- **Decimal, Hexadecimal and Binary Numbers**
- **Writing an assembly language program**
  - Disassembly of MC9S12 op codes
  - Use flow charts to lay out structure of program
  - Use common flow structures
    - if-then
    - if-then-else
    - do-while
    - while
  - Do not use spaghetti code
  - Plan structure of data in memory
  - Plan overall structure of program
  - Work down to more detailed program structure
  - Implement structure with instructions
  - Optimize program to make use of instruction efficiencies
  - **Do not sacrifice clarity for efficiency**

Binary, Hex and Decimal Numbers (4-bit representation)

Binary	Hex	Decimal
0000	0	0
0001	1	1
0010	2	2
…	…	…
1010	A	10
1011	B	11
1100	C	12
1101	D	13
1110	E	14
1111	F	15

What does a number represent?

Binary numbers are a code, and represent what the programmer intends for the code.

0x72 Some possible meanings:

- ’r’ (ASCII)
- INC MEM (hh ll) (HC12 instruction)
- 2.26V (Input from A/D converter)
- 114_{10} (Unsigned number)
- $+114_{10}$ (Signed number)
- Set temperature in room to 69 °F
- Set cruise control speed to 120 mph

Binary to Unsigned Decimal:

Convert Binary to Unsigned Decimal

1111011_2

$1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$

$1 \times 64 + 1 \times 32 + 1 \times 16 + 1 \times 8 + 0 \times 4 + 1 \times 2 + 1 \times 1$

123_{10}

Hex to Unsigned Decimal

Convert Hex to Unsigned Decimal

$82D6_{16}$

$8 \times 16^3 + 2 \times 16^2 + 13 \times 16^1 + 6 \times 16^0$

$8 \times 4096 + 2 \times 256 + 13 \times 16 + 6 \times 1$

33494_{10}

Unsigned Decimal to Hex

Convert Unsigned Decimal to Hex

Division	Q	R	
		Decimal	Hex
721/16	45	1	1 ↑
45/16	2	13	D
2/16	0	2	2

$$\mathbf{721_{10} = 2D1_{16}}$$

Signed Number Representation in 2's Complement Form:

If the most significant bit (MSB) is 0 (most significant hex digit 0−7), then the number is positive.

Get decimal equivalent by converting number to decimal, and use the + sign.

Example for 8−bit number:

$\mathbf{3A_{16}}$ −> $+ (3 \times 16^1 + 10 \times 16^0)_{10}$
$+ (3 \times 16 + 10 \times 1)_{10}$
$\mathbf{+ 58_{10}}$

If the most significant bit is 1 (most significant hex digit 8−F), then the number is negative.

Get decimal equivalent by taking 2's complement of number, converting to decimal, and using − sign.

Example for 8−bit number:

$$\mathbf{A3_{16}} \rightarrow -\ (5C+1)_{16}$$
$$-\ (5 \times 16^{1} + 13 \times 16^{0})_{10}$$
$$-\ (5 \times 16 + 13 \times 1)_{10}$$
$$-\ \mathbf{93_{10}}$$

One's complement table makes it simple to finding 2's complements

0	F
1	E
2	D
3	C
4	B
5	A
6	9
7	8

3 → One's complement → C

A → One's complement → 5

One's complement table makes it simple to finding 2's complements

0	F
1	E
2	D
3	C
4	B
5	A
6	9
7	8

To take two's complement, add one to one's complement.

Take two's complement of **D0C3**:

2F3C + 1 = **2F3D**

Addition and Subtraction of Binary and Hexadecimal Numbers

Setting the C (Carry), V (Overflow), N (Negative) and Z (Zero) bits

How the C, V, N and Z bits of the CCR are changed?

- N bit is set if result of operation is negative (MSB = 1)
- Z bit is set if result of operation is zero (All bits = 0)
- V bit is set if operation produced an overflow
- C bit is set if operation produced a carry (borrow on subtraction)

Note: Not all instructions change these bits of the CCR

Addition of Hexadecimal Numbers

ADDITION:

C bit set when result does not fit in word

V bit set when P + P = N or
N + N = P

N bit set when MSB of result is 1

Z bit set when result is 0

7A	2A	AC	AC
+52	+52	+8A	+72
-----	-----	------	------
CC	7C	36	1E
C: 0	C: 0	C: 1	C: 1
V: 1	V: 0	V: 1	V: 0
N: 1	N: 0	N: 0	N: 0
Z: 0	Z: 0	Z: 0	Z: 0

Subtraction of Hexadecimal Numbers

SUBTRACTION:

C bit set on borrow (when the magnitude of the subtrahend is greater than the minuend

V bit set when N - P = P or
P - N = N

N bit set when MSB is 1

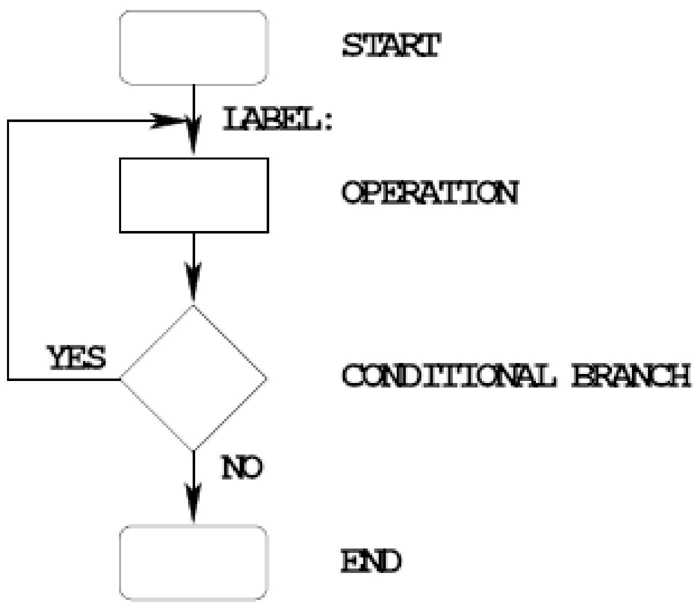
Z bit set when result is 0

7A	8A	5C	2C
-5C	-5C	-8A	-72
-----	-----	------	------
1E	2E	D2	BA
C: 0	C: 0	C: 1	C: 1
V: 0	V: 1	V: 1	V: 0
N: 0	N: 0	N: 1	N: 1
Z: 0	Z: 0	Z: 0	Z: 0

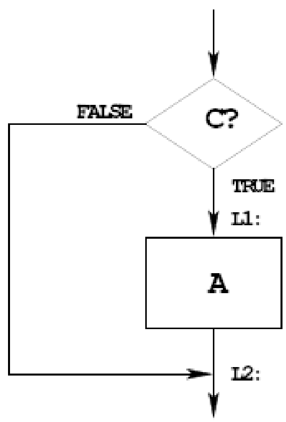
Writing Assembly Language Programs

Use Flowcharts to Help Plan Program Structure

Flow chart symbols:



IF-THEN Flow Structure




```
if (C)
{
        A;
}
```

EXAMPLE:

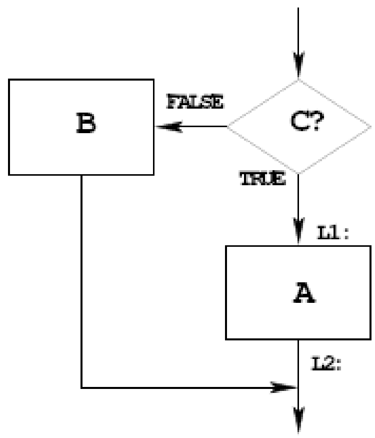
```
if (A<10)
{
   var = 5;
}
```

```
        CMPA  #10 ; if (A<10)
        BLT   L1  ; signed numbers
        BRA   L2
L1:     LDAB  #5  ; var=5
        STAB  var
L2:     next instruction
```

OR:

```
        CMPA  #10 ; if(A<10)
        BGE   L2  ; signed numbers
        LDAB  #5  ; var=5
        STAB  var
L2:     next instruction
```

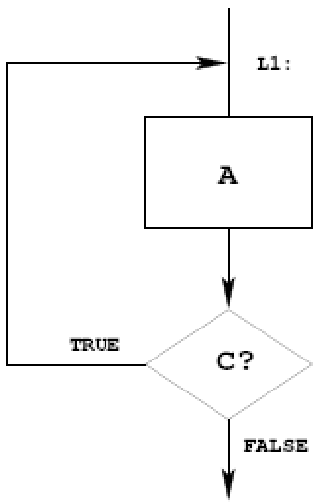
IF-THEN-ELSE Flow Structure




```
if (C)
{
   A;
}
else
{
   B;
}
```

```
if(A < 10)              CMPA    #10 ; if(A<10)
{                       BLT     L1  ; signed numbers
   var = 5;             CLR     var ; var=0
}                       BRA     L2
else               L1:  LDAB    #5  ; var=5
{                       STAB    var
   var = 0;        L2:  next instruction
}
```

DO WHILE Flow Structure

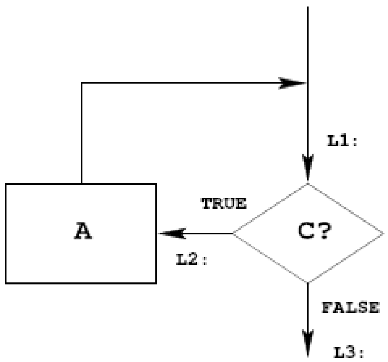



```
do
{
   A;
}
while ( C );
```

EXAMPLE:

```
i = 0;                     LDX    #table
do                         CLRA            ; i=0
{                      L1: ASR    1,X+     ; table[i] /=2
    table[i]=table[i]/2;   INCA            ; i=i+1
    i=i+1;                 CMPA   #LEN     ; while(i<=10)
}                          BLE    L1       ; unsigned
 while (i <= LEN);                         ; numbers
```

WHILE Flow Structure




```
while ( C )
 {
       A;
 }
```

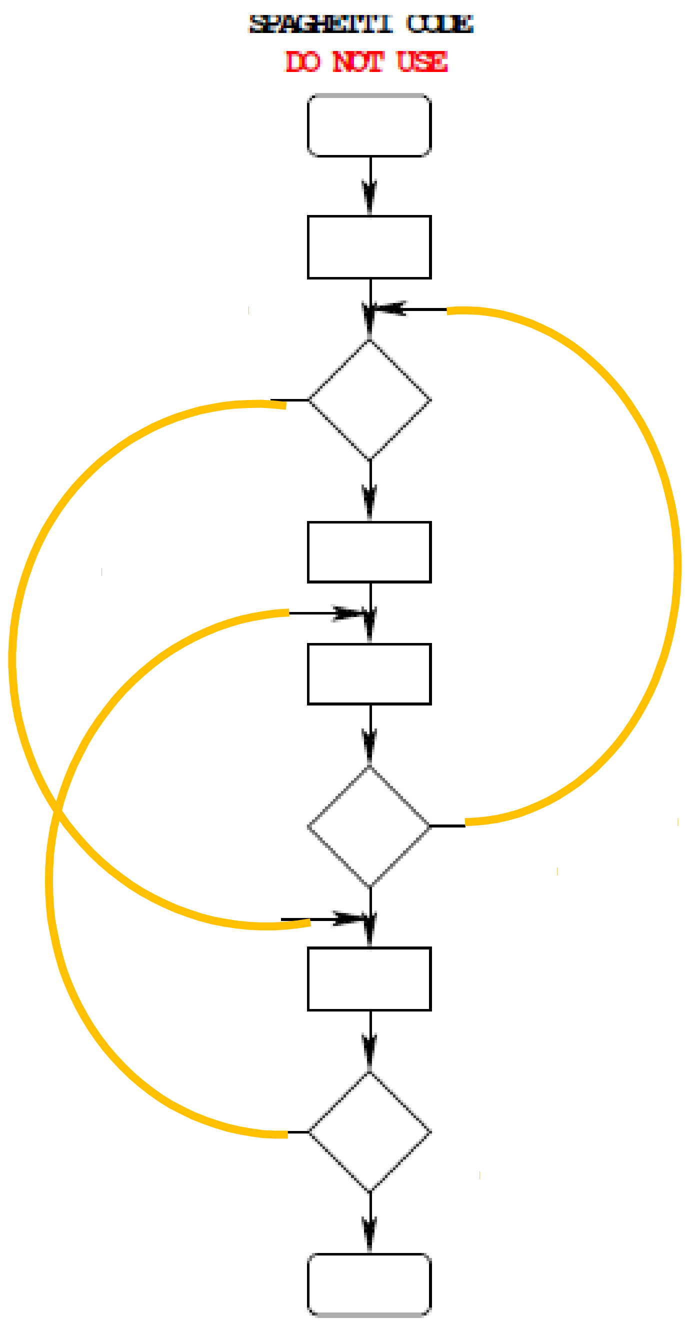
EXAMPLE:

```
i = 0;
while( i <= LEN)
{
    table[i]=table[i]*2;
    i=i+1;
}
```

```
      LDX    #table
      CLRA
L1:   CMPA   #LEN
      BLT    L2
      BRA    L3
L2:   ASL    1,X+
      INCA
      BRA    L1
L3:   next instruction
```

Use Good Structure When Writing Programs

— Do Not Use Spaghetti Code



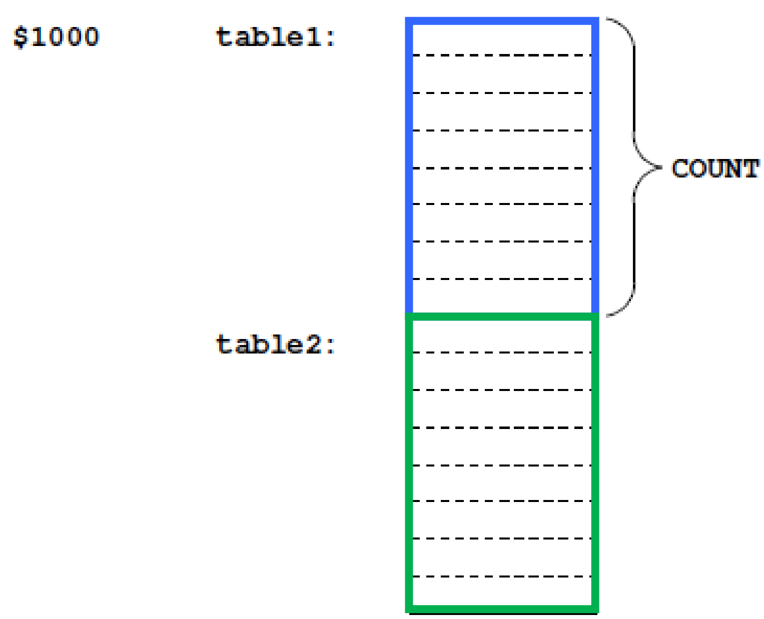
Example Program: Divide a table of data by 2

Problem: Start with a table of data. The table consists of 5 values. Each value is between 0 and 255. Create a new table whose contents are the original table divided by 2.

1. Determine where code and data will go in memory.
Code at $2000, data at $1000.

2. Determine type of variables to use.
Because data will be between 0 and 255, can use unsigned 8-bit numbers.

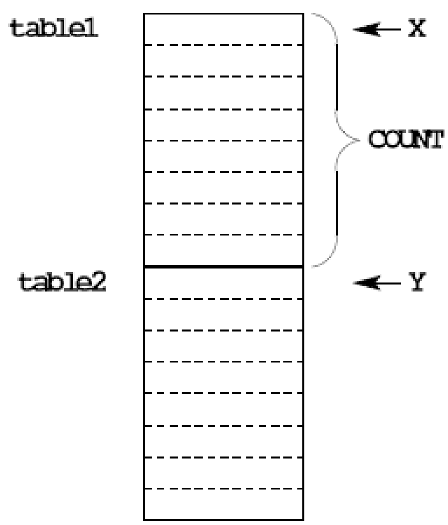
3. Draw a picture of the data structures in memory:

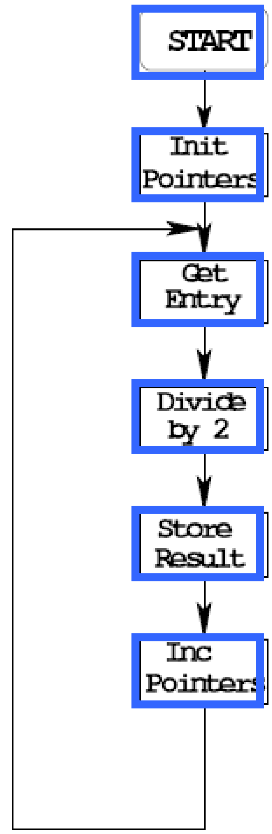


4. Strategy: Because we are using a table of data, we will need pointers to each table so we can keep track of which table element we are working on.

Use the X and Y registers as pointers to the tables.

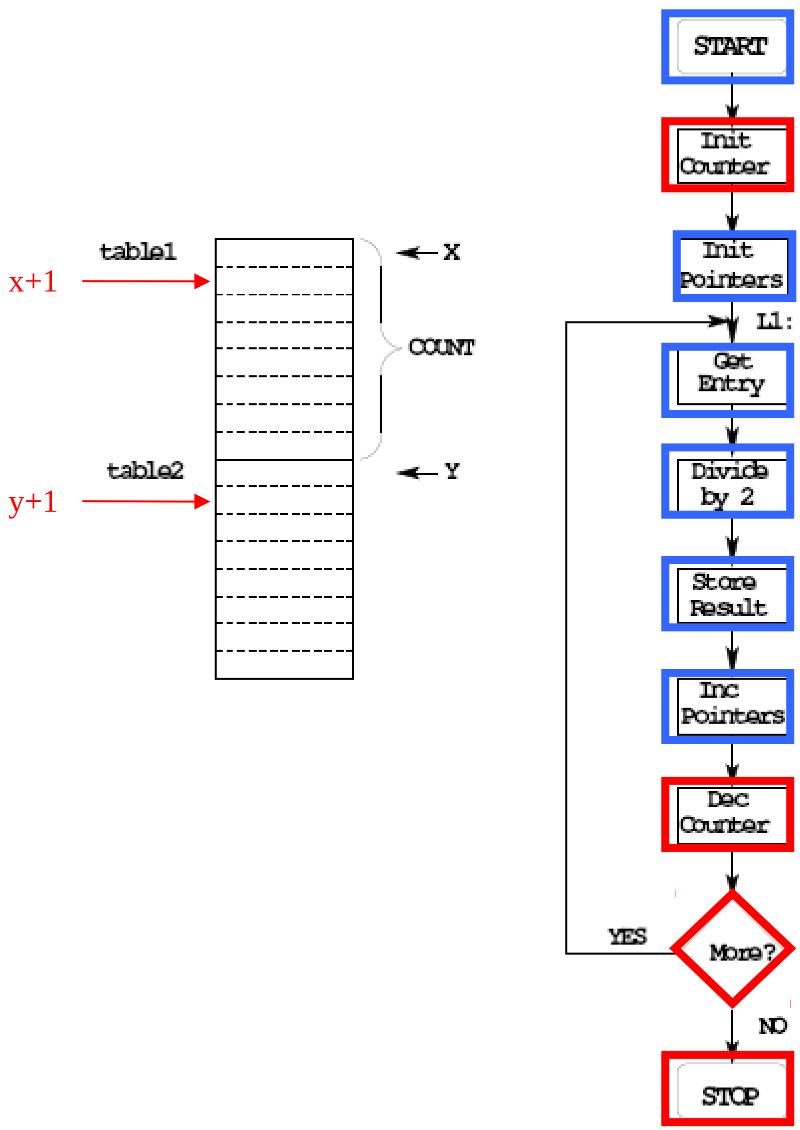
5. Use a simple flow chart to plan structure of program.



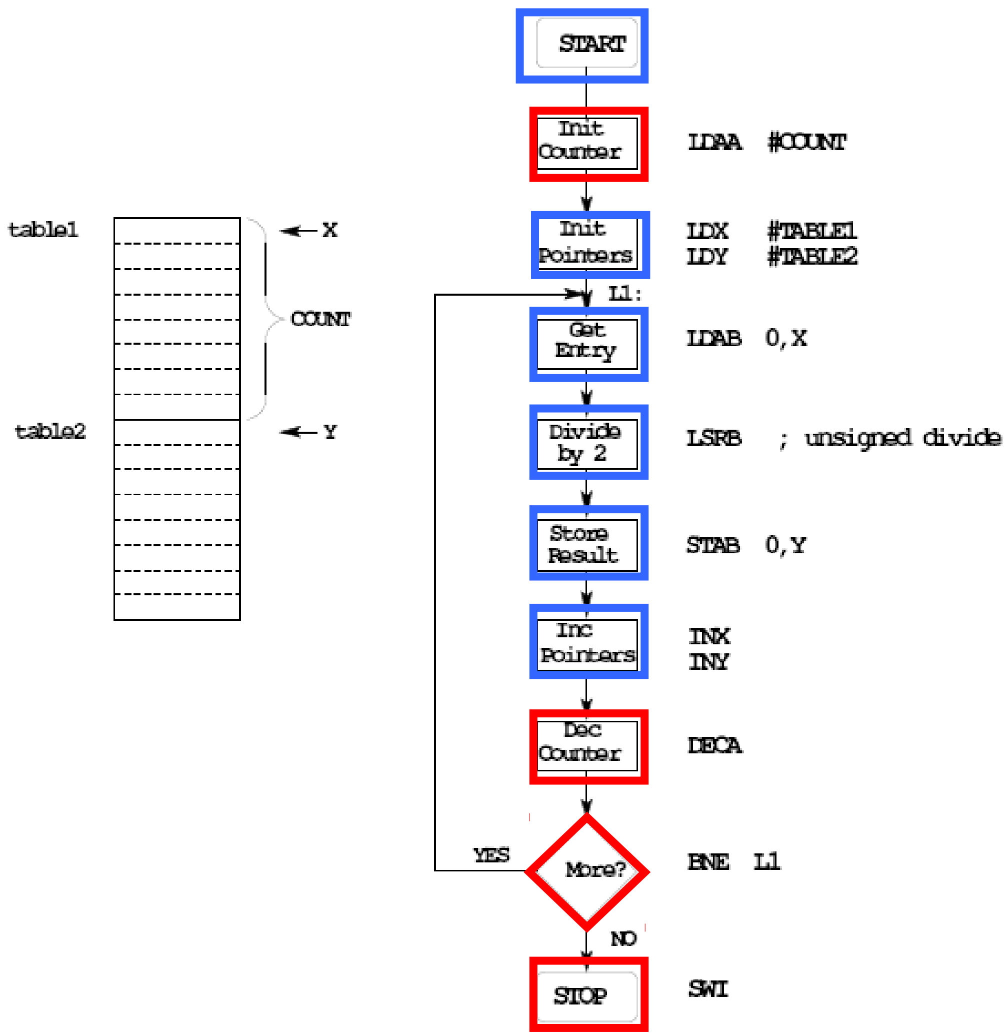


6. Need a way to determine when we reach the end of the table.

One way: Use a counter (say, register A) to keep track of how many Elements we have processed.



7. Add code to implement blocks:



8. Write the program:

```
; Program to divide a table by two
; and store the results in memory

prog:  equ    $2000
data:  equ    $1000
count:        equ    5

        org    prog   ; Set program counter to 0x2000
        ldaa   #count        ; Use A as counter
        ldx    #table1       ; Use X as data pointer to table1
        ldy    #table2       ; Use Y as data pointer to table2
l1:     ldab   0,x           ; Get entry from table1
        lsrb                 ; Divide by two (unsigned)
        stab   0,y           ; Save in table2
        inx                  ; Increment table1 pointer
        iny                  ; Increment table2 pointer
        deca                 ; Decrement counter
        bne    l1            ; Counter != 0 => more entries
                             ; to divide
        swi                  ; Done


        org data
table1: dc.b   $07,$c2,$3a,$68,$f3
table2: ds.b   count
```

9. Advanced: Optimize program to make use of instructions set efficiencies:

```
; Program to divide a table by two
; and store the results in memory

prog:   equ     $1000
data:           equ     $2000

count:          equ     5

                org     prog            ; Set program counter to 0x1000
                ldaa    #count          ; Use A as counter
                ldx     #table1         ; Use X as data pointer to table1
                ldy     #table2         ; Use Y as data pointer to table2
l1:             ldab    1,x+            ; Get entry from table1; then inc ptr.
                lsrb                    ; Divide by two (unsigned)
                stab    1,y+            ; Save in table2; then inc ptr.
                dbne    a,l1            ; Decrement counter; if not 0,
                                        ;  more to do
                swi                     ; Done


                org     data
table1:         dc.b    $07,$c2,$3a,$68,$f3
table2:         ds.b    count
```

TOP-DOWN PROGRAM DESIGN

- PLAN DATA STRUCTURES IN MEMORY

- START WITH A LARGE PICTURE OF THE PROGRAM STRUCTURE

- WORK DOWN TO MORE DETAILED STRUCTURE

- TRANSLATE STRUCTURE INTO CODE

- OPTIMIZE FOR EFFICIENCY

DO NOT SACRIFICE CLARITY FOR EFFICIENCY