Dynamic Binding

- Associate a set of functions — “methods” — with each ***class***

shape.h:

```
#include "point.h"

typedef struct Methods_T {
    Point_T (*where)(Shape_T s);
    void (*move)(Shape_T s, Point_T to);
    void (*draw)(Shape_T s);
} *Methods_T;

typedef struct Shape_T {
    Methods_T methods;
    Point_T center;
} *Shape_T;

extern Point_T Shape_where(Shape_T s);
extern void Shape_move(Shape_T s, Point_T to);
extern void *Shape_init(T s, Point_T center, Methods_T
methods);
```

‘abstract’ superclass

- ***Indirection*** invokes appropriate method

```
Shape_T s;
(*s->methods->move)(s, to);
```

Methods

- **Subclasses have separate interfaces; types inherit fields *and methods***

  `circle.h`:

```
#include "shape.h"

typedef struct Circle_T {
    struct Shape_T super;
    float radius;
} *Circle_T;
extern Circle_T Circle_new(float radius);
```

  `square.h`:

```
#include "shape.h"

typedef struct Square_T {
    struct Shape_T super;
    float side;
} *Square_T;
extern Square_T Square_new(float side);
```

- **`Methods`** appears ***only*** in **`Shape_T`**
- Implementations initialize methods to ***class-specific*** functions

Implementations

shape.c:

```
#include "assert.h"
#include "shape.h"

Point_T Shape_where(Shape_T s) {
    return s->center;
}

void Shape_move(Shape_T s, Point_T to) {
    s->center = to;
    (*s->methods->draw)(s);
}

void *Shape_init(Shape_T s, Point_T center, Methods_T methods)
{
    assert(s);
    assert(methods);
    s->methods = methods;
    s->center  = center;
    return s;
}
```

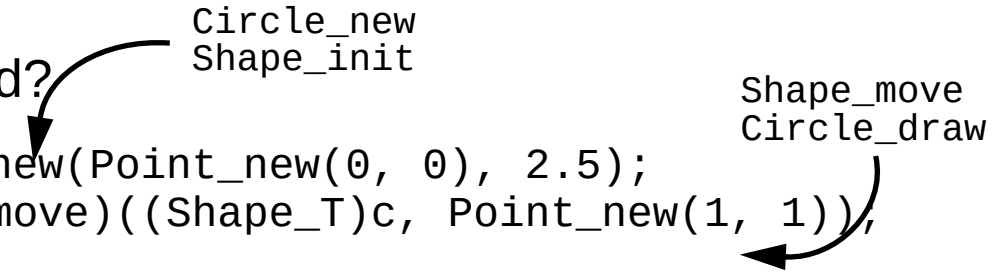
Implementations, cont'd

circle.c: (**square.c** is similar)

```
#include "assert.h"
#include "circle.h"

static void Circle_draw(Circle_T s) { ... }

static struct Methods_T methods = {
    Shape_where, Shape_move, Circle_draw
};

Circle_T Circle_new(Point_T center, float radius) {
    Circle_T s = malloc(sizeof *s);

    assert(s);
    s = Shape_init((Shape_T)s, center, &methods);
    s->radius = radius;
    return s;
}
```

- What functions get called?

```
Circle_T c = Circle_new(Point_new(0, 0), 2.5);
(*c->super.methods->move)((Shape_T)c, Point_new(1, 1));
```



- OOPLs ***support*** this methodology — with much less ink and with ***type safety***

Obect-Oriented Programming in Plain C

- ***Objects*** are pointers to structures
- ***Methods*** are invoked by "sending a message to the object"

```
extern void *send(void *obj, char *msg, ...);
```

obj identifies the ***object*** — the "receiver"

msg names the ***method*** — an arbitrary string

send applies the method to the object with the arguments "**...**"

default return value is an object

- ***Classes*** — object type definitions — are also objects

class methods are sent to ***classes***

```
Point_T  p = send(&Point,  "new:", 0.0, 0.0);
Circle_T c = send(&Circle, "new:", p, 2.5);
```

instance methods are sent to ***objects***

```
send(c, "move", send(&Point, "new:", 1.0, 1.0));
p = send(c, "where");
```

Example: Texts (a.k.a. Strings)

- Interface: **`text.h`**

```
#include <stdio.h>
#include "object.h"

#define T Text_T
typedef struct T {
    struct Object_T super; /* superclass */
    ...
} *T;
extern struct Class_T Text, metaText;
/*
Class Methods
~~~~~~~~~~~~~
T new:(char *text);
returns a new text and initialized to a copy of text.

Instance Methods
~~~~~~~~~~~~~~~~
...
Responsibilities
~~~~~~~~~~~~~~~~
It is a checked runtime error to pass a NULL text or char* to
any method in this interface.
*/
```

Reading Words

- A class method “manufactures” instances of its class
- **`getword`**: returns the next word from the standard input as a **`Text_T`**

```
Text_T getword(void) {
    char buf[100], *s;
    int c;

    while ((c = getchar()) != EOF && !isalpha(c))
        ;
    for (s = buf; c != EOF && isalpha(c); c = getchar())
        if (s - buf < sizeof buf - 1)
            *s++ = c;
    *s = 0;
    return s > buf ? send(&Text, "new:", buf) : 0;
}
```

Text Interface

- Instance methods manipulate objects — specific instances of classes

  `int compare:(T text);`
  returns <0, 0, >0 if the receiver's text is less than, equal to, or greater than text's text, respectively.

  `T free(void);`
  deallocates the receiver and returns NULL.

  `char *get(void);`
  returns a pointer to the receiver's text.

  `unsigned hash(void);`
  returns a hash number based on the receiver's text.

  `int length(void);`
  returns the number of characters in the receiver's text.

  `T fprint(FILE *fp);`
  prints the text on the file fp. If fp is NULL, print it on stderr and returns the receiver.

  `T set:(char *text);`
  deallocates, reinitializes, and returns a new text

- If **`s`** and **`t`** are **`Text_Ts`**

```
send(t, "set:", "hello world");
(int)send(s, "compare:", t)
```

Access and Encapsulation in C++

- Class can define public and private members (data or functions)

```
class intArray{
    public:
        void init();
        void setSize(size_t value);
        size_t getSize();
        void setElem(size_t index, int value);
        int getElem(size_t index);
    private:
        int *elems;
        size_t numElems;
}


int intArray::getElem(size_t index) {
    if (index >+ numElems) error("bad index");
    return elems[index];

}
```

- What corresponds to private function in C?
- Difference between structs and classes in C++?

A Stack of Integers in C++

```
class intStack {
    public:
        void init();
        void push (int value);
        int pop();
        void isEmpty();

    private:
        intArray items;
        size_t depth;
}
```

- What if I want to sum the elements of a Stack?

```
class intStack {
    public:

        ... // all the above public members
        void goFirst();
        void goNext();
        int getCur();
        int curIsValid();

    private:

        ... // all the above private members
        size_t curItems;
}
```

Cooperating Classes

```
class intStackIter {
    public:
        void init();
        void push (int value);

        int setIter(IntStack *stack);
        void goFirst();
        void goNext();
        int getCur();
        int curIsValid();

    private:
        IntStack *iterStack;
        size_t curItem;
}

main {
    IntStack stack;
    IntStackIter iter;
    int sum;
    // ...
    stack.init(); iter.init();
    // ...
    sum = 0; iter.setIter(&stack);
    for (iter.goFirst(); iter.curIsValid(); iter.goNext())
        sum += iter.getCur();

}
```

How does Iterator Access Stack Internals?

```
int IterStack::getCur() {
    if (!curIsValid()) error("no current item");
    return iterStack->items.getElem(curItem);
}
```

- Problem?
- Solution:

```
class intStack {
    friend class IntIterStack;

    public:
        ... // rest all the same
}
```

- Friends can access all
- Friendship is a one-way street
- A friend of my friend is no friend of mine