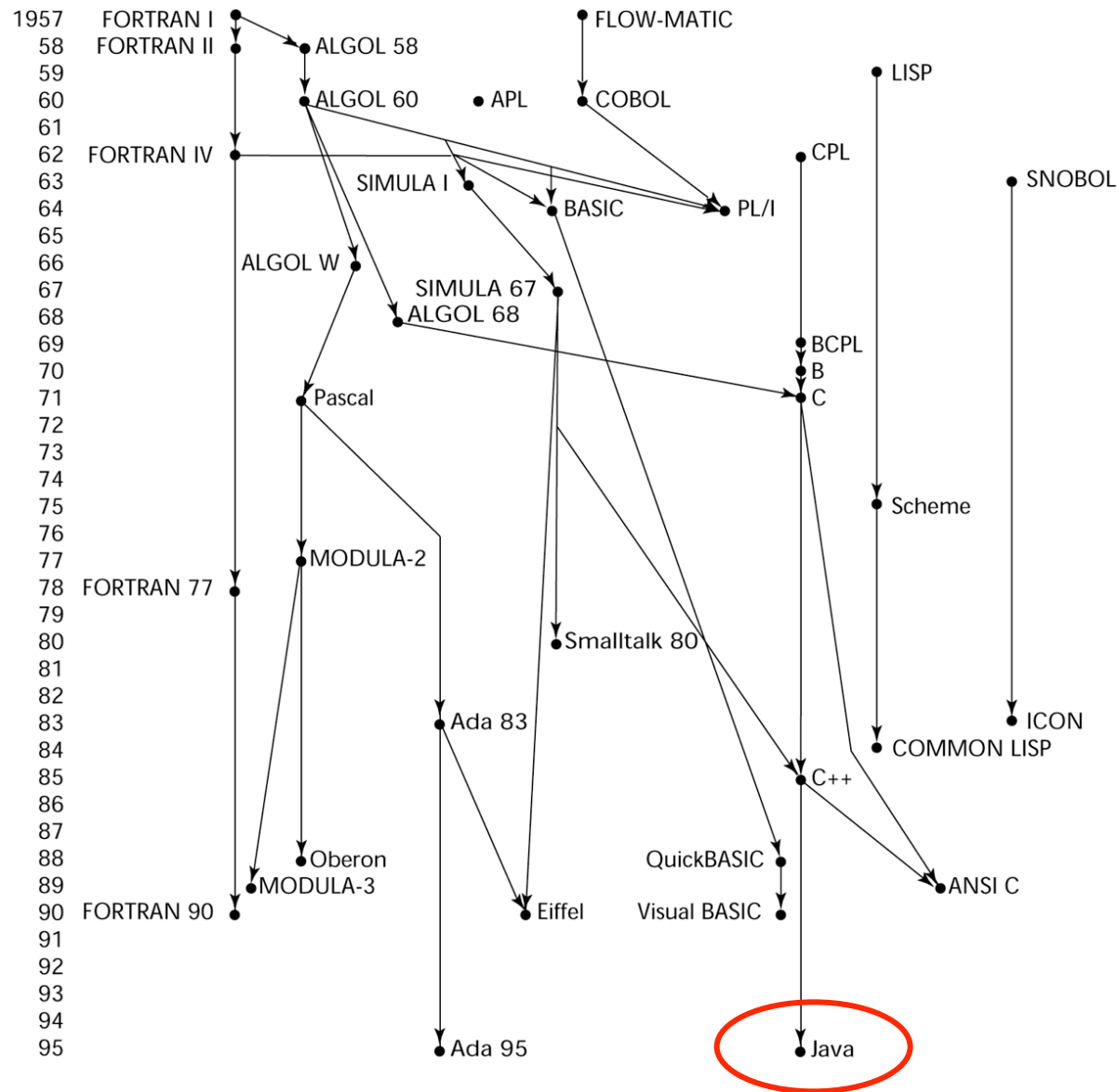


- Developed at Bell Labs by Bjarne Stroustrup
- Evolved from C and SIMULA 67
- Facilities for object-oriented programming, taken partially from SIMULA 67, were added to C
- Also has exception handling
- A large and complex language, in part because it supports both procedural and OO programming
- Rapidly grew in popularity, along with OOP
- ANSI standard approved in November, 1997

C++ Related Languages

- Eiffel - a related language that supports OOP
 - (Designed by Bertrand Meyer - 1992)
 - Not directly derived from any other language
 - Smaller and simpler than C++, but still has most of the power
- Delphi (Borland)
 - Pascal plus features to support OOP
 - More elegant and safer than C++

Genealogy of High-Level Languages



Java (1995)

- Developed at Sun in the early 1990s
- Based on C++
 - Significantly simplified (does not include **struct**, **union**, **enum**, pointer arithmetic, and half of the assignment coercions of C++)
 - Supports *only* OOP
 - No multiple inheritance
 - Has references, but not pointers
 - Includes support for applets and a form of concurrency
 - Portability was “Job #1”

Scripting Languages for the Web

- JavaScript
 - Used in Web programming (client-side) to create dynamic HTML documents
 - Related to Java only through similar syntax
- PHP
 - Used for Web applications (server-side); produces HTML code as output
- Perl
- JSP
- Python

C#

- Part of the .NET development platform
- Based on C++ and Java
- Provides a language for component-based software development
- All .NET languages (C#, Visual BASIC.NET, Managed C++, J#.NET, and Jscript.NET) use Common Type System (CTS), which provides a common class library
- Likely to become widely used

Some Important Special Purpose Languages

- SQL
 - Relational Databases
- LaTeX
 - Document processing and typesetting
- HTML
 - Web page
- XML
 - Platform independent data representation
- UML
 - Software system specification
- VHDL
 - Hardware description language

Website with lots of examples in
different programming languages old
and new

http://www.ntecs.de/old-hp/uu9r/lang/html/lang.en.html#_link_sather

Strongly
recommended
for the curious mind!



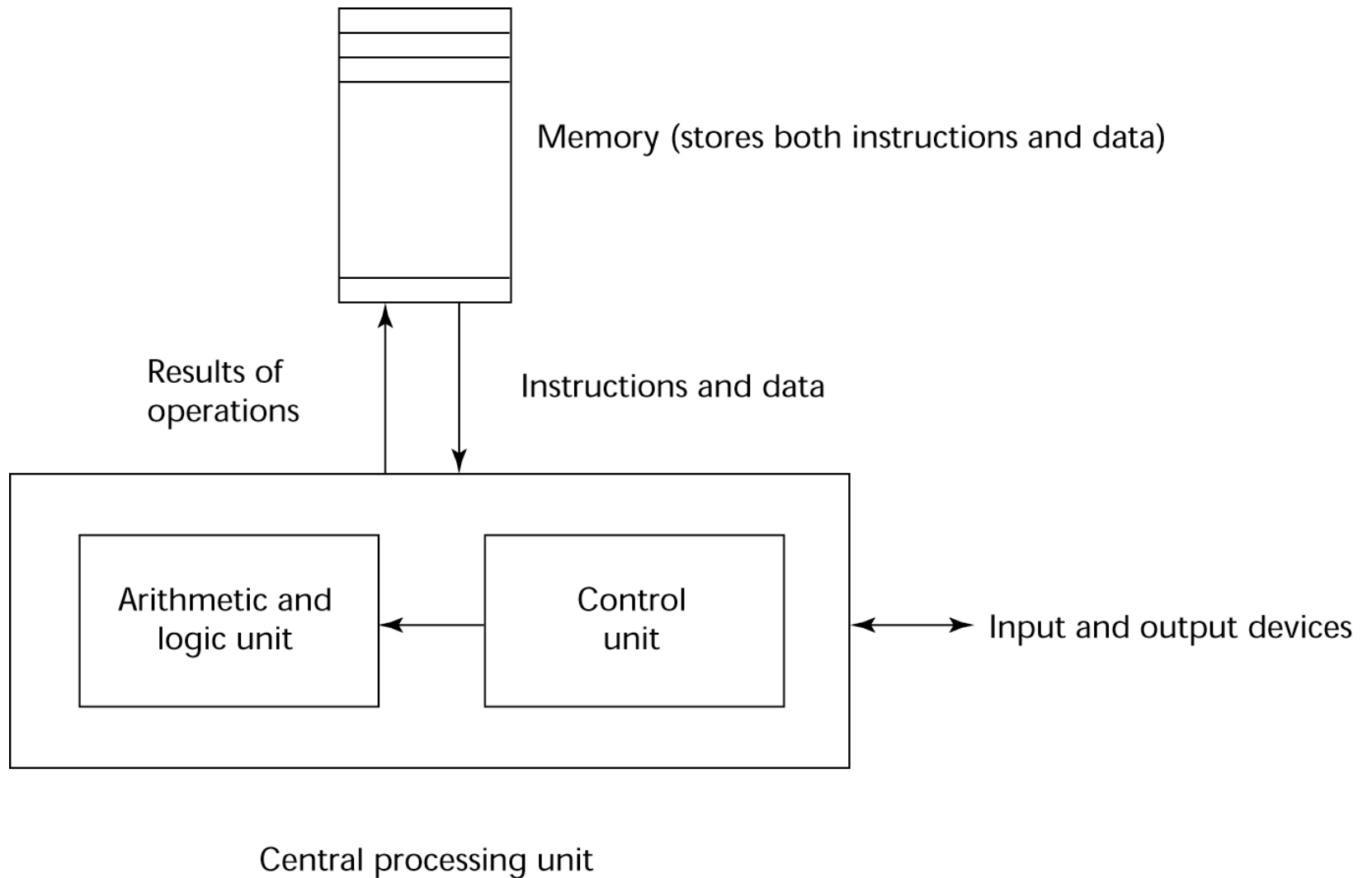
END OF LECTURE 1

EXTRA SLIDES

Influences on Language Design

- Computer architecture: Von Neumann
- We use imperative languages, at least in part, because we use von Neumann machines
 - Data and programs stored in same memory
 - Memory is separate from CPU
 - Instructions and data are piped from memory to CPU
- Basis for imperative languages
 - Variables model memory cells
 - Assignment statements model piping
 - Iteration is efficient

Von Neumann Architecture



LISP

- Pioneered functional programming
 - No need for variables or assignment
 - Control via recursion and conditional expressions
- Still the dominant language for AI
- COMMON LISP and Scheme are contemporary dialects of LISP
- ML, Miranda, and Haskell are related languages

Zuse's Plankalkül - 1945

- Never implemented
- Advanced data structures
 - floating point, arrays, records
- Invariants

Plankalkül

- Notation:

$$A[7] = 5 * B[6]$$

		5 * B =>	A	
V		6	7	(subscripts)
S		1.n	1.n	(data types)

Pseudocodes - 1949

- What was wrong with using machine code?
 - Poor readability
 - Poor modifiability
 - Expression coding was tedious
 - Machine deficiencies--no indexing or floating point

Pseudocodes

- Short code; 1949; BINAC; Mauchly
 - Expressions were coded, left to right
 - Some operations:
 - $1n \Rightarrow (n+2)\text{nd power}$
 - $2n \Rightarrow (n+2)\text{nd root}$
 - $07 \Rightarrow \text{addition}$

Pseudocodes

- Speedcoding; 1954; IBM 701, Backus
 - Pseudo ops for arithmetic and math functions
 - Conditional and unconditional branching
 - Autoincrement registers for array access
 - Slow!
 - Only 700 words left for user program

Pseudocodes

- Laning and Zierler System - 1953
 - Implemented on the MIT Whirlwind computer
 - First "algebraic" compiler system
 - Subscripted variables, function calls, expression translation
 - Never ported to any other machine

ALGOL 58

- Comments:
 - Not meant to be implemented, but variations of it were (MAD, JOVIAL)
 - Although IBM was initially enthusiastic, all support was dropped by mid-1959

COBOL - 1960

- State of affairs
 - UNIVAC was beginning to use FLOW-MATIC
 - USAF was beginning to use AIMACO
 - IBM was developing COMTRAN

COBOL

- Based on FLOW-MATIC
- FLOW-MATIC features:
 - Names up to 12 characters, with embedded hyphens
 - English names for arithmetic operators (no arithmetic expressions)
 - Data and code were completely separate
 - Verbs were first word in every statement

COBOL

- First Design Meeting (Pentagon) - May 1959
- Design goals:
 - Must look like simple English
 - Must be easy to use, even if that means it will be less powerful
 - Must broaden the base of computer users
 - Must not be biased by current compiler problems
- Design committee members were all from computer manufacturers and DoD branches
- Design Problems: arithmetic expressions? subscripts?
Fights among manufacturers

Ada 95

- Ada 95 (began in 1988)
 - Support for OOP through type derivation
 - Better control mechanisms for shared data (new concurrency features)
 - More flexible libraries