ICOM 4036

Structure and Properties of Programming Languages

Lecture 1

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 complex software
  - …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
- Writability
- 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 Writability

- 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
- …

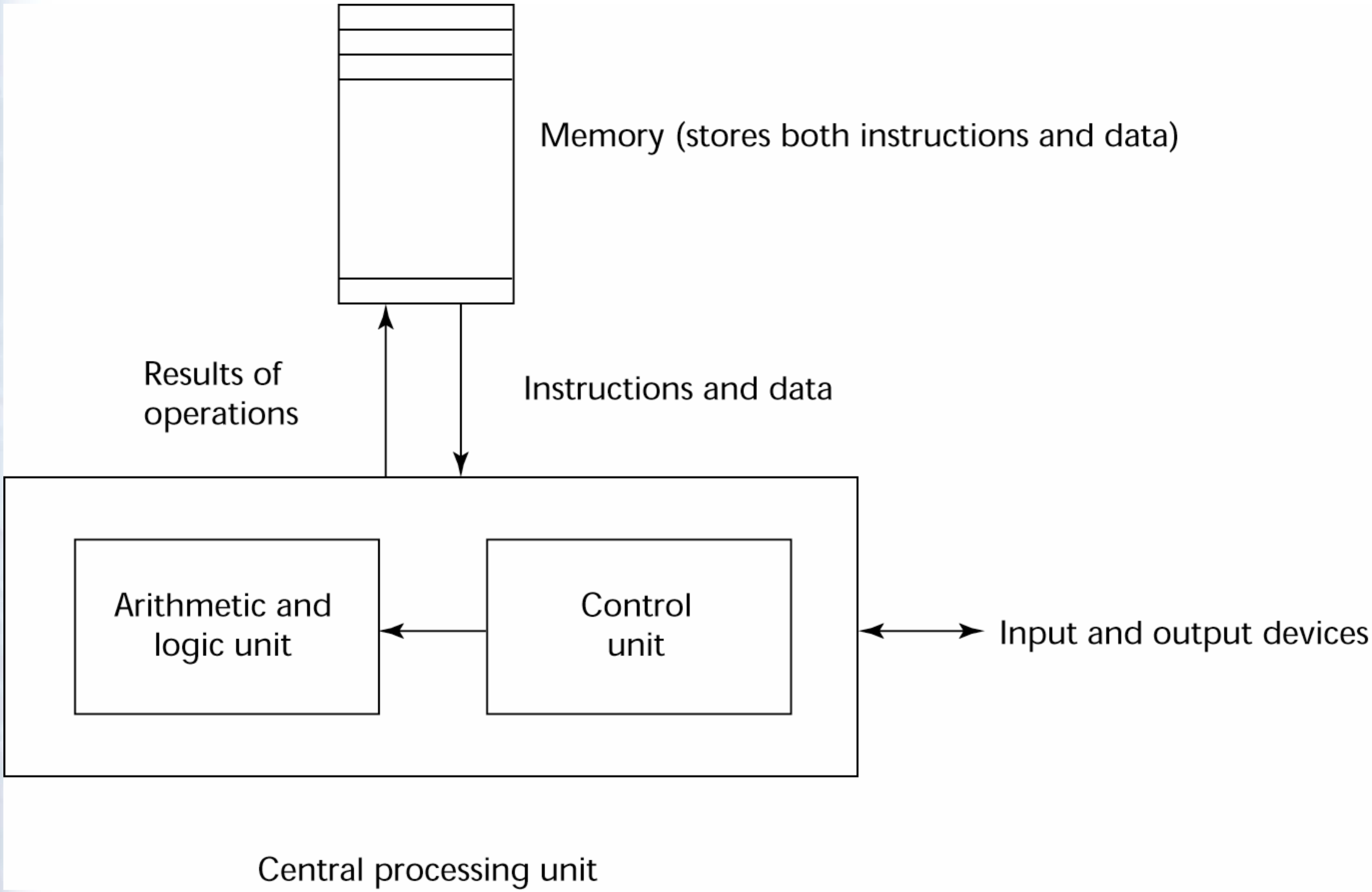
Some Language Design Trade-Offs

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

Influences on Language Design

- 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



Influences on Language Design Through the Years

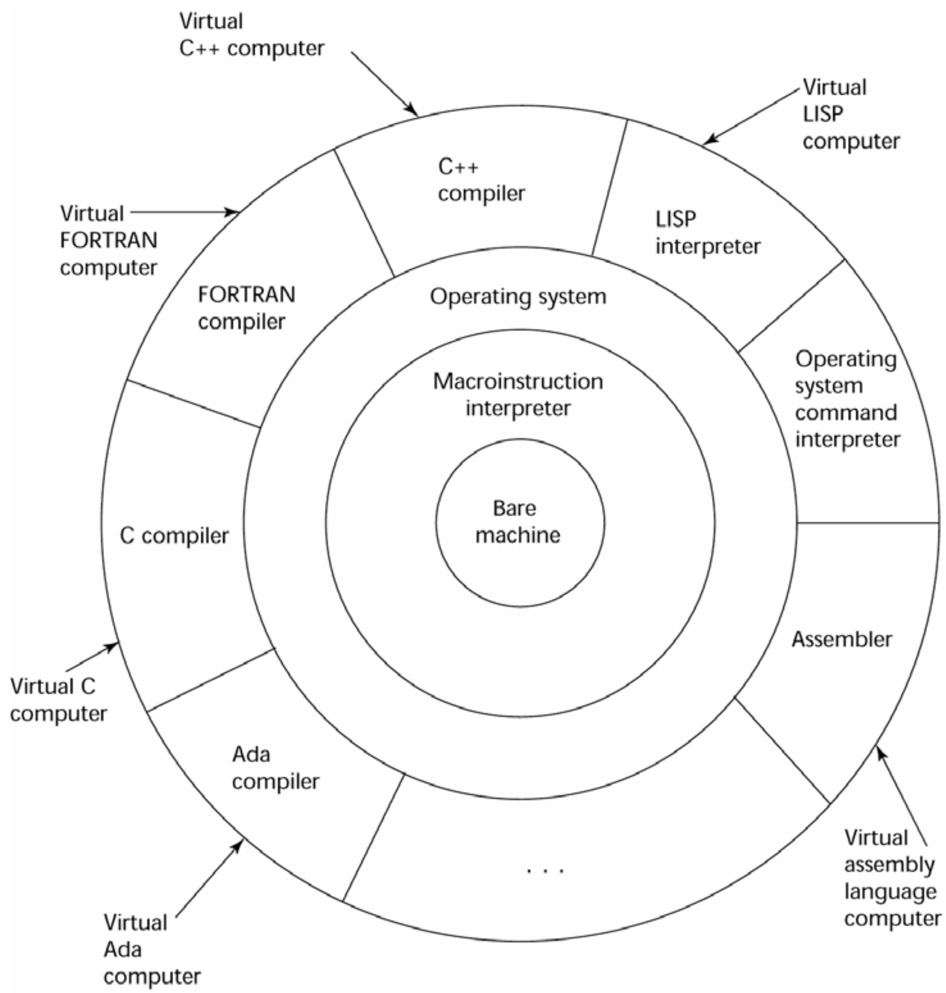
- Programming methodologies thru time:
  - 1950s and early 1960s:
    - Simple applications; worry about machine efficiency
  - Late 1960s:
    - People efficiency became important;
    - readability, better control structures
    - Structured programming
    - Top-down design and step-wise refinement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

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

People

Application Programs

ICOM

High-Level Language

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Assembly Language

Machine Language (ISA)

computers

Computer Human Interaction, User Interfaces

CS1/CS2, Programming, Data Structures

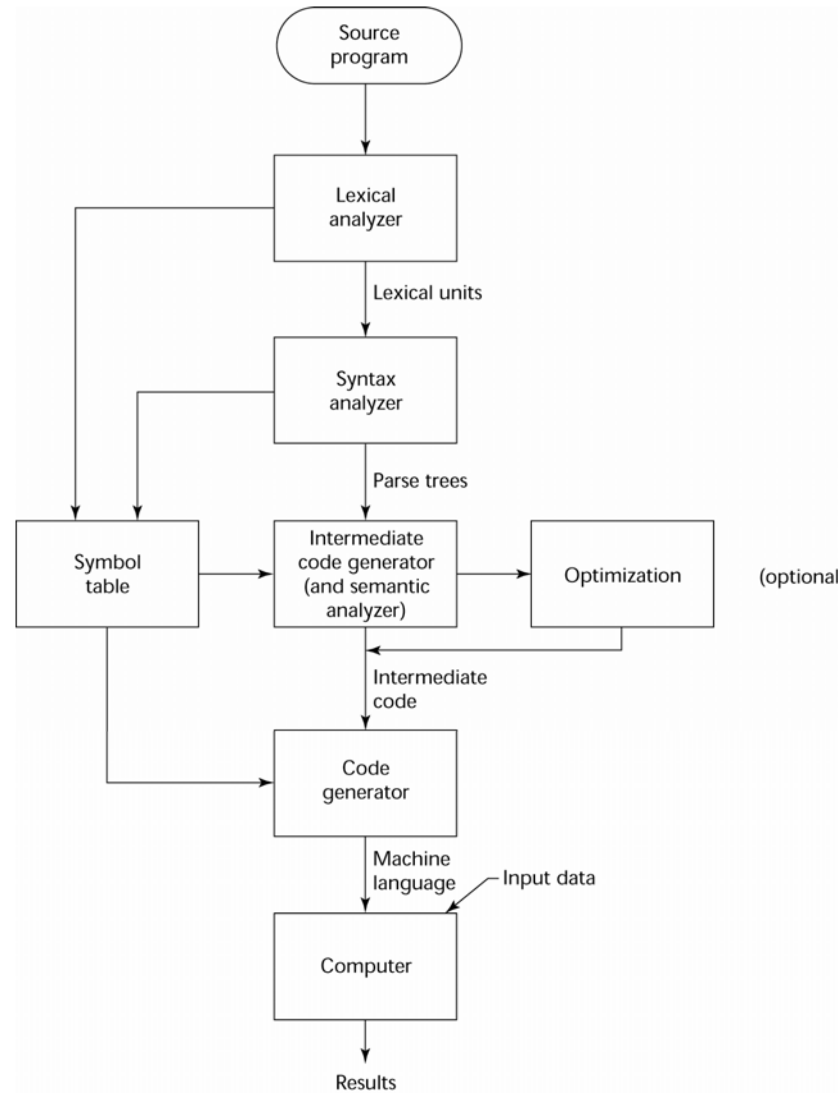
Programming Languages, Compilers

Computer Architecture

Each layer implements an INTERPRETER for some programming language

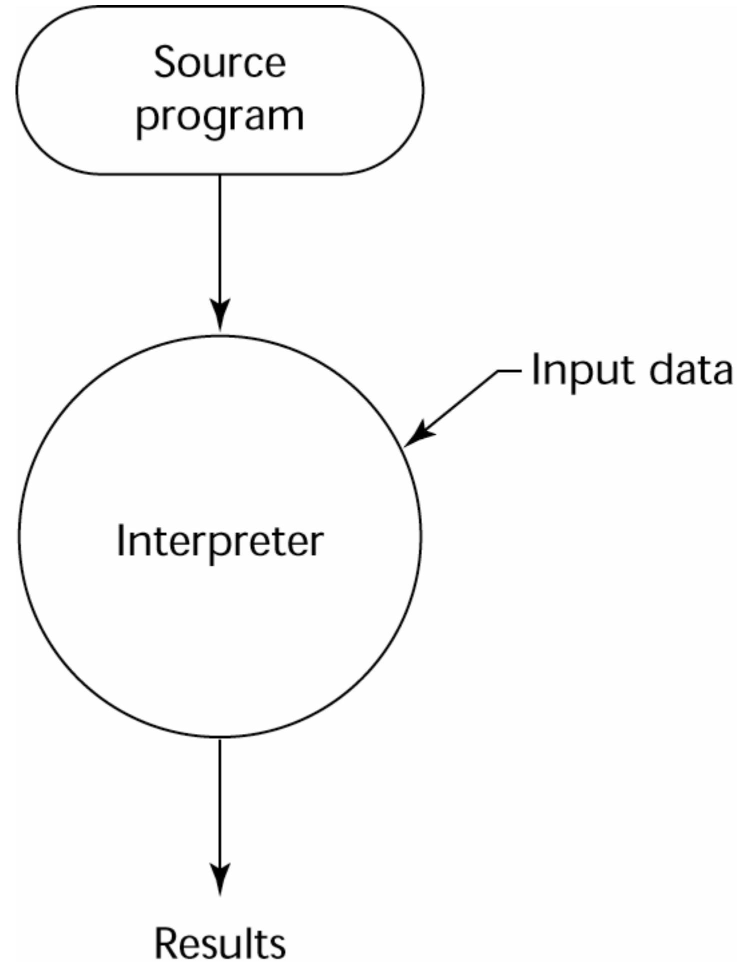
Implementation Methods
Compilation

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



Implementation Methods
Interpretation

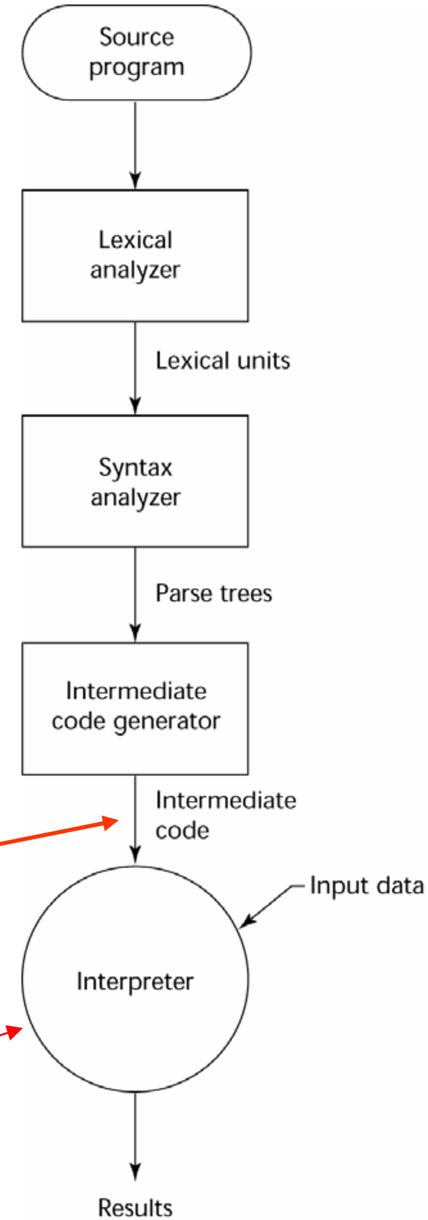
- No translation
- Slow execution
- Common in Scripting Languages



Implementation Methods

Hybrid Approaches

- Small translation cost
- Medium execution speed
- Portability



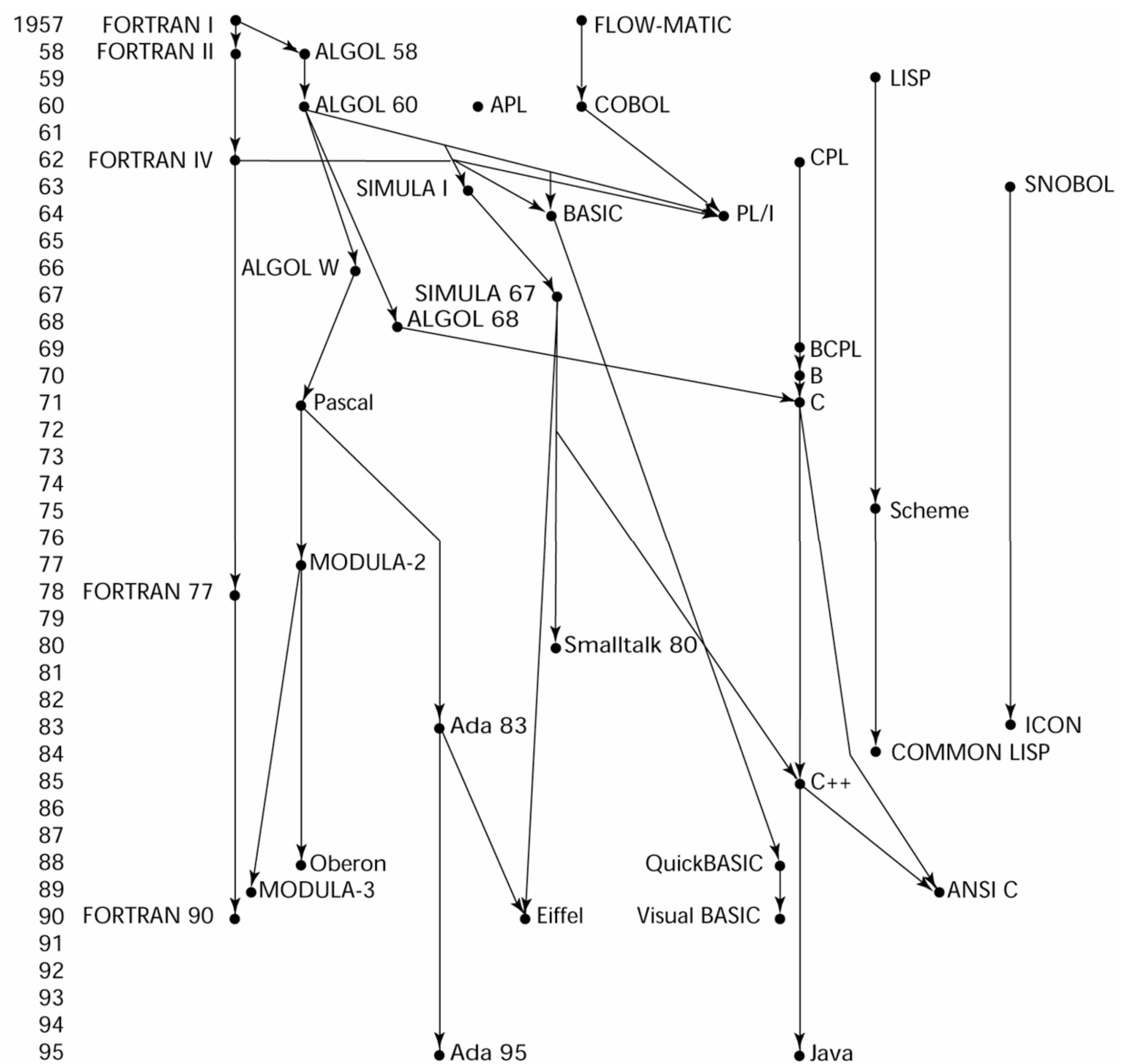
Examples of Intermediate Languages:
- Java Bytecodes
- .NET MSIL

Java VM

Software Development Environments (SDE's)

- The collection of tools used in software development
- GNU/FSF Tools
  - Linux, Servers, and other free software
- Borland JBuilder
  - 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++

Genealogy of High-Level Languages



Machine Code

- 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	0	00 111	4
10	0	00 100	1004
12	0	00 110	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

Assembly Language

Improvements

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

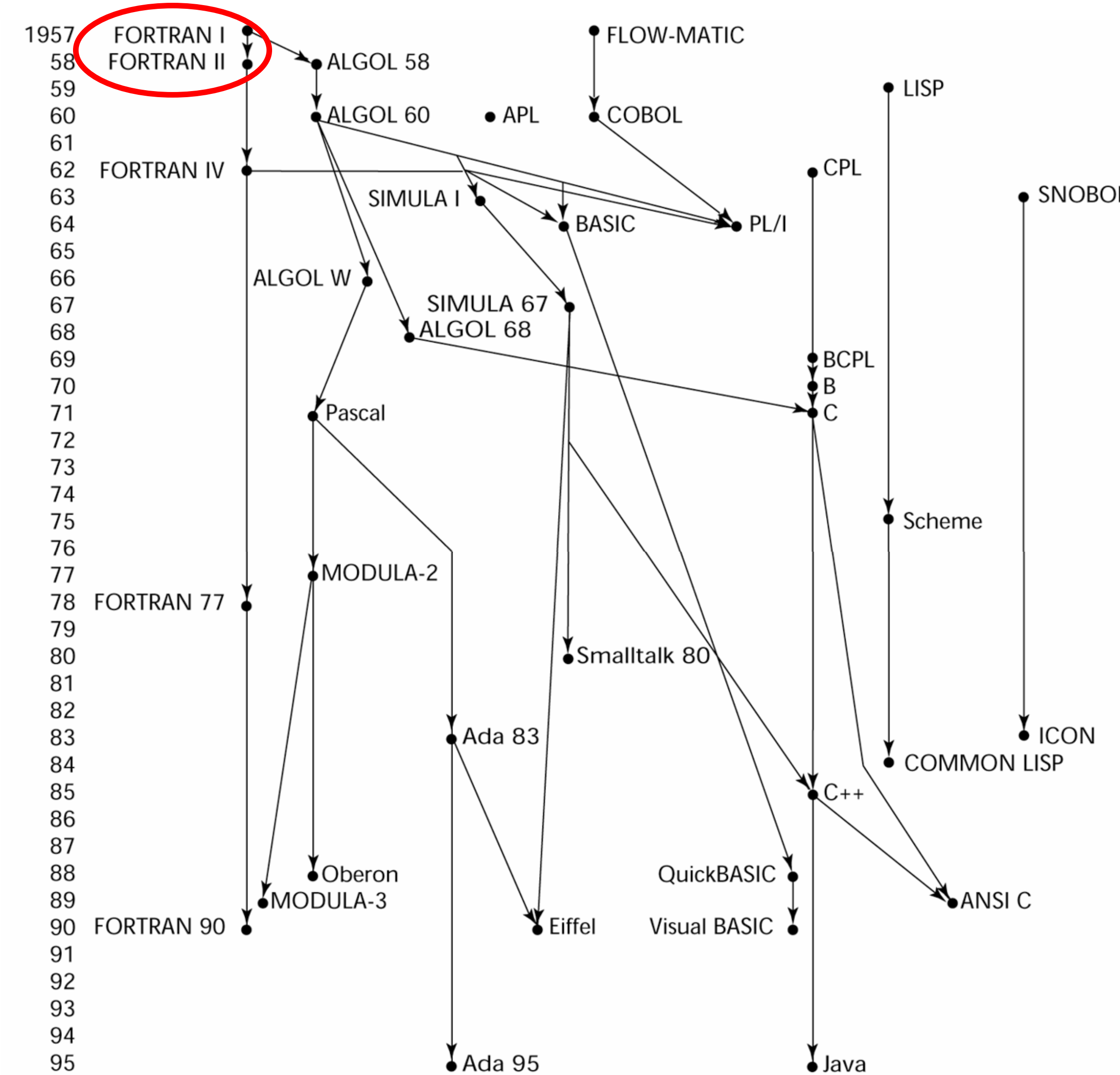
But

- 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              # using 2's complement add
          addi   1
          add    1000
          brni   exit       # exit if AC negative
loop:     loadi  1000
          brni   endloop
          loadi  1004       # compute a – b in AC
          comp              # using 2's complement add
          addi   1
          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
```

Evolution of FORTRAN

- FORTRAN 0 - 1954
  - Never implemented
- FORTRAN I - 1957
  - Designed for the new IBM 704, which had index registers and floating point hardware
- FORTRAN II – 1958
- FORTRAN IV - 1960-62
- FORTRAN 77 – 1978
- FORTRAN 90 - 1990

Over fifty years and still one of the most widely used languages

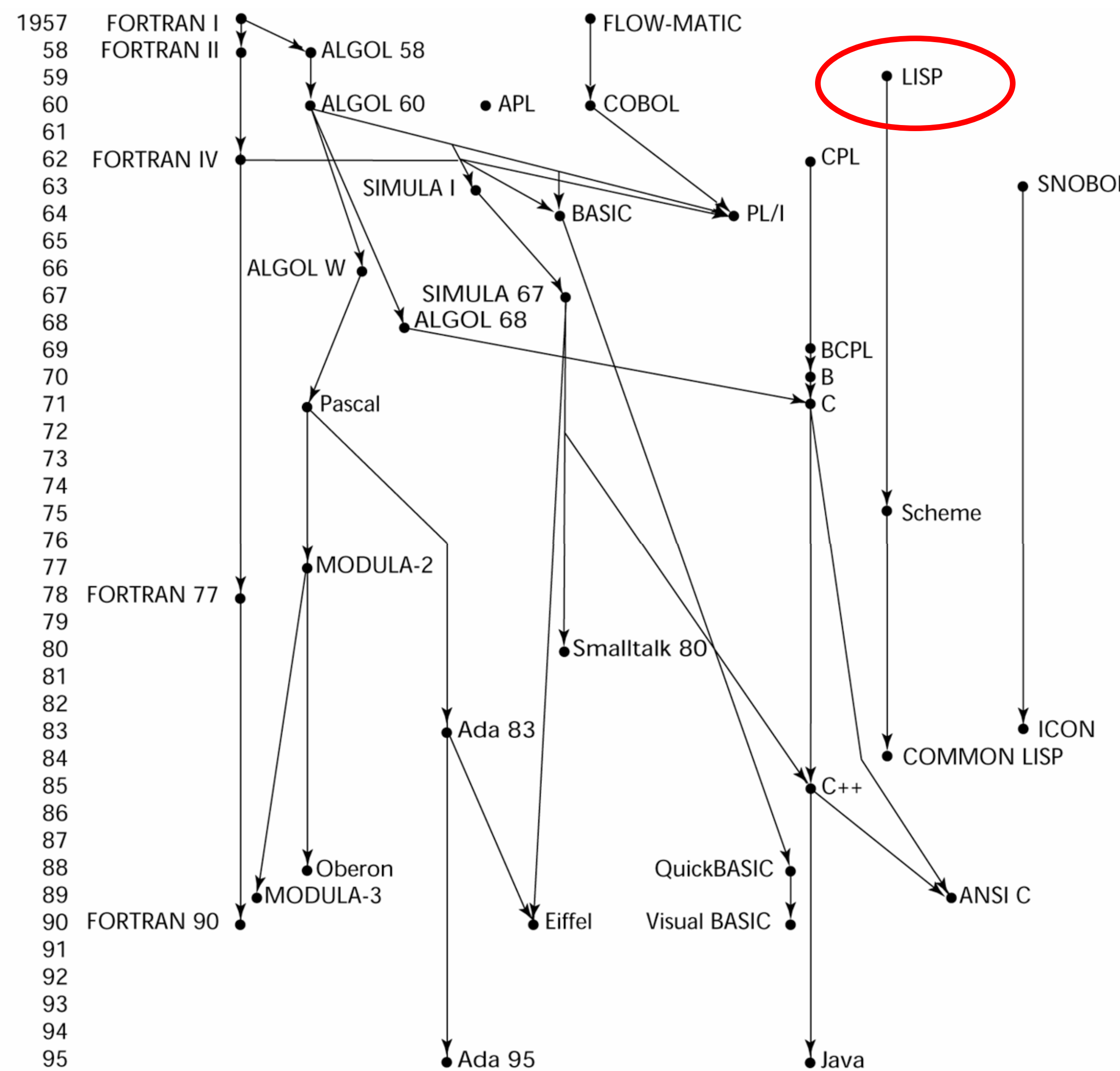
FORTRAN I (1957)

- 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

FORTRAN Evolution

- 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



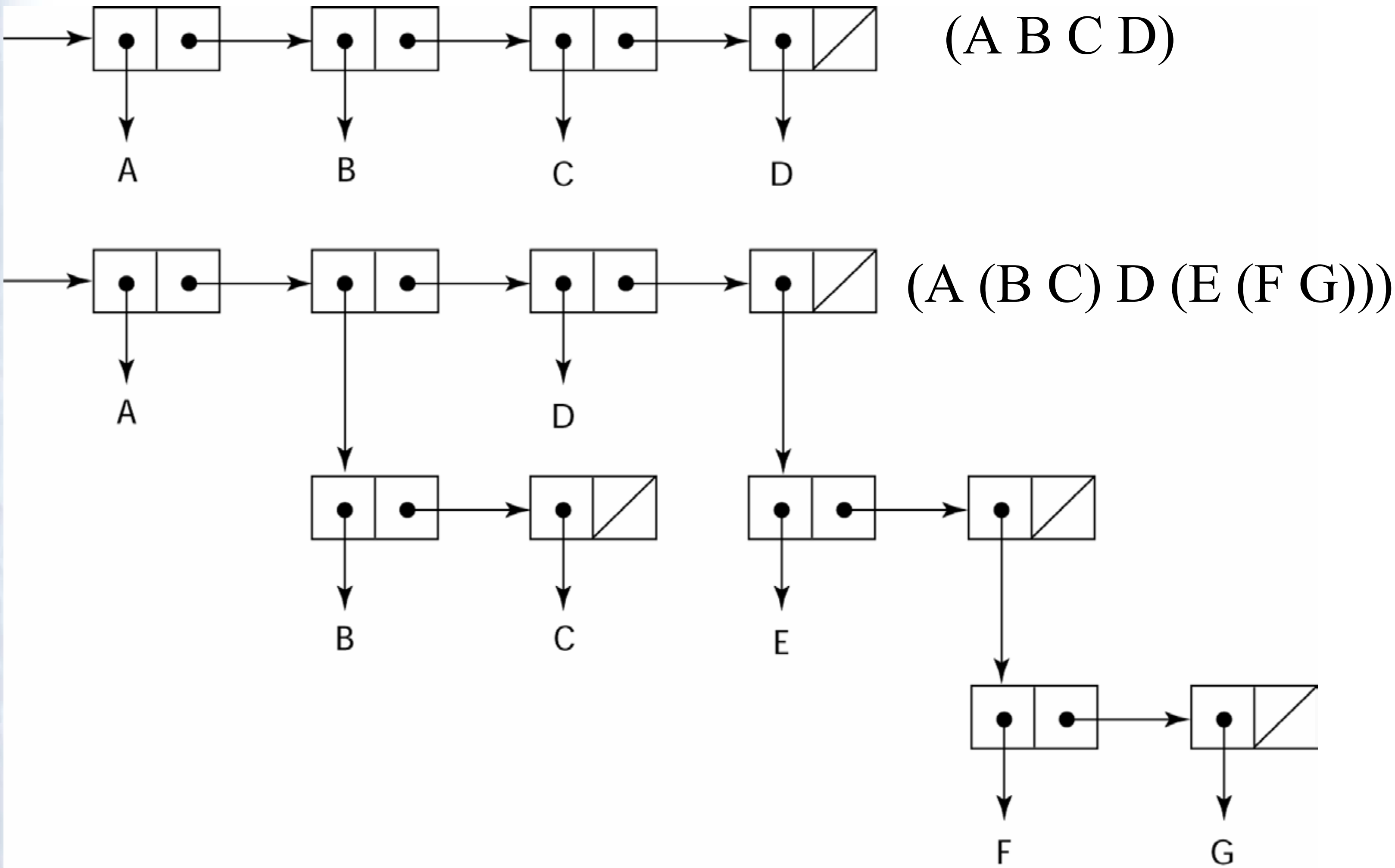
LISP - 1959

- 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

Representation of Two LISP Lists

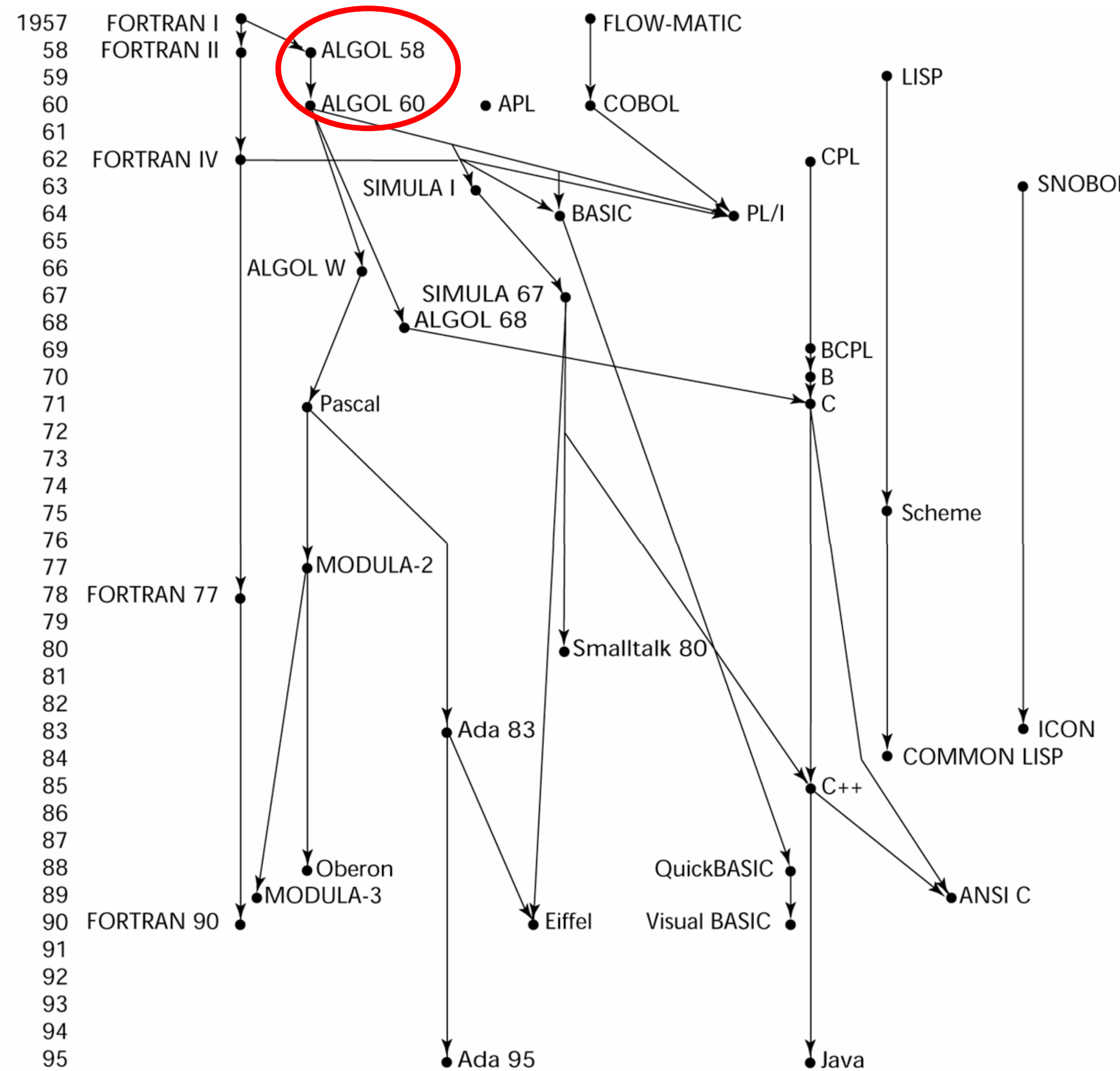


Scheme Example

```scheme
;;; 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))
```

```scheme
(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)

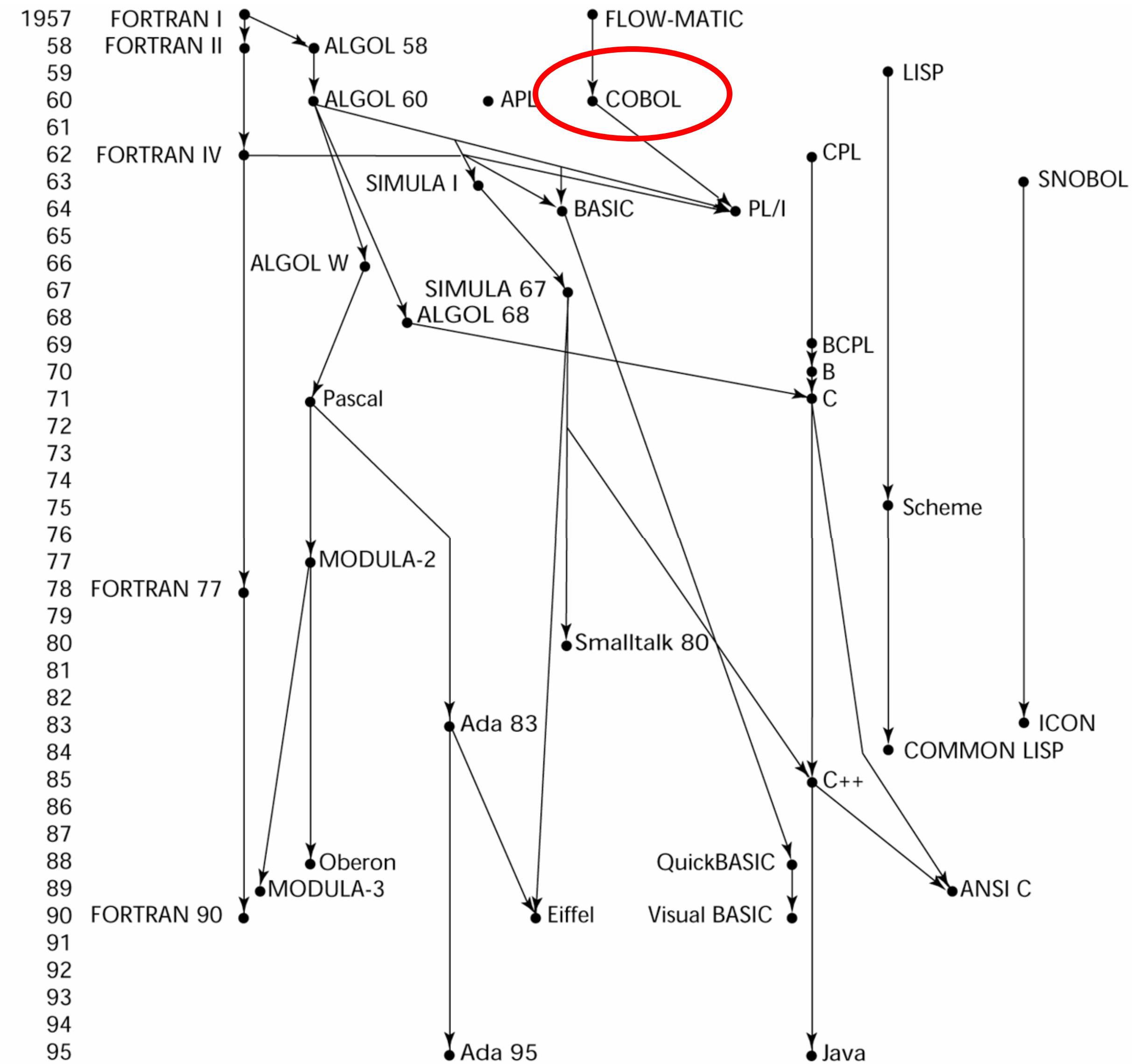
ALGOL 60

- Failure:
  - Never widely used, especially in U.S.
- 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

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

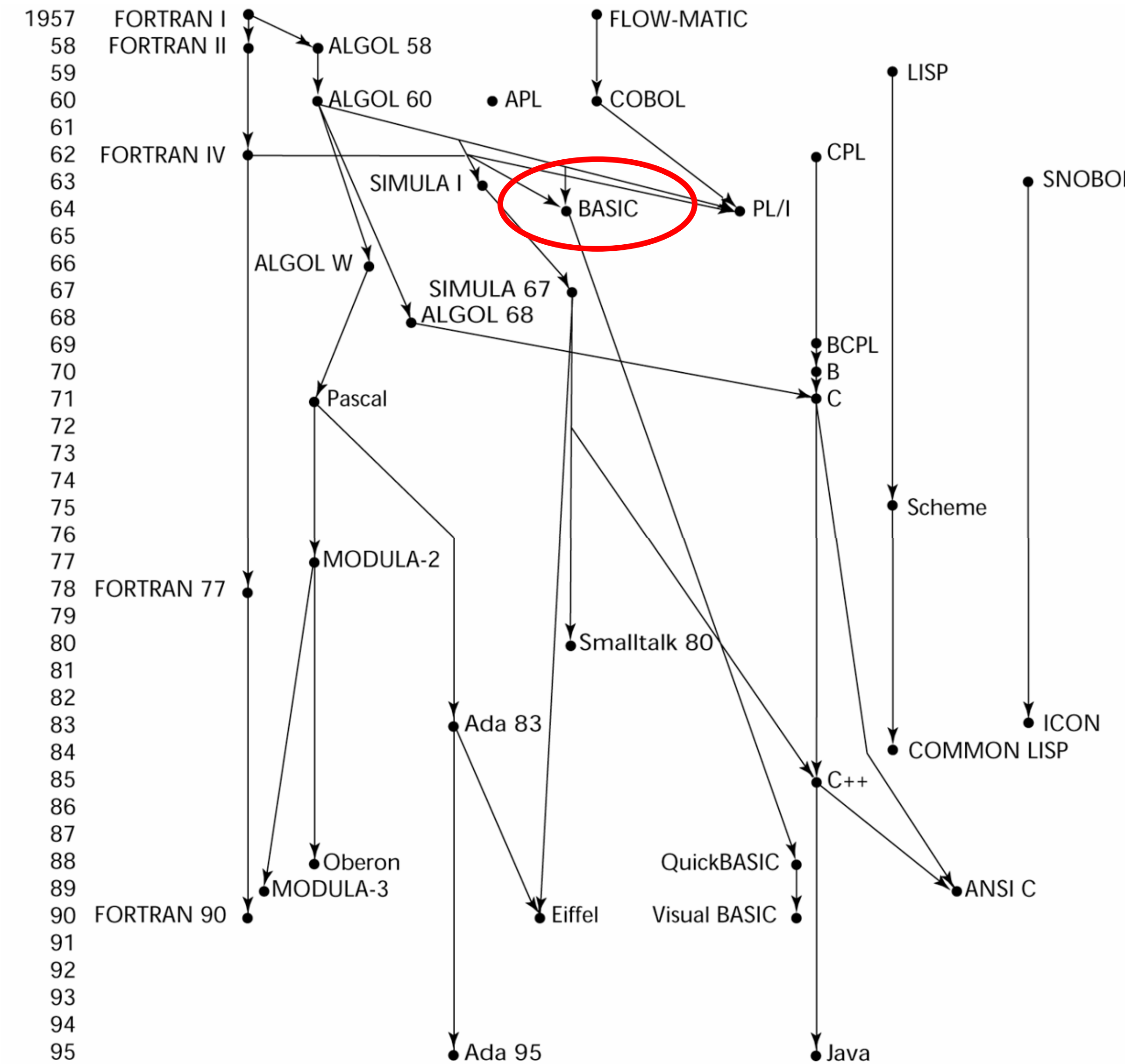
- Contributions:
  - First macro facility in a high-level language
  - Hierarchical data structures (records)
  - Nested selection statements
  - Long names (up to 30 characters), with hyphens
  - Separate data division
- Comments:
  - First language required by DoD
  - Still (2004) the most widely used 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.
```

http://www.csis.ul.ie/COBOL/examples/

Genealogy of High-Level Languages



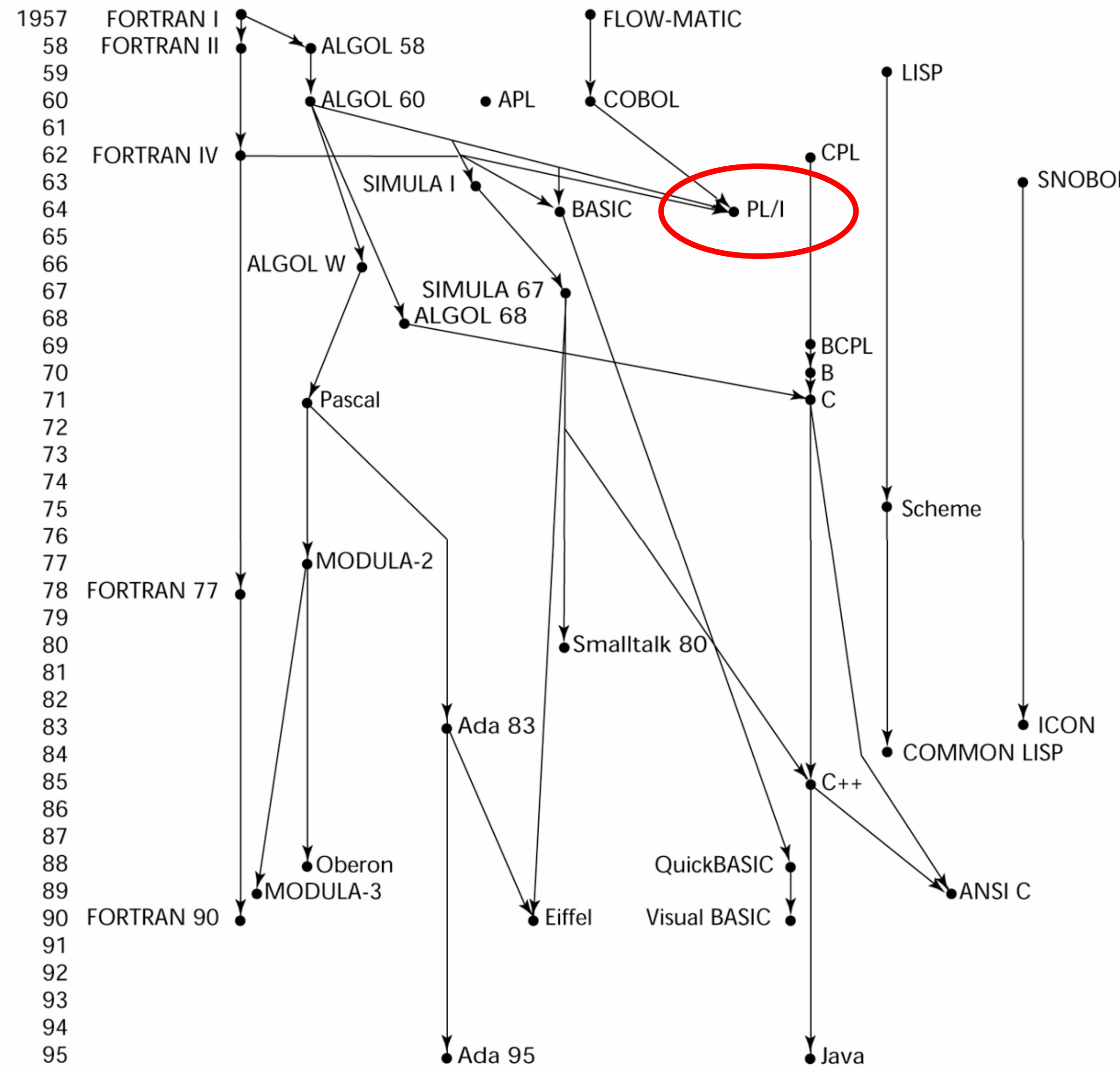
BASIC - 1964

- 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&lt;9 THEN 170
260 PRINT "TIE GAME!!!!"
265 PRINT
270 INPUT "PLAY GAIN (Y OR N)",A$
275 IF A$="Y" THEN 80                    (No need to Dimension a string
280 PRINT "SO LONG"                      with lengh 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

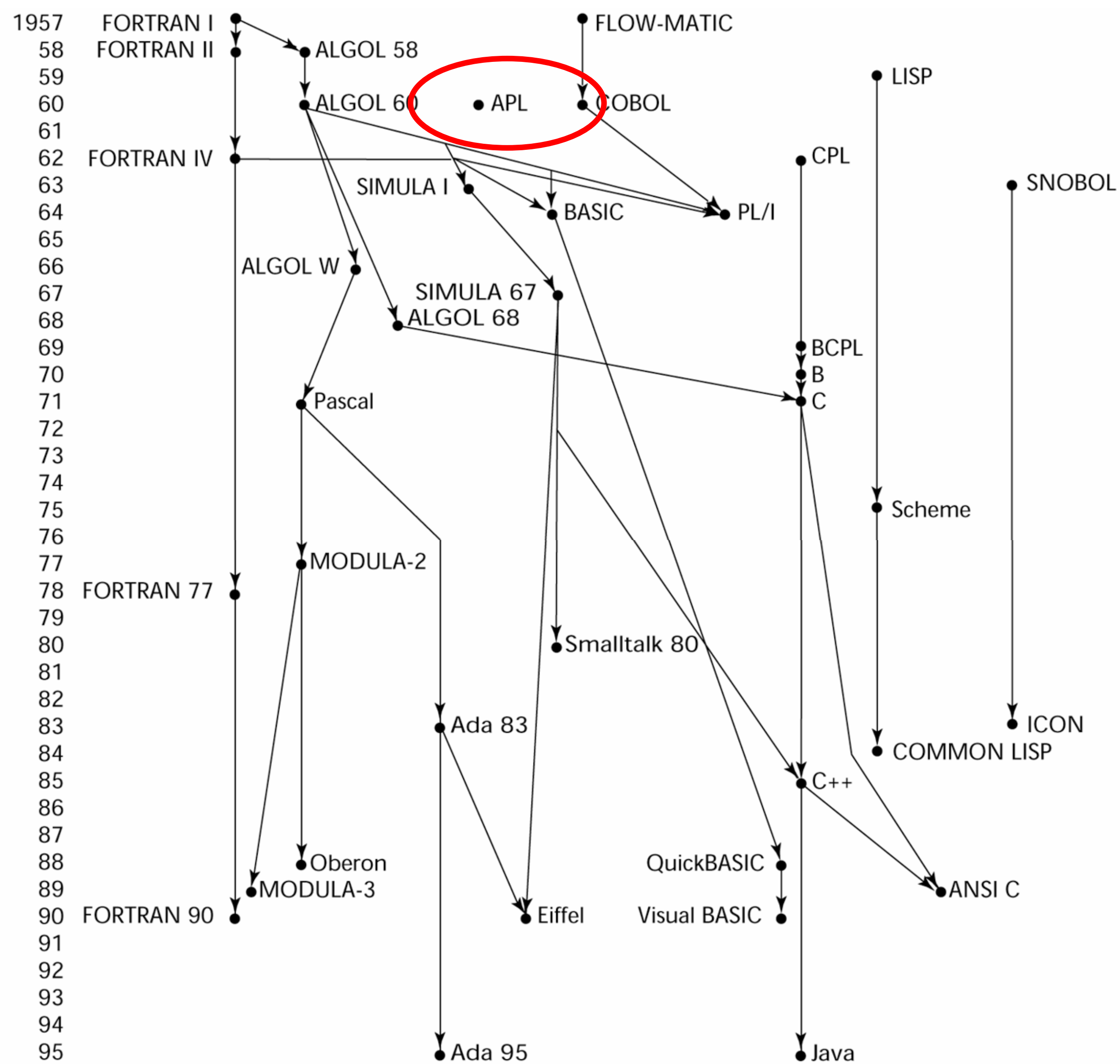
PL/I

- 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

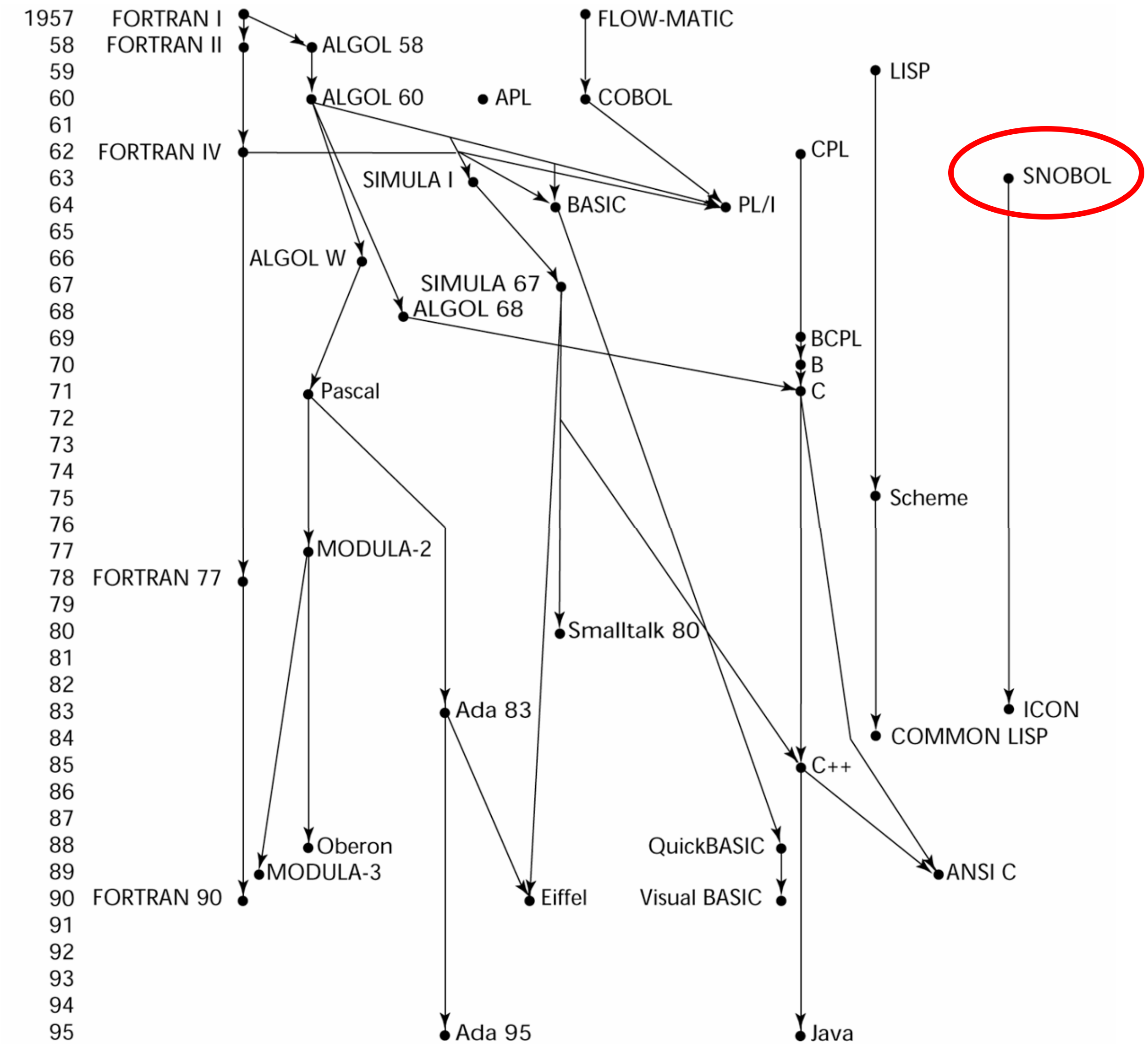
Genealogy of High-Level Languages



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

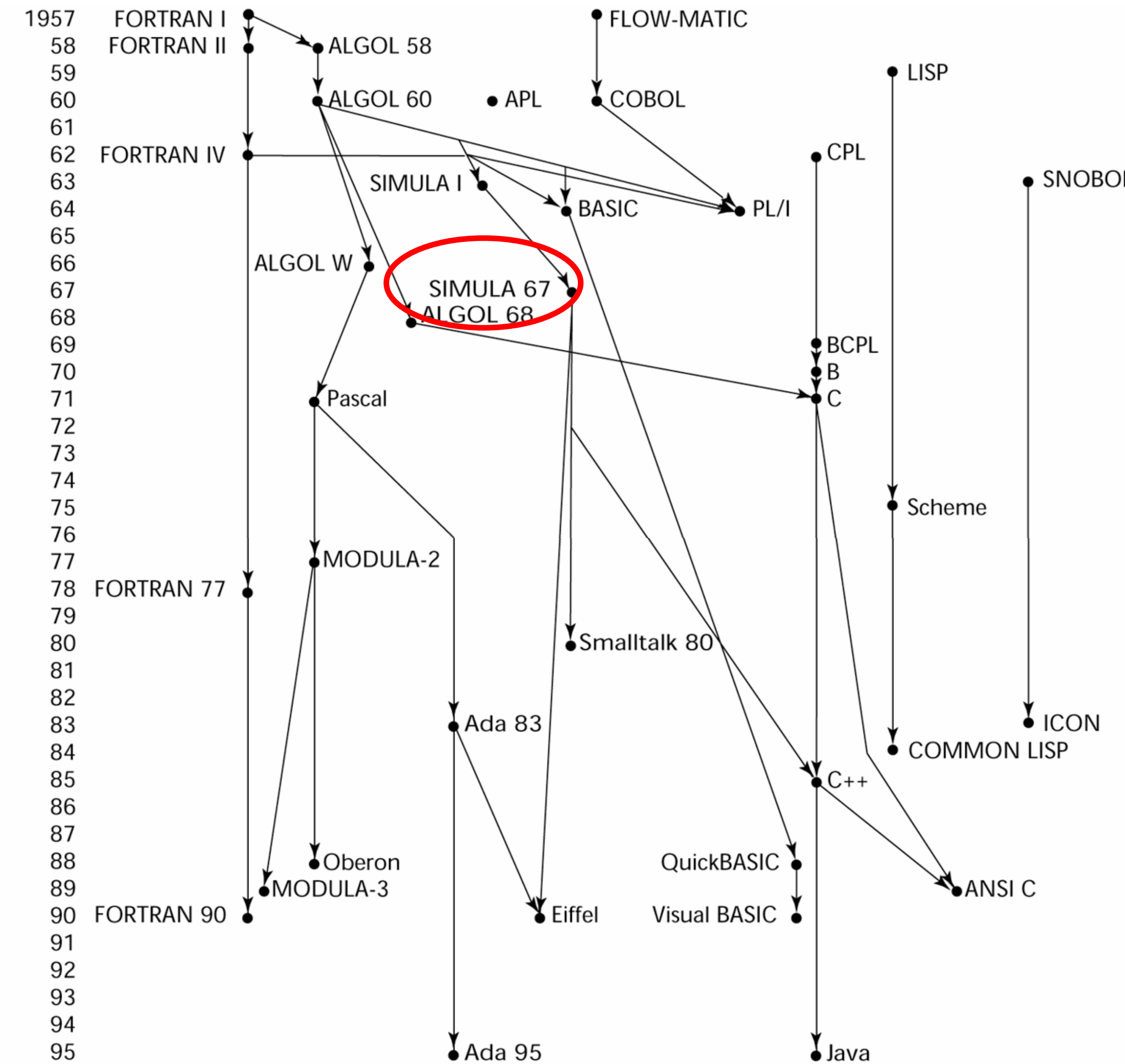
Genealogy of High-Level Languages



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

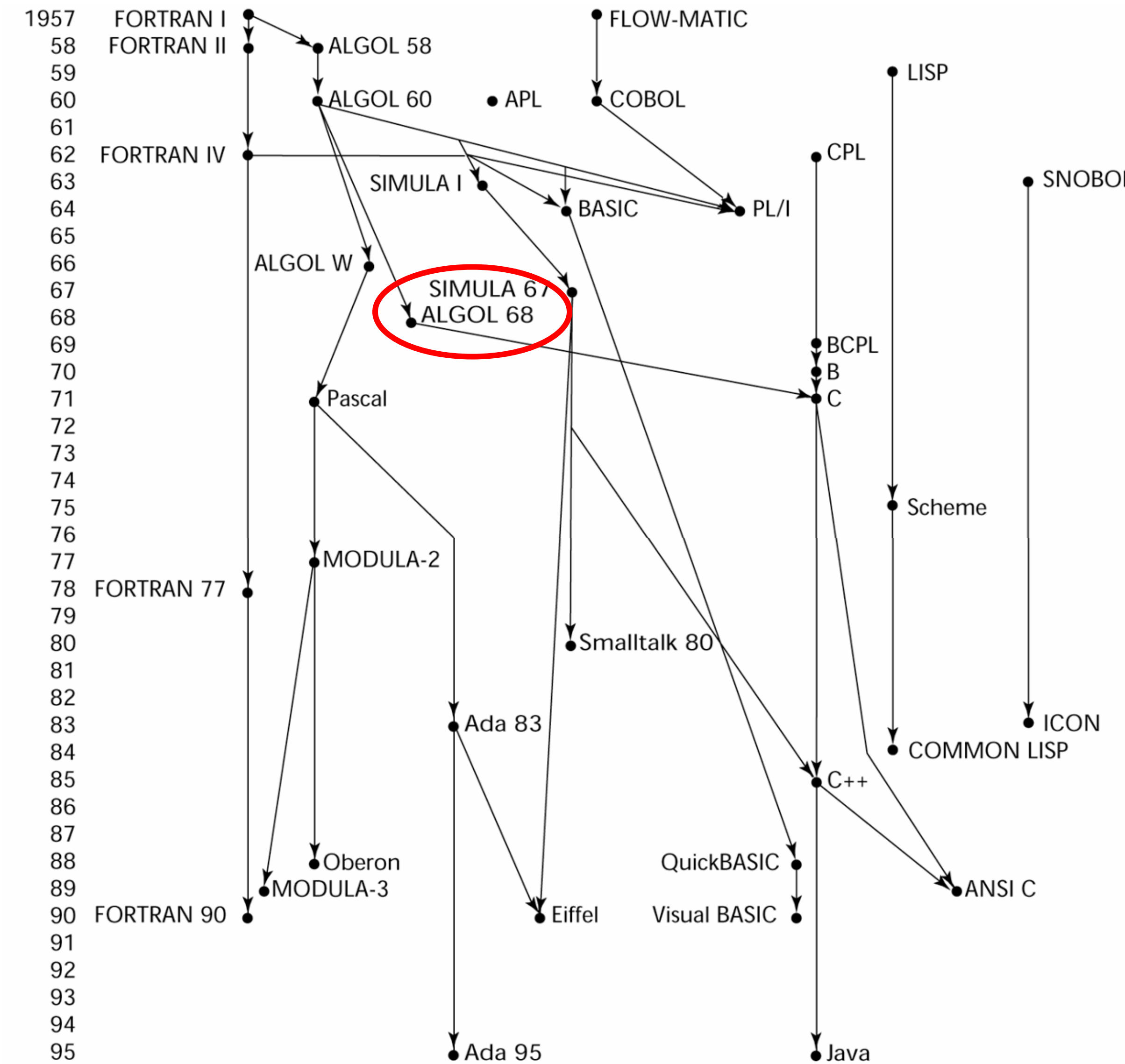
Genealogy of High-Level Languages



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

- 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

- 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)

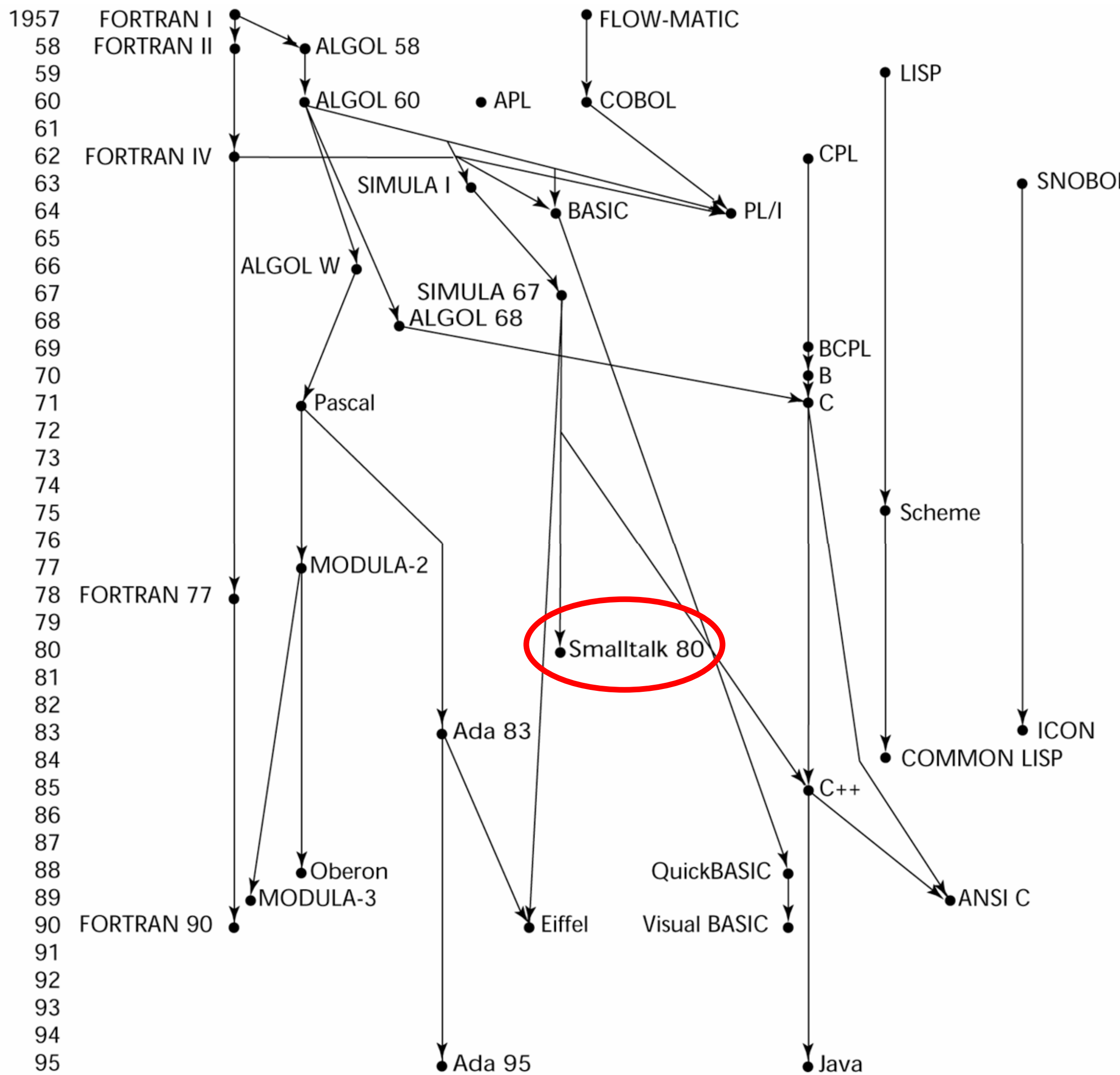
Prolog - 1972

- 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 Example

```
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.
```

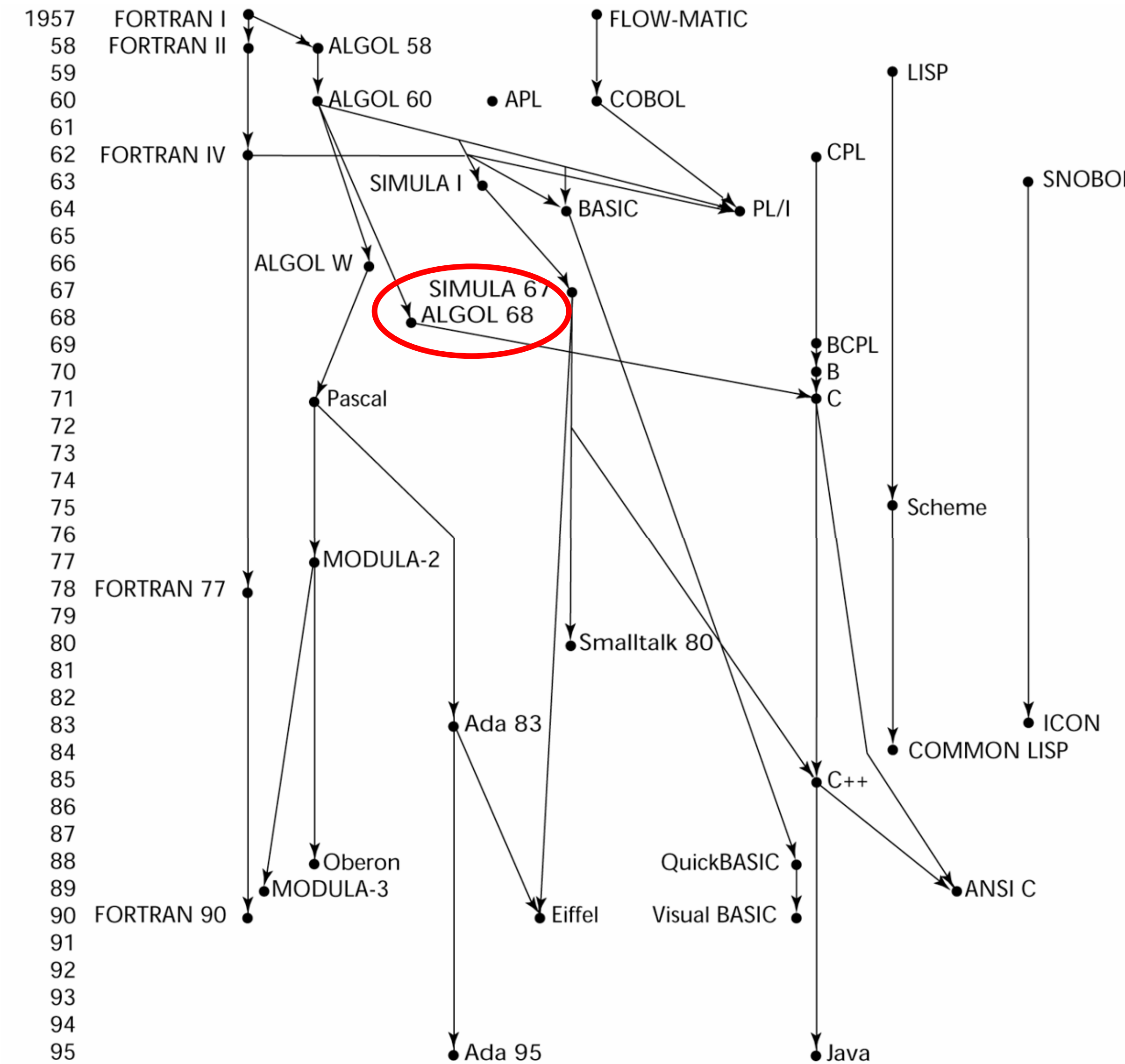
Genealogy of High-Level Languages



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

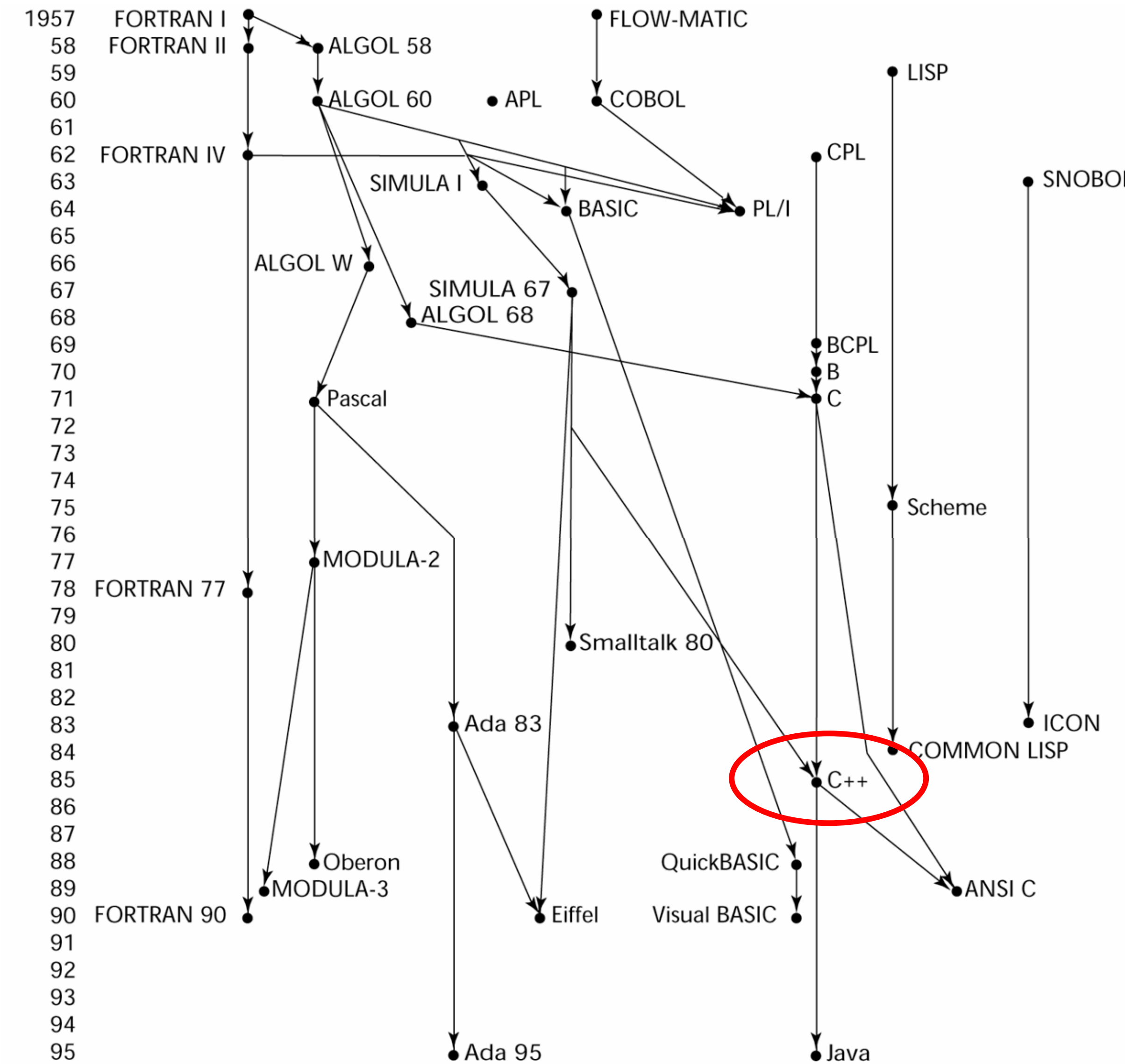
Genealogy of High-Level Languages



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



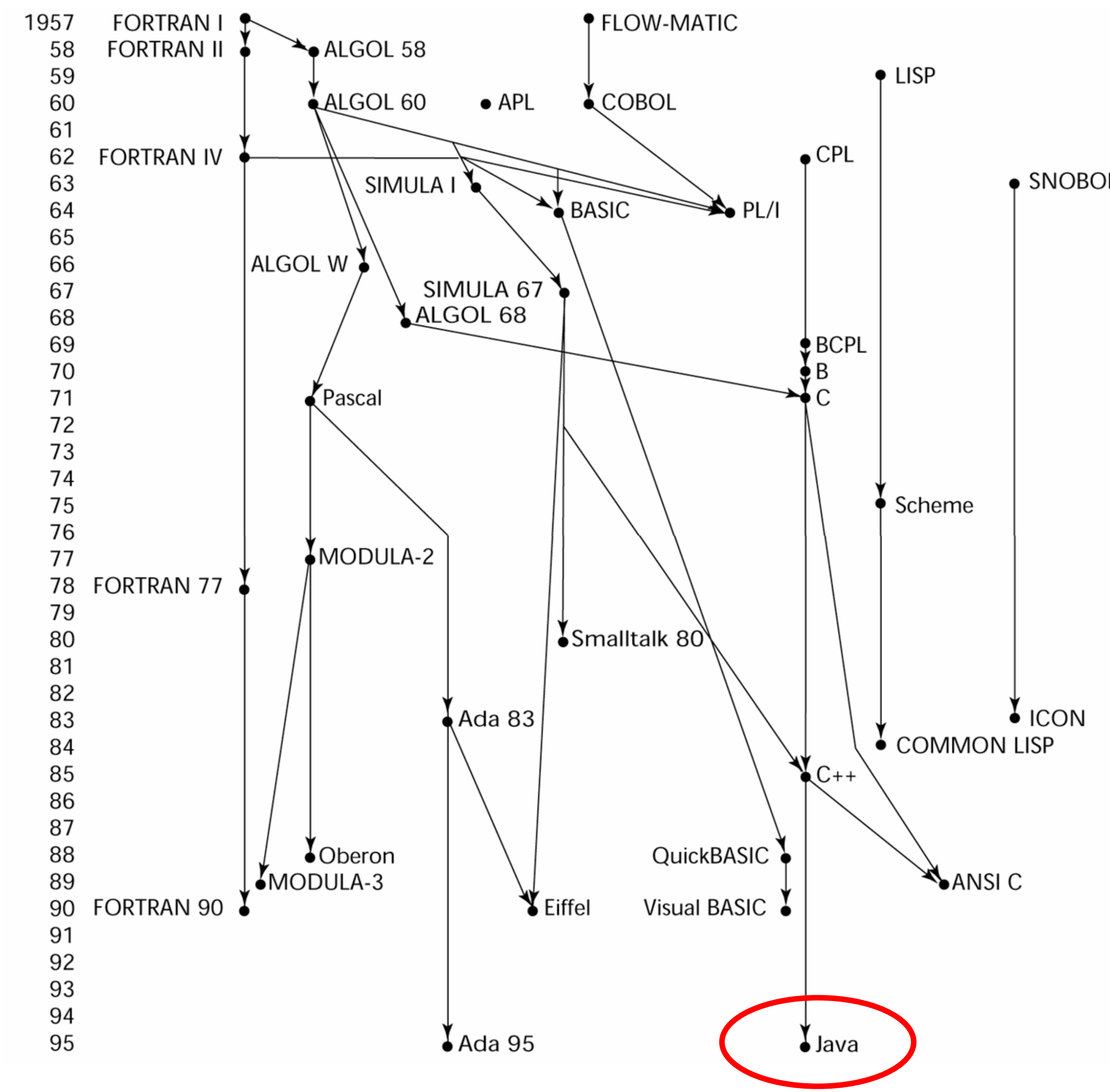
C++ (1985)

- Developed at Bell Labs by 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

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

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

END OF LECTURE 1

To Do Slide

- Examples of Programs in each language

EXTRA SLIDES

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 => (n+2)nd power

    2n => (n+2)nd root

    07 => 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

- Sate 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