Dynamic Selection

An access type can refer to a subprogram; an access-to-subprogram value can be created by the **'Access** attribute. A subprogram can be called using this pointer. This allows you to include a pointer to a routine inside of a record, or as a parameter. This is known as a ***callback***.

```
type Trig_Function is access function (F : Float) return Float;

T : Trig_Function;
X, Theta : Float;

T := Sin'Access;
X := T(Theta);        -- implicit dereferencing.  SHOULD NOT BE USED!
                      -- This looks like normal function call.

X := T.all (Theta); -- explicit dereferencing.  THIS IS PREFERRED.
```

T can *point to* functions (such as Sin, Cos and Tan) that have a matching parameter list. Functions must have matching return types.

"If" Statement

Format

<if_statement> ::=
if <condition> then
    <sequence_of_statements>
{elsif <condition> then
    <sequence_of_statements>}
|else
    <sequence_of_statements>|
end if;

Conditional Expressions

Expression where results are True or False.

Qualifiers

= /= > < >= <= in not in

Boolean Operators

and or xor not

Examples

```
type DAY is (Monday, Tuesday, … , Sunday);
    TODAY,  TOMORROW : DAY;

if TODAY = Sunday then              -- simple if-then
    TOMORROW := Monday;
end if;

if TODAY = Sunday then              -- if-then-else
    TOMORROW:= Monday;
else
    TOMORROW := DAY ' SUCC(TODAY);
end if;
```


Nested IF Example

```
type DIRECTION is (Left, Right, Back);

    ORDER :  DIRECTION;
if  ORDER = Left  then
    TURN_LEFT;
else
    if  ORDER = Right then
            TURN_RIGHT;
    else
            if  ORDER = Back then
                    TURN_BACK;
        end if;
    end if;
end if;
```

ELSIF Construct

Reduces level of nesting in a program

Example:

```
If ORDER = Left then
    TURN_LEFT;
elsif ORDER = Right then
    TURN_RIGHT;
elsif ORDER = Back then
    TURN_BACK;
end if;
```


More IF Examples

```
if  TODAY = FRIDAY then
    Num_Weeks := Num_Weeks + 1;
    Num_Left := Num_Left - 1;
    Ada.Text_IO.Put_Line("TGIF!!!");
end if;
 if     SCORE >= 90 then LETTER_GRADE := 'A';
   elsif SCORE >= 80 then LETTER_GRADE := 'B';
   elsif SCORE >= 70 then LETTER_GRADE := 'C';
   elsif SCORE >= 60 then LETTER_GRADE := 'D';
   else LETTER_GRADE := 'F';
   end if;
```


Short Circuit Control Forms

```
if COUNTER < TABLE'LAST then
        if RESULT(COUNTER) /= 0 then
                --          some statements
        end if;
end if;

if COUNTER < TABLE'LAST and then
        RESULT(COUNTER) /= 0 then
        --          some statements
end if;
if MY_PTR = null or else MY_PTR.ALL.ITEM = 0 then
        --          some statements
end if;
```

Sometimes, we run into the case of trying to use an if statement with an array, but the index might not be valid

Use the short circuit control forms to guarantee safe checks: (and then, or else)

Why Avoid "not"

- "Not" can add unnecessary complexity
- you should use statements that there are no questions what is meant by a false out come

BAD

```
if not x = y or z = q
then
        something;
end if;
```

GOOD (or BETTER)

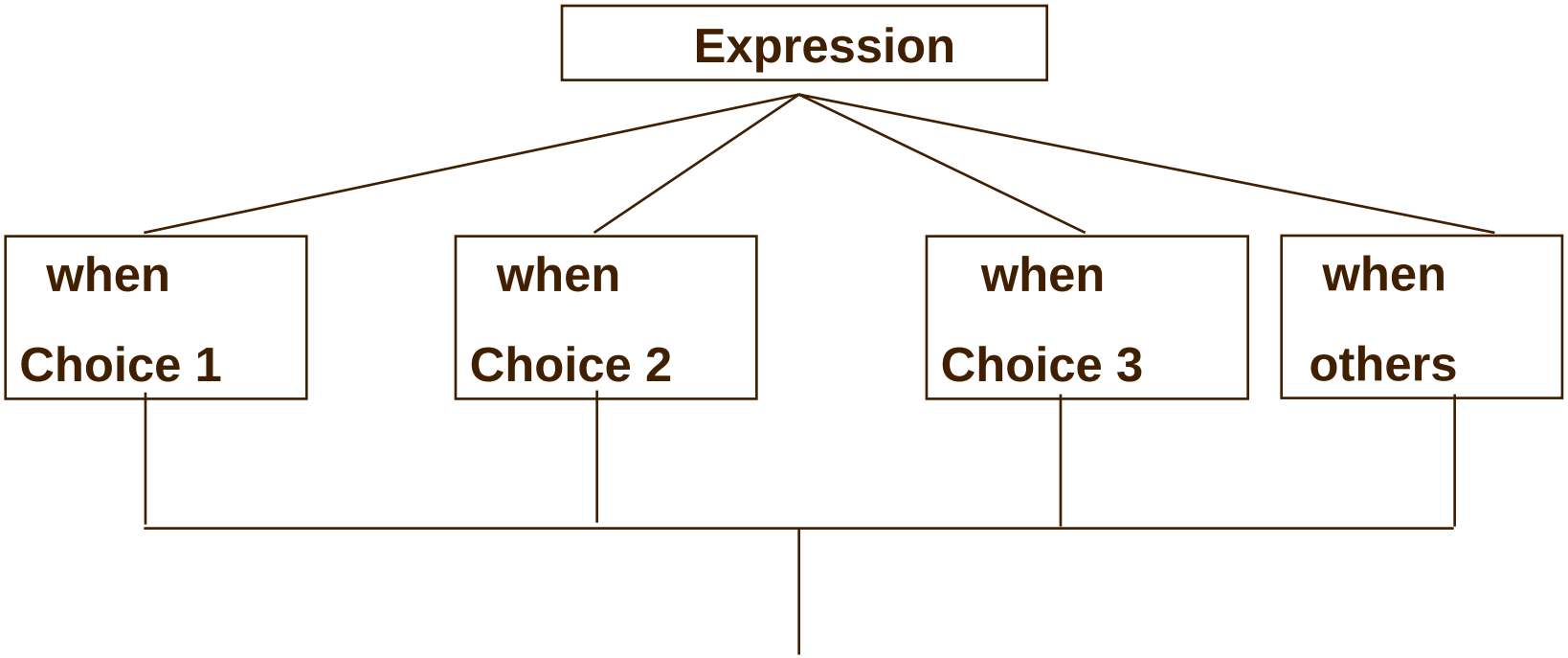
```
if  x = y or z = q
then
        null;
else
        something;
end if;
```


Case Statement

Format

```
case <discrete_expression> is
   when <choice> {|<choice>} =>
        <sequence_of_statements>
   {when <choice> {|<choice>} =>
        <sequence_of_statements>}
end case;
```


Expression



<discrete_expression>|

<discrete_range>|

others

"others"

- The rest (or all) receive this action or value
- Used in case statements, setting values, and exception handling
- Must be last alternative

Rules for ‘case’

- ✓ Expression must be discrete
- ✓ Choices must be mutually exclusive and exhaustive
- ✓ When "others" is used, it is only allowed as the last alternative
- ✓ There is no “fall through” in Ada. Each case, when complete, goes to the end of the case statement, NOT the next option

CASE Statement Examples

Alternatives must be:

- **discrete**
- **exhaustive**, and
- **mutually exclusive**.

```
type Grade_Type is ('A','B','C','D','F','I');

case LETTER_GRADE is
   when 'A' => -- a sequence of statements
   when 'B' => -- a sequence of statements
   when 'C' => -- a sequence of statements
   when 'D' => -- a sequence of statements
   when 'F' => -- a sequence of statements
   when 'I'  => -- a sequence of statements
end case;

case LETTER_GRADE is
   when 'A' | 'B' | 'C' => -- a sequence of statements
   when 'D' =>              -- a sequence of statements
   when 'F' =>             -- a sequence of statements
   when others =>          -- a sequence of statements
end case;

case LETTER_GRADE is
   when 'A' .. 'C' => -- a sequence of statements
   when 'D' =>        -- a sequence of statements
   when 'F' =>        -- a sequence of statements
   when others =>   -- a sequence of statements
end case;
```

More CASE Examples

```
procedure SWITCH (HEADING :in out DIRECTION) is
begin
   case HEADING is
      when NORTH => HEADING := SOUTH;
      when EAST  => HEADING := WEST;
      when SOUTH => HEADING := NORTH;
      when WEST  => HEADING := EAST; --what happens if I add SW?
  end case;
end SWITCH;
```

```
case NUMBER is  --assume NUMBER is an integer
   when 2          => DO_SOMETHING;
   when 3 | 7 | 8 => DO_SOMETHING_ELSE;
   when 9 .. 20    => DO_SOMETHING_RADICAL;
   when others     => DO_OTHER_THINGS;
                      Ada.Text_IO.PUT_LINE ("Others");
end case;
```


Better than “if ” ???

```
procedure SWITCH (HEADING :in out DIRECTION) is
 begin
   case HEADING is
     when NORTH => HEADING := SOUTH;
     when EAST  => HEADING := WEST;
     when SOUTH => HEADING := NORTH;
     when WEST  => HEADING := EAST;
  end case;
 end SWITCH;
```

```
procedure SWITCH (HEADING :in out DIRECTION) is
 begin
   if Heading = North then  Heading := South;
   elsif Heading = East then Heading := West;
   elsif Heading = South then Heading := North;
   else Heading := East;
   end if;
end SWITCH;
```

Summary of Case Statements

- ✓ Expression must be discrete
- ✓ Choices must be mutually exclusive and exhaustive
- ✓ When "others" is used, it is only allowed as the last alternative

ITERATIVE STATEMENTS

Iterative Statements (Loops)

- Basic Loop -- used to execute a sequence of statements up to an infinite number of times.
- For .. loop -- used to execute a sequence of statements a finite number of times.
- While .. loop -- used to execute a sequence of statements until a certain condition is met.

Iterative Statement Examples

```
loop
    <sequence of statements>
end loop;

for I in 1 .. 10 loop
    <sequence_of_statements>
end loop;

while I < 10 loop
    <sequence_of_statements>
end loop;
```

Basic Loop

Basic loop is infinite because in embedded systems sometimes we want to loop continuously.

```
loop
                <sequence of statements>
end loop;
```

Basic Loop

EXAMPLES:

```
loop
    GET (SAMPLE);
    PROCESS (SAMPLE);
end loop;

loop
    GET (ALTITUDE);
    if ALTITUDE < 1000 and not GEAR_DOWN then
            LIGHT_GEAR_DOWN_LAMP;
            SOUND_ALARM;
    end if;
end loop;
```


Exit Statement

Two Forms:

Unconditional exit

exit;

Conditional exit

exit when <boolean expression>;

Basic Loop
'exit' Statement

```
loop
    ...
    if x = 20 then
        exit;
    end if;
end loop;
--or--
loop
    ...
    exit when x = 20;
end loop;
```

Basic Loop

```
EXAMPLE:
INDEX : integer := 1;
E       : Float    := 0.0;
TERM  : Float    := 1.0;
loop
      exit when INDEX := MAX_TERM;
      INDEX := INDEX + 1;
      TERM := TERM / FLOAT(INDEX);
      E :=  E + TERM;
end loop;
loop
      if INDEX = MAX_TERM then
            exit;
      else
           INDEX := INDEX + 1;
          TERM := TERM / FLOAT(INDEX);
          E := E + TERM;
      end if;
end loop;
```

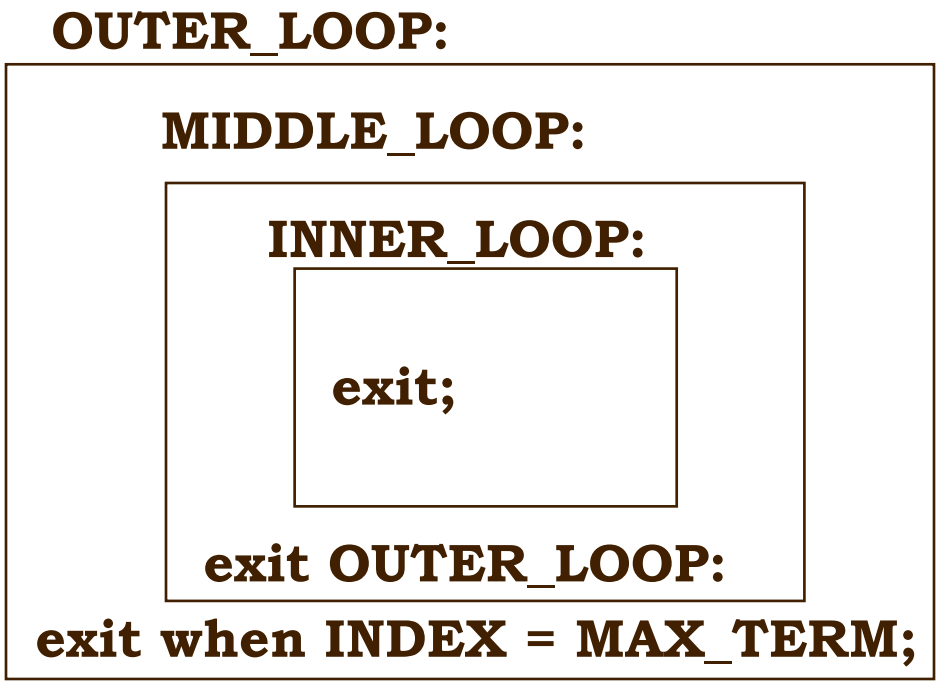
Named Loops

```
OUTER:
loop
    INNER:
    loop
       exit OUTER;
    end loop INNER;
    exit;
end loop OUTER;
```

Exit Statement

exit; -- exits the innermost enclosing loop

exit Outer_loop; -- exits a named loop



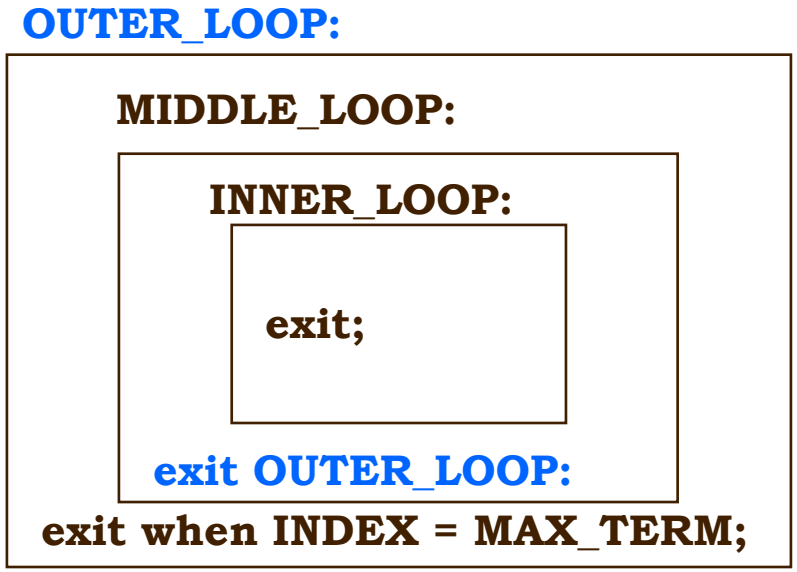
Basic Loop

EXAMPLE:

```
X := ...
OUTER:
loop
      INNER:
      loop
         if X = 20 then
           exit OUTER;
         end if;
         exit INNER when X = 21;
         X := X + 2;
      end loop INNER;
end loop OUTER;
```

Exit Statement

```
exit when INDEX = MAX_TERM;
        -- exits innermost enclosing
        -- loop when condition is true
exit OUTER_LOOP when INDEX = MAX_TERM
        exits the named loop
        when condition is true
```



To go from the INNER_LOOP to the OUTER_LOOP we could use exit MIDDLE_LOOP

For Loop

for <loop index> in <start value> .. <stop value> loop
    <sequence of statements>
end loop;

<loop index> is an identifier. It is declared implicitly--it is NOT declared by the programmer. Its type depends on the type of <start value> and <stop value>. It is treated as a constant within the loop. It “disappears” after the loop

<start value> and <stop value> must be discrete expressions.

Control Variables

- ARE IMPLICITLY DECLARED
- MUST BE DISCRETE
- TAKE THEIR TYPE FROM THE DISCRETE RANGE
- ARE IN EXISTENCE ONLY UNTIL end loop
- CANNOT BE MODIFIED (LOCAL CONSTANT)
- ONLY SINGLE STEP INCREMENT (DECREMENT)
- CAN 'HIDE' A VARIABLE WITH SAME NAME

Example of Control Variables

```
for DAY in DAYS loop
    ...
end loop;

for COUNTER in reverse 1..10 loop
    ...
end loop;
```


For Loop

EXAMPLES:

```
for INDEX in 1..15 loop
    --      Index is type Universal INTEGER
    <SOS>
end loop;

for INDEX in reverse  1..15  loop
    --      Backwards
    <SOS>
end loop;
```


For Loop

EXAMPLE:

```
procedure MAIN is
    SUM  : INTEGER := 0;
    I    : INTEGER := 10;
begin
    for I in 1..5 loop
                    SUM := I + MAIN.I + SUM;
    end loop;
end MAIN;
```


For Loop

```
procedure MAIN is
      type DAYS is (Mon, Tue, Wed, Thu, Fri, Sat, Sun);
      subtype WEEKDAYS is DAYS range Mon .. Fri;
begin
      for  TODAY  in Mon .. Sun loop
            <sequence of statements>
      end loop;

      for TODAY in DAYS loop
          <sequence of statements>
      end loop;

    for TODAY in DAYS range Mon .. Fri loop
            <sequence of statements>
    end loop;

    for TODAY in WEEKDAYS loop
          <sequence of statements>
      end loop;
end;
```

For Loop

EXAMPLE:

```
with Ada.Text_IO;
procedure PRINT_ALL_VALUES is
      type COLORS is (RED, WHITE, BLUE);
      package COLOR_IO is new
          Ada.Text_IO.ENUMERATION_IO (COLORS);
begin

      for INDEX in 1..5  loop
          null;
      end loop;

      for A_COLOR in COLORS loop
          COLOR_IO.PUT(A_COLOR);
          Ada.Text_IO.NEW_LINE;
      end loop;
end PRINT_ALL_VALUES;
```


For Loop

```
with Ada.Text_IO;
procedure MAIN_PROGRAM is
        type INDEX_TYPE is range 1 .. 100;
        type CTR_TYPE is INTEGER range -10 .. 10;
        package INDEX_IO is new
            Ada.Text_IO.INTEGER_IO(INDEX_TYPE);
        package COUNTER_IO is new
            Ada.Text_IO.INTEGER_IO(CTR_TYPE);
begin
        for INDEX in INDEX_TYPE'FIRST.. INDEX_TYPE'LAST loop
                Ada.Text_IO.PUT("The index number is ");
                INDEX_IO.PUT(INDEX);
                Ada.Text_IO.NEW_LINE;
        end loop;

        for COUNTER in  CTR_TYPE'RANGE loop
                Ada.Text_IO.PUT("The counter number is ");
                COUNTER_IO.PUT(CONTER);
                Ada.Text_IO.NEW_LINE;
        end loop;
end MAIN_PROGRAM;
```

For Loop Example

```
procedure MAIN is
    type INDEX is range 0 .. 200;
begin
    for I in reverse INDEX loop
        <sequence of statements>
    end loop;

    for I in reverse INDEX range 1 .. 50 loop
        <sequence of statements>
    end loop;s`s
end MAIN;
```


Iterative Statement (While Loop)

```
while <boolean expression> loop
    <sequence of statements>
end loop;

while not Ada.Text_IO.END_OF_FILE(INPUT_FILE)
    loop
    ARGU_IO.GET(INPUT_FILE, ARGUMENT);
    Ada.Text_IO.PUT(ARGUMENT);
end loop;

while INPUT < 0 or INPUT > 100 loop          :
    Ada.Text_IO.PUT_LINE("Bad Input - Try again");
end loop;
```


While Loop

EXAMPLES:

```
while NOT_DARK loop
    PLAY_TENNIS;
end loop;
TURN_ON_LIGHTS;
while COUNT <= 100 loop
    COUNT := COUNT+ 1;
    if EMERGENCY then
       exit;
    end if;
end loop;
```


While Loop Example

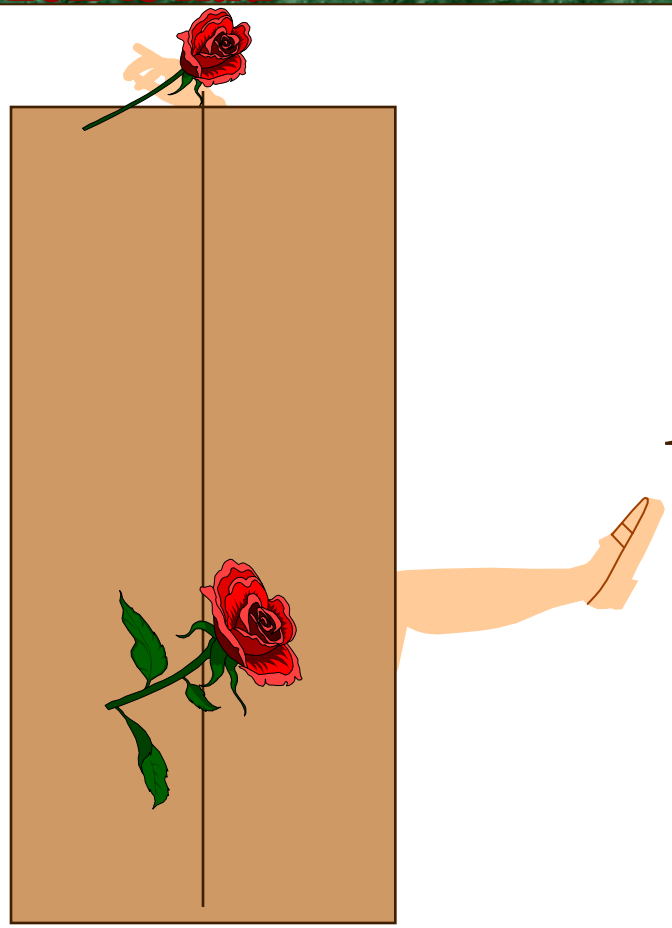
```
package INT_IO is new
    Ada.Text_IO.INTEGER_IO(INPUT_TYPE);
package ENUM_IO is new
    Ada.Text_IO.ENUMERATION_IO(DONE_TYPE);

while INPUT not in 1 .. 99 loop
     Ada.Text_IO.PUT_LINE("Bad Input - Try again.");
    INT_IO.GET(INPUT);
end loop;

while not DONE loop
    INT_IO.GET(INPUT);
    Ada.Text_IO.PUT("More input (true/false)?");
    ENUM_IO.GET(Done);
end loop;
```

Nested Example

```
with Ada.Text_IO;
procedure COUNT_SMALL_LETTERS is
        CURRENT_LINE : STRING(1 .. 100);
        LENGTH : NATURAL;
        NO_SMALL_LETTERS : NATURAL := 0;
begin
        for LINE_NUMBER in 1 .. 10 loop
                Ada.Text_IO.GET_LINE(CURRENT_LINE, LENGTH);
                for CHAR_NUMBER in 1 .. LENGTH loop
                        if  CURRENT_LINE(CHAR_NUMBER) in  'a' .. 'z'  then
                                NO_SMALL_LETTERS :=
                                   NO_SMALL_LETTERS + 1;
                        end if;
                end loop;

                Ada.Text_IO.PUT("There are ");
                Ada.Text_IO.PUT(NATURAL'IMAGE(NO_SMALL_LETTERS));
                Ada.Text_IO.PUT_LINE(" small letters");
        end loop;
end;
```

Summary

- ✓ LOOPING CONSTRUCTS
  - **BASIC LOOP**
    - execute an infinite number of times
  - **FOR LOOP**
    - execute a finite number of times
  - **WHILE LOOP**
    - execute until a certain condition is met



Ada's Private Parts

What is essential is invisible to the eye.

Antoine de Saint-Exupery, The Little Prince

Ada's Private Parts

Information hiding -- Avoid revealing implementation details. The more that is hidden the more freedom you will enjoy in maintenance.

Private -- *outside view, predefined "=" and "/="*

Limited Private -- *outside view, only user defined operations (equality not defined!)*

```
package B_R is
        type NUMBERS is range 0..99;
        procedure TAKE (A_NUMBER : out NUMBERS);
        function NOW_SERVING return NUMBERS;
        procedure SERVE (NUMBER : in NUMBERS);
end B_R;

package body B_R is

SERV_A_MATIC : NUMBERS := 1;

procedure TAKE (A_NUMBER : out NUMBERS ) is
begin
      A_NUMBER := SERV_A_MATIC;
      SERV_A_MATIC := SERV_A_MATIC + 1;
end TAKE;

function NOW_SERVING return NUMBERS
    is separate;
procedure SERVE (NUMBERS : in NUMBERS) is
    separate;
end B_R;
```

```
with B_R;     --  logical link to package
      specification
use B_R;      --  direct visibility for infix notation
procedure ICE_CREAM is
      YOUR_NUMBER : NUMBERS;
begin
        TAKE (YOUR_NUMBER);
        loop
             if NOW_SERVING = YOUR_NUMBER
             then
                    SERVE (YOUR_NUMBER);

        --correct use of the abstraction
        --wait for your number to be called

              exit;
            end if;
        end loop;
end ICE_CREAM;
```

Abusing the abstraction

```
with B_R; use B_R;
procedure ICE_CREAM is
      YOUR_NUMBER : NUMBERS;
begin
      TAKE (YOUR_NUMBER);
      loop
        if NOW_SERVING = YOUR_NUMBER then
              SERVE (YOUR_NUMBER);
              exit;
        else
              YOUR_NUMBER := YOUR_NUMBER - 1;

--BUT, nothing prevents me from modifying my number.
--This is an abuse of the “abstraction”

        end if;
      end loop;
end ICE_CREAM;
```

```
--Solution?  Use a private type to prevent changing
--the value of objects of type NUMBERS

package B_R is

type NUMBERS is private;

--  Only the type name is exportable; the data
--  structure has not been defined
--  Only operations below are defined

procedure TAKE (A_NUMBER : out NUMBERS);
function NOW_SERVING return NUMBERS;
procedure SERVE (NUMBER : in NUMBERS);

private
      type NUMBERS is range 0..99;
end B_R;

--PROBLEM - “assignment” is still defined, so I
--can still abuse the abstraction
```

```
with B_R; use B_R;
procedure ICE_CREAM is
      YOUR_NUMBER : NUMBERS;
begin
TAKE (YOUR_NUMBER);
loop
      if NOW_SERVING = YOUR_NUMBER then
        SERVE (YOUR_NUMBER);
        exit;
      else

        YOUR_NUMBER := NOW_SERVING;
        --just go to the front of the line!


      end if;
end loop;
end ICE_CREAM;
```


```
--CORRECT SOLUTION – use limited private type
--to prevent improper access

package B_R is

type NUMBERS is limited private;

--with limited private, not even "=" is defined.

procedure TAKE (A_NUMBER : out NUMBERS);
function NOW_SERVING return NUMBERS;
procedure SERVE (NUMBER : in NUMBERS );

function "=" (LEFT, RIGHT : in NUMBERS)
      return  BOOLEAN;
--  this operation must be added to allow the user
--  to compare two objects of a limited private type

private
      type NUMBERS is range 0..99;
end B_R;
```

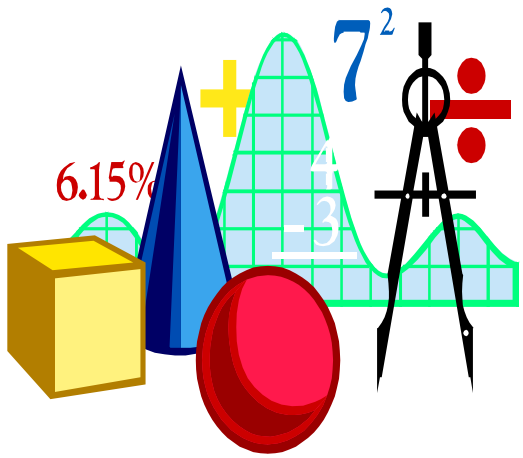
```
with B_R; use B_R;
procedure ICE_CREAM is
        YOUR_NUMBER : NUMBERS;
        procedure GO_TO_DQ is separate;
begin
        TAKE (YOUR_NUMBER);
        loop
             if NOW_SERVING = YOUR_NUMBER
             then
               SERVE (YOUR_NUMBER);
               exit;
             else
               GO_TO_DQ;  --only other option ;=}
               exit;
             end if;
        end loop;
end ICE_CREAM;

--To sum it up, "private" and "limited private"
--restrict the visibility and access to types and
--objects.  This allows you to "Enforce your
--abstractions"
```

Exercise

- Modify your previous program.
- Change Age to Private. Pass Age between subprograms.
- Modify Age objects.
- Try adding and multiplying Ages;
- Change Age to Limited Private and *, / operations.

Object-Oriented Programming

- Hierarchical Library Units
- Tagged types
- Class Wide programming
- Dispatching
- Control



Benefits of OOD for Complex Systems

- ✓ An OOD approach facilitates
- ✓ Identifying and creating software modules with strong internal cohesion and weak external coupling with other modules.
- ✓ Identifying and creating Ada packages.
- ✓ Providing a direct correspondence between the physical world and the computer software.

Disadvantages of OOD for Complex Systems

- ✓ OOD may have negative space and timing impact.
- ✓ OOD requires replacing the traditional functional decomposition mindset.

What is an Object?

- A self-contained thing which is characterized by:
  - it's states
  - the actions it performs
  - the actions that can be performed upon it
  - an unique designation
- An Object is an instance of a Class (set,type,group)
- Views of an Object:
  - External perspective
  - Internal perspective
- An Object may be composed of one or more Objects

Ada Object

- In Ada, an Object is typically implemented as an:

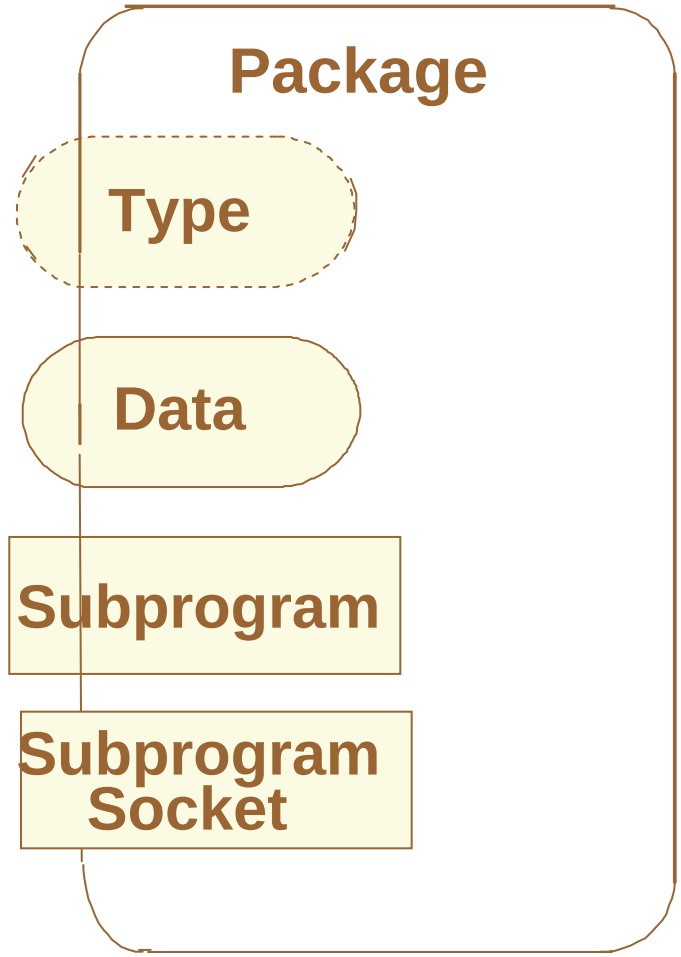
- Abstract State Machine (ASM)
  package or generic package, with no exportable type. There is only one object, the state machine itself.

- Abstract Data Type (ADT)
  package or generic package, with exportable type. You can make as many instances as you need.

What is an ASM?

- An ASM package or generic package encapsulates:
- A single, possibly complex Ada object of a single type, both typically hidden in the body
  Note: It may also encapsulate hidden auxiliary Ada objects and types.
- Exported operations (e.g. subprograms or task entry points) that operate on this object.
  Note: It may also encapsulate hidden auxiliary operations.
- Exceptions (error conditions) that are raised (and must be properly handled) when the operations cannot produce a valid result.
- An ASM is represented by a singular noun (e.g., Account_Payable).

Buhr Sample 1
Abstract State Machine



Example of an Abstract State Machine

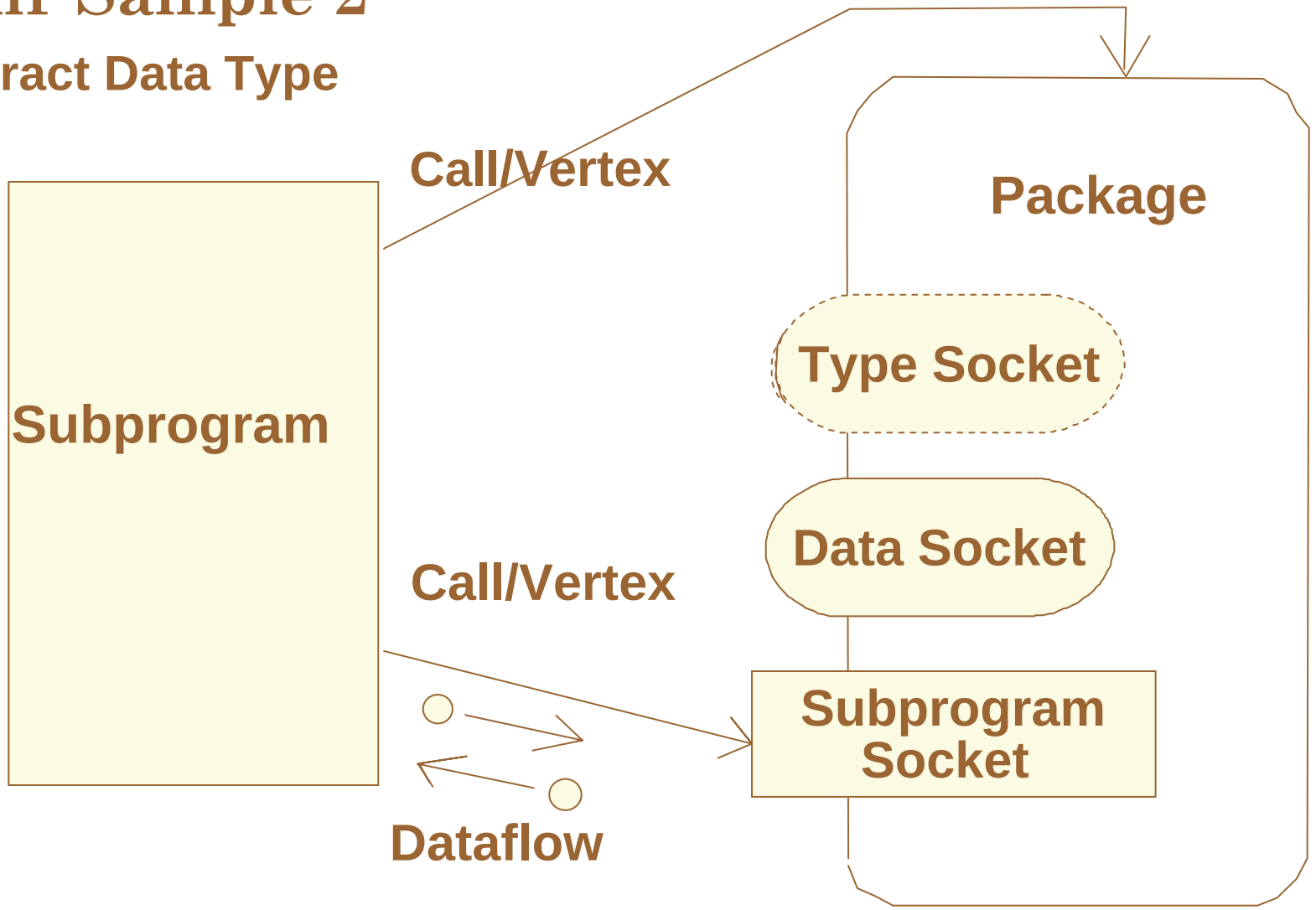
```
with Aircrew_Characteristics;
package Aircrew is
- Abstract State machine
procedure Select_Crew_Member (Crew_Member : in
                Aircrew_Characteristics.Crew_Members);
procedure Swap_Crew_Member (Old_Crew_Member : in
                Aircrew_Characteristics.Crew_Members;
                New_Crew_Member : in
                Aircrew_Characteristics.Crew_Members);
procedure Select_Crew_For (Aircraft : in
                Aircrew_Characteristics.Aircraft_Class);
procedure Build_Crew;
function Numbers_Of_Crew_Members return Natural;
Can_Not_Build_Crew        : exception;
Crew_Member_Does_Not_Exist : exception;
end Aircrew;
with Aircraft_Classes;
package Aircrew_Characteristics is
  type Crew_Member is limited private;
  -- private part ...
end Aircrew_Characteristics;
```


What is an ADT?

- An ADT package or generic package encapsulates:
- Multiple export Ada objects (data variables) of a single type.
  Note: It may also encapsulate hidden auxiliary Ada objects and types.
- Exported operations (e.g. subprograms or task entry points) that operate on these objects.
  Note: It may also encapsulate hidden auxiliary operations.
- Exceptions (error conditions) that are raised (and must be properly handled) when the operations cannot produce a valid result.
- An ADT is represented by a plural noun (e.g. Windows)

Buhr Sample 2

Abstract Data Type



Example of an Abstract Data Type

```
with Coordinates, Velocity;
package Targets_Id is
  type TARGETS is private;
  type TARGET_CLASSIFICATION is (FRIENDLY, ENEMY, UNKNOWN);
  type TARGET_FORM is (AIRCRAFT, MISSILE, UNKNOWN);

procedure Classify (Target : in out TARGETS);
procedure   Create (Target :    out TARGETS);
procedure   Delete (Target : in     TARGETS);
function Classification_Of (Target : in TARGETS)
                    return TARGET_CLASSIFICATION;
function Coordinates_Of    (Target : in TARGETS)
                 return Coordinates.COORDINATES_TYPE;
function Exists (Target : in TARGETS) return BOOLEAN;
function Form_Of (Target : in TARGETS) return TARGET_FORM;
function Velocity_Of (Target : in TARGETS) return
                           Velocity.VELOCITY_TYPE;
CAN_NOT_CREATE : exception; -- Create_Next
DOES_NOT_EXIST : exception; -- Classify, Delete, Form_Of
                      -- Classification_Of
private -- Hidden definition of target identification
  -- private part.  We don't care!
end Targets_Id;
```

Kinds of Objects

- Active
- Acts Autonomously
- Acts upon other objects
- May be acted upon
- Passive
- Never acts autonomously
- May act upon other objects
- Is acted upon

Classifications of Operations in OOD

- Constructors: Operations that change the state of an object (e.g. Push (Element_On,My_Stack);).
- Selectors: Operations that retrieve the state of an object (e.g. Is_Empty --Return true if stack is empty).
- Iterators: For an object that is a collection of other objects, operations that visit the collection's components. (e.g. Get_Next(The_Iterator : in out Iterator); - Advance the iterator to the next item in the queue).
- Desired characteristics of object operations
- Sufficient to permit all common uses of the object
- Complete to permit all common uses of the object
- Primitive whose efficient implementation can only be achieved with access to the undelying data representation.

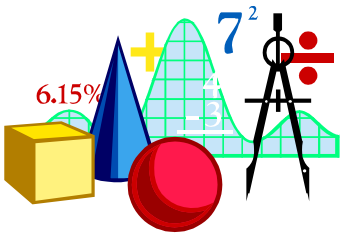
Classes

- A class has the following characteristics:
- represents real world object
- is a template to create objects (variables)
- encapsulates protected data with the operation on the data
- access to protected data is through calls (messages) that invoke operations
- In Ada a class may be a package that encapsulates a user defined data type and operations. There are many ways to create classes in Ada.

What a language needs for OOP

Essentials	***Nice to have***
Abstraction	Typing
Encapsulation	Concurrency
Modularity	Persistence
Hierarchy	

Ada 95 and OOSE

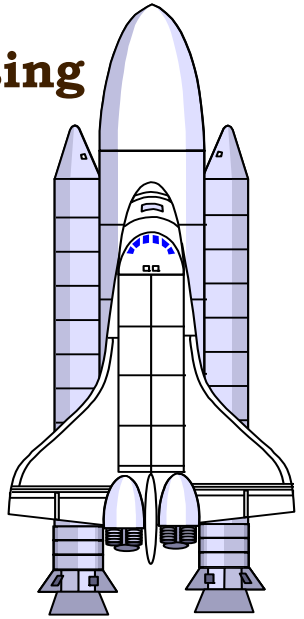


Ada 95

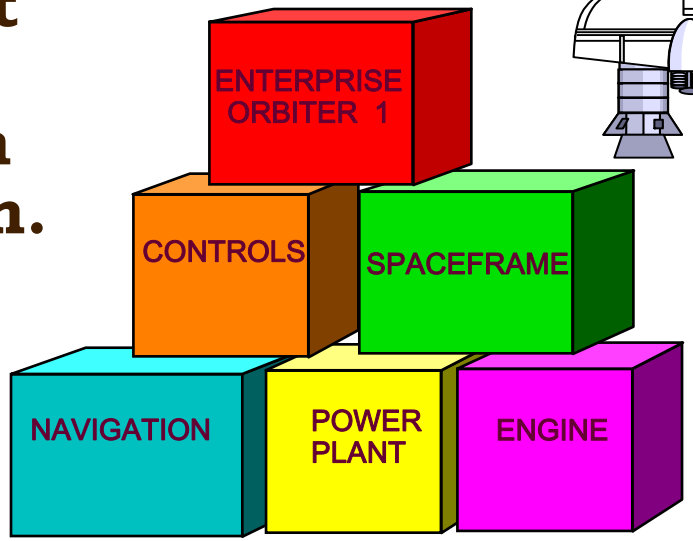
- Is a superior language for supporting software engineering principles.
- Is a language which provides support for OOP for those who wish to use it.
- Provides a somewhat different model for OOP than other languages.

Object-Oriented Methodologies

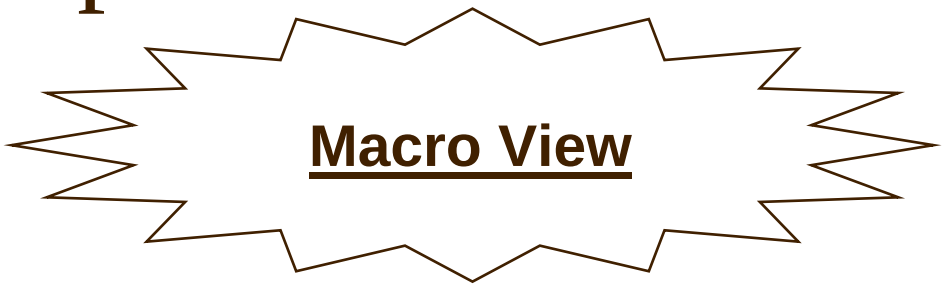
- **OO methodologies attempt to build complex systems using "classes" and "objects" as the building blocks**
  - **Attempts to model the real world via abstraction**
  - **Evolutionary, not revolutionary**



- **Experience has shown that this is the superior way to manage and decompose an inherently complex system. Functional methodologies require you to understand the entire system before you can modularize it!**



How to implement the OO Paradigm



- **Identify the core requirements for the software (conceptualization)**
- **Develop a model of the system's desired behavior (analysis)**
- **Create an architecture for the implementation (design)**
- **Evolve the implementation through successive refinements (evolution)**
- **Manage post delivery evolution (maintenance)**

How to implement the OO Paradigm

- Identify the classes at a given level of abstraction (OOD issue)
- Identify the objects at a given level of abstraction (OOD issue)
- Identify the relationships among these classes and objects (OOD issue)
- Specify the interface and then code the implementation of these classes and objects (OOP issue).

Benefits of the OO Paradigm

Reuse

Well-designed classes can be extended via inheritance.

- Previous code can be reused without modification to users of the original code.
  - Allowing lots of subclasses allows special cases to be truly special without modifications to normal classes.

Integration

OO supports incremental development.

- Additions to the system are easier.
- It is easy to develop the parent class first, and then concentrate on subordinate classes.

Benefits of the OO Paradigm (cont.)

Testing

Easier to test, as specific behaviors and classes can be tested individually.

- Specific test cases can be designed to test a class, and then this behavior does not need to be retested for subordinate classes

Maintenance

Additions to the system can be accomplished without modifying existing code.

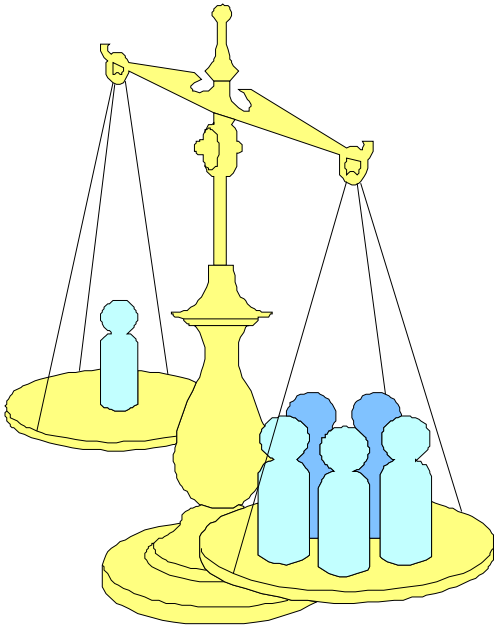
- Instead of modifications to existing classes, new classes can be constructed

Ada 95

- Ada 95 core language =

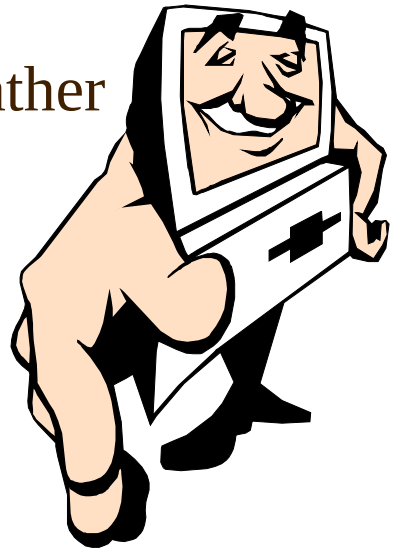
  Ada 83

  + OOP(inheritance, Polymorphism, Dynamic Binding)
  + Hierarchical library units
  + data-oriented synchronization
  + flexible scheduling
  + … Specialize needs annexes



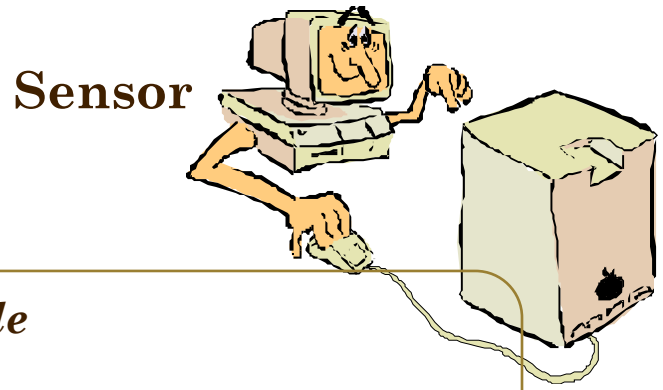
Ada 95 and OOSE

- ✓ Ada 95 has attempted to build on Ada 83 rather than changing the syntax drastically
- ✓ Mechanism for inheritance has been added
  - Permits type extension
  - Uses tagged types



- Child library units provide different views to different clients
- Ada 95 provides full support for OOP (Object-Oriented Programming)

Extensible vs. non-extensible types

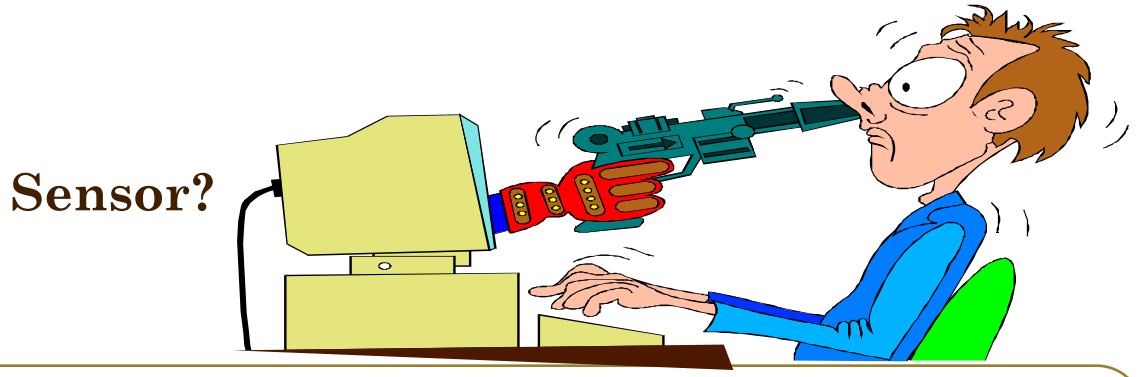



```
type Sensor is  record -- Not Extensible
            Current_State : State := On;
end Record;

procedure XXX ( Some_Parameter : Sensor);
function YYY return Sensor;
function ZZZ (Some_Parameter : in Sensor) return WWW;
```

This is an Abstract Data Type (ADT).

You can extend the functionality by adding operations. The data structure is static.

Extensible vs. non-extensible types




```
type Sensor is  tagged record --  Extensible
            Current_State : State := On;
end Record;

procedure XXX ( Some_Parameter : Sensor);
function YYY return Sensor;
function ZZZ (Some_Parameter : in Sensor) return WWW;
```

This is a tagged type that can be used as the parent of an inheritance chain.

The data structure may be extended, and operations added.

Encapsulation

- Declare a class
- Attributes
- Methods (Operations)
- An object's state based on attributes
- An object's behavior based on methods
- Packaged public & private components

- ✓ Encapsulation
- ☑ Inheritance
- ☑ Polymorphism

Encapsulation...

- Is sometimes used as a synonym for "information hiding" [Meyer97]
- Encompasses a classes attributes and operations [Pressman01]
- Is the combination of hiding and message interface abstraction; of hiding and packaging [Eliens00]
- Extends the concept of abstraction from data to both data and functions [Daconta99]
- The basic idea behind a package or a module [Ledgard96]

Encapsulation

- Declare a class
  - Attributes
  - Methods (Operations)
  - An object's state based on attributes
  - An object's behavior based on methods
  - Packaged public & private components

- ✓ Encapsulation
- ☑ Inheritance
- ☑ Polymorphism

Declaring a Class: Ada 95

```
package Rx is
type Rx_type is private;
procedure del_Rx (Rx_num);
procedure refill_Rx (Rx_num);
procedure wr_Rx (Rx_num, patient, physician,
                 ...);
private:
  type Rx_type is record
    Rx_num: int;
    patient: string;
    physician: string;
    med_name: string;
    num_refills: integer;
  end record;
end Rx;
```

Private Parts: Pkg Body

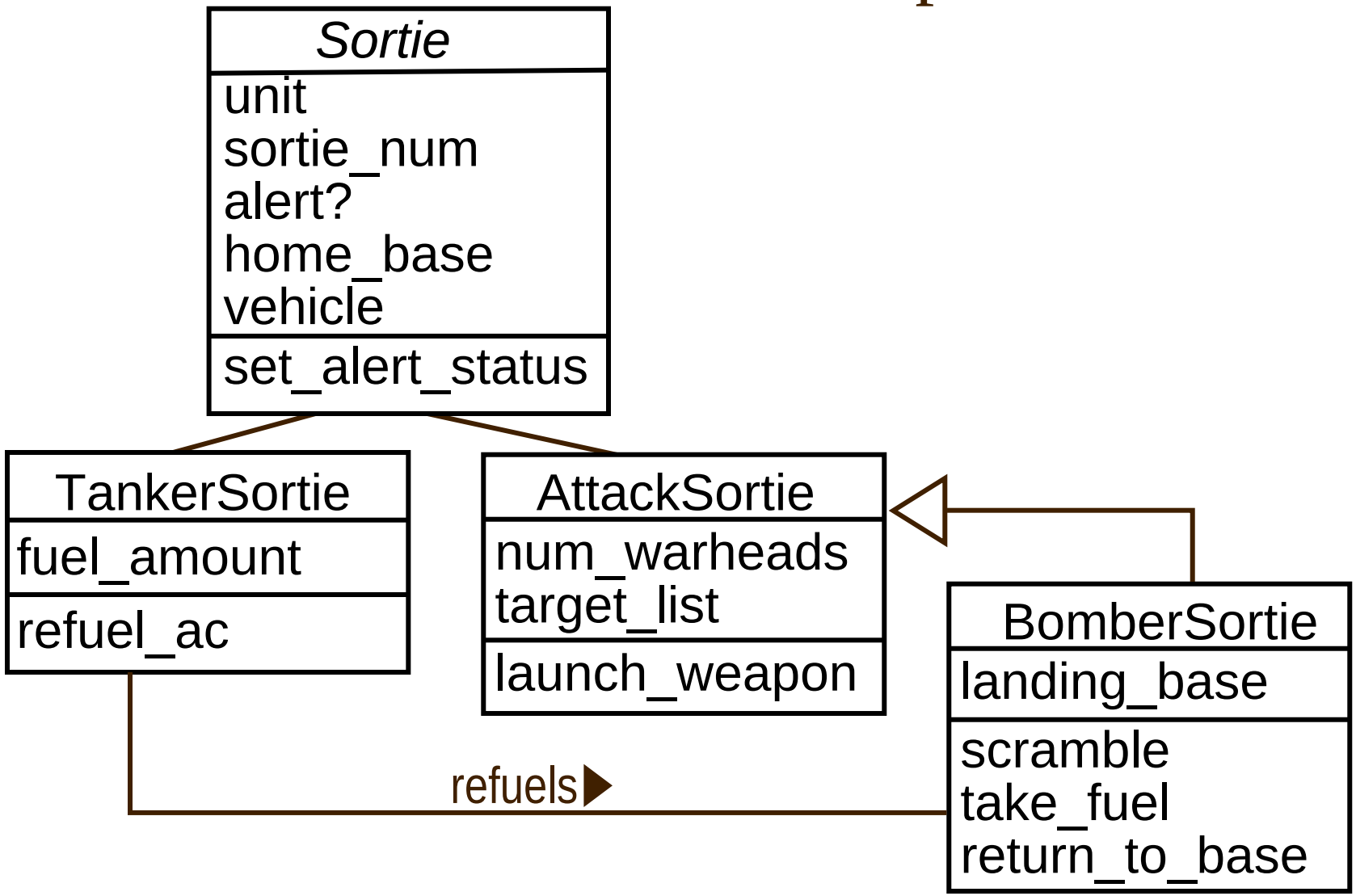
```
package body Rx is

procedure refill_Rx (the_num : in int) is
Rx : Rx_type;
begin
  --traverse Rx store, find Rx record
  if Rx.Rx_num = the_num then
    if Rx.num_refills > 0 then
      Rx.num_refills := Rx.num_refills - 1;
    else
      raise no_refills_left;
    endif;
  endif;
end refill_Rx;
```


Inheritance

- Declare a parent class
  - May be abstract
  - Can have children
  - Children inherit ALL attributes & ops
  - Children may also have children

- ☑ Encapsulation
- ✓ Inheritance
- ☑ Polymorphism

Inheritance Example



Inheritance: Ada 95

```
type attack_sortie is new sortie with
  record
    num_warheads: integer;
    target_list: target_list_type;
  end record;

type bomber_sortie is new attack_sortie with
  record
    landing_base: string;
  end record;
```


Inheritance: Ada 95

```
type attack_sortie is new sortie with
  record
    num_warheads: integer;
    target_list: target_list_type;
  end record;

type bomber_sortie is new attack_sortie with
  null record;
```


Tagged Types

```
type Rectangle is tagged
    record
        Length : Float := 0.0;
        Width   : Float := 0.0;
     end record;
--  Operations for inheritance now defined
--   Example: Rectangles have a defined perimeter, and
--   children derived from Rectangle will have Perimeter

function Perimeter (R : in Rectangle ) return Float is
  begin
     return 2.0 * (R.Length +R.Width);
  end Perimeter;
```

Tagged Types - Inheritance

```
type Square is new Rectangle with
    null record; -- inherit from parent, add no new fields

--Square will inherit the primitive operation Perimeter

function Area (S : in Square ) return Float is
  begin
    return (S.Length  * S.Width);
  end Area;
```

Any operation declared in the scope of a tagged type (or in the scope of a type derived from a tagged type) is a “primitive” operation. It is automatically inherited.

This is an example of “extending” the type without adding any new components. This is similar to the way Ada 83 used derived types.

Tagged Types - Inheritance


```
type Cuboid is new Rectangle with
     record
       Height : Float := 0.0;
      end record;

function Perimeter (C : in Cuboid ) return Float is
begin
    return Perimeter (Rectangle(C)) * 2 + ( 4 * C.Height);
end Perimeter;
```

Cuboid inherits Perimeter from Rectangle. The function will have to be updated for the new type (Perimeter is defined differently for cubes!).

To do this, you need to *override* the operation. One way to do this is to write a new Perimeter. A better way it to base the new Perimeter on the parent class operation. Note the *view conversion* in Perimeter - preventing recursion, and basing the perimeter of a cube on the perimeter of the base class.

Ada 95 Inheritance Programming

```
with Calendar;

package New_Alert_System is

    type Device is (Teletype, Console, Big_Screen);

        --define the "base class"

    type Alert is tagged
        record
            Time_of_Arrival : Calendar.Time;
            Message : Text;
        end record;
    procedure Display ( ...
    procedure Handle (A : in out Alert);
    procedure Set_Alarm ( …
```

Ada 95 Inheritance Programming

```
        --now, use the base class and extend it via inheritance

        type Low_Alert is new Alert;

        type Medium_Alert is new Alert with
                record
                        Action_Officer : Person;
                end record;

        --and override one of the inherited operations

        procedure Handle (MA : in out Medium_Alert);

        type High_Alert is new Medium_Alert with
                record
                        Ring_Alarm_At : Calendar.Time;
                end record;

        procedure Handle (HA: in out High_Alert);

end New_Alert_System;
```

Completing the subprograms...

```
package body New_Alert_System is
    procedure Handle(A: in out Alert) is begin
            A.Time_of_Arrival:= Calendar.Clock;
            Log(A);
            Display(A, Teletype);
    end Handle;
    procedure Handle(MA: in out Medium_Alert) is begin
            Handle(Alert(MA) );  -- conversion(no dispatch)
            MA.Action_Officer:= Assign_Volunteer;
            Display(MA, Console);
    end Handle;
procedure Handle(HA: in out High_Alert) is begin
            Handle(Medium_Alert(HA) );  -- conversion(no dispatch)
            Display(HA, Big_Screen);
            Set_Alarm(HA);
    end Handle;
...
end New_Alert_System;
```

Another user needs to extend again ...

```
with New_Alert_System;
package Emergency_Alert_system is
    type Emergency_Alert is
        new New_Alert_System.Alert with private;
  procedure Handle (EA : in out Emergency_Alert);
  procedure Display (EA : in Emergency_Alert;
                     On : in New_Alert_System.Devices);

procedure Log (EA : in Emergency_Alert);

private
   ....
end Emergency_Alert_System;
```

Abstract Types & Subprograms

```
-- Baseline package used to serve as root of  inheritance tree
package Vehicle_Package is
   type Vehicle is abstract tagged null record;
   procedure Start (Item : in out Vehicle) is abstract;
end Vehicle_Package;
```

- Purpose of an abstract type is to provide a common foundation upon which useful types can be built by derivation.
- An abstract subprogram is a place holder for an operation to be provided (it may not have a body).
- An abstract subprogram MUST be overridden for EACH subclass before any object of the subclass can be declared.

Abstract Types and Subprograms

```
type Train is new Vehicle with
     record
          passengers : Integer;
     end Train;

My_Train : Train;                    --  ILLEGAL
```

We can't yet declare an object of *Train*. Why? Because we haven't filled in the *abstract parts* declared in its parent. We have completed the *abstract record*, but still need to define procedure *Start* for the *Train*.

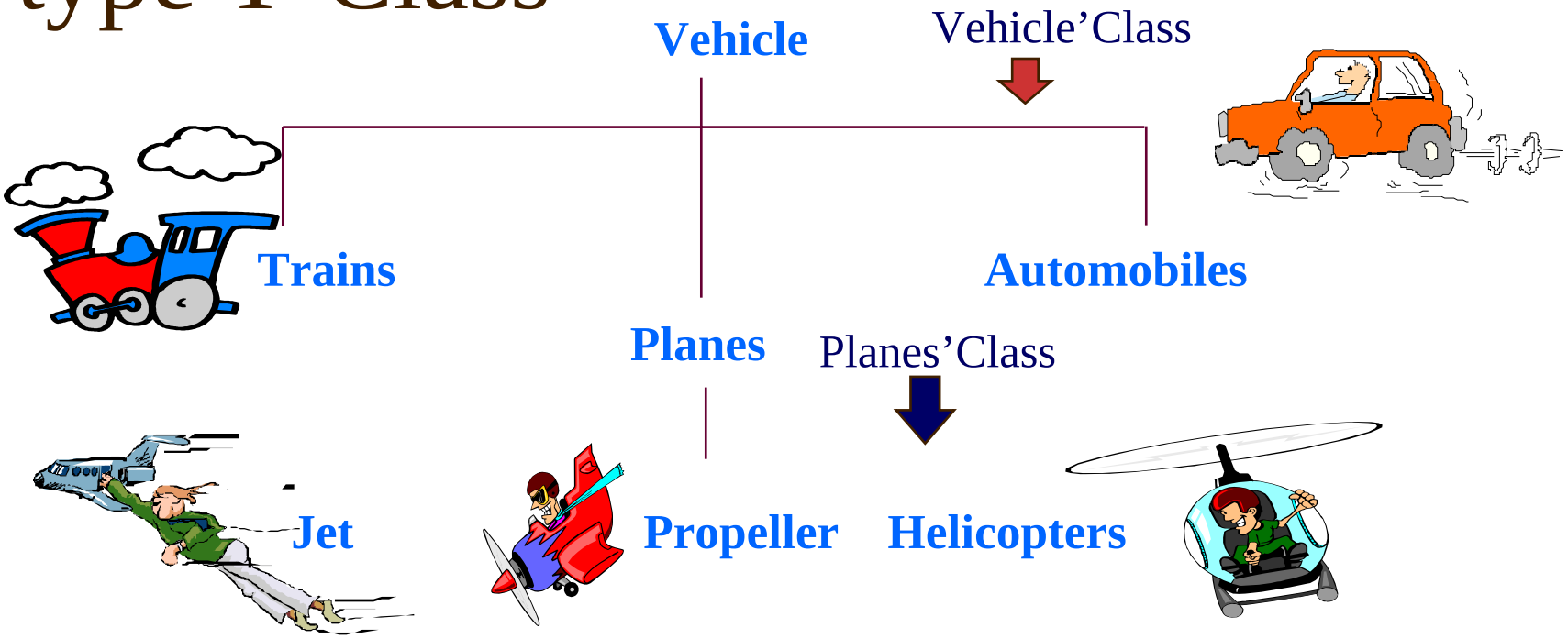
```
type Train is new Vehicle with
     record
          passengers : Integer;
     end Train;

procedure Start (Item : in out Train) is ....
My_Train : Train;
```


Abstract types

```
type Planes is abstract new Vehicle with
        record
                Wingspan : Some_Type;
        end Planes;

function Runway_Needed_To_Land
                        (Item : Planes) return Feet is abstract;
```

Type Planes is an abstract type based on Vehicle, which is also an abstract type. Therefore, the procedure Start must be overridden (to satisfy the requirements for Vehicle) and the function Runway_Needed_To_Land must be overridden (to satisfy the requirements for Planes) for any type derived from Planes.

Class Wide Programming type T'Class



With each tagged type T there is an associated type T'Class. This type comprises the union of all the types in the tree of derived types rooted at T. Legal values of T'Class are the values of T and all its derived types. A value of any type derived from T can be implicitly converted to the type T'Class.

Polymorphic Data

- Class-wide variables are said to be polymorphic because their values are of different “shapes” (from the Greek poly, many, and morphe, form).
- When calling a subroutine with a polymorphic parameter, the compiler is unable to determine which subroutine to call, since the actual type of a polymorphic variable will not be known until run time!
- Thus, the binding to some subroutines must be delayed until execution - hence the term “dynamic binding”.
- A call to a routine that must be dynamically bound is called a “dispatching” call

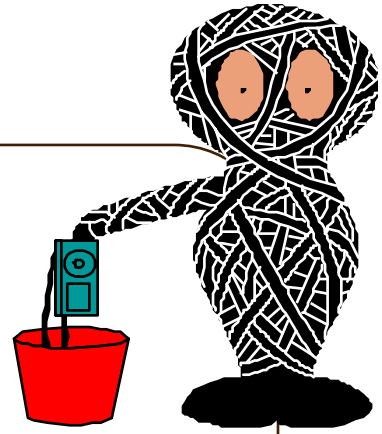
Class Wide Programming (Dispatching)

```
-- class-wide value as parameter
Procedure Move_All ( Item : in out Vehicle'Class) is
...
begin
   ...
   Start (Item);          -- dispatch according to tag
   ...
end Move_All;
```

The procedure Move_All is a ***class-wide*** operation, since any variable in the Vehicle hierarchy can be passed to it.

Start, however, is defined for each type within the Vehicle hierarchy. Depending on the type of Item, a different Start will be called. During runtime, the specific type of Item is known, but it is not known at compile time. The ***runtime system*** must ***dispatch*** to the correct procedure call.

Static Binding



```
-- class-wide value as parameter

Procedure Move_All ( Item : in out Vehicle'Class) is
...
begin
   ...
   Start (Item);          -- dispatch according to tag (Dynamic Dispatching)
                --vs.
   if Item in Jet then
      Start (Jet(Item));    -- static call to the Start for Jet.   .
                                    -- This is a membership test and View Conversion.


   ...
end Move_All;
```