Darwin Contest

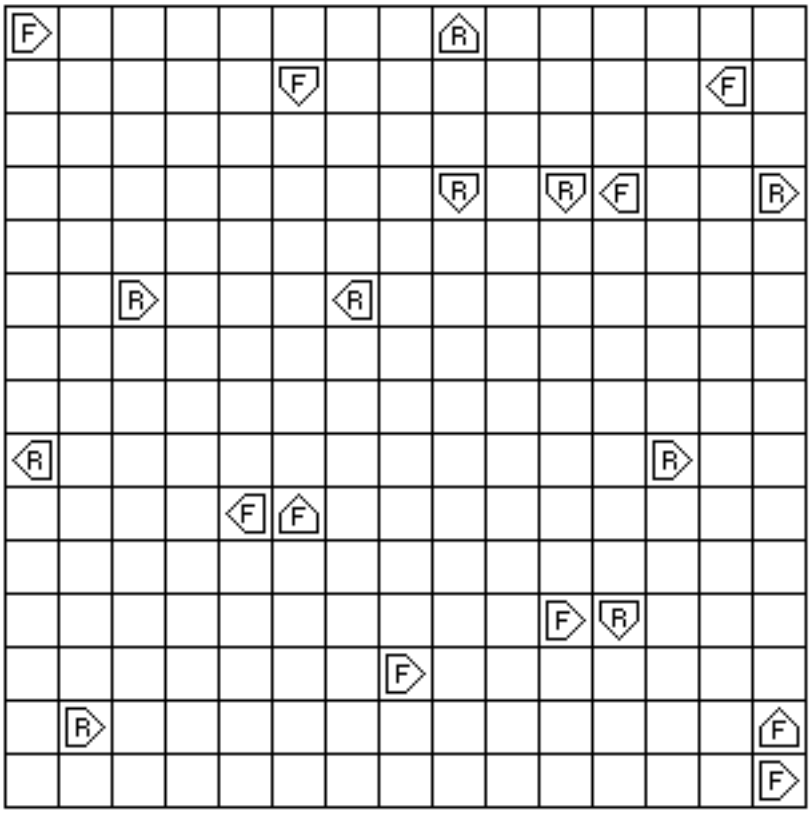
Due: Wednesday, Feb 17 at 11:59pm

In this assignment, your job is to build a simulator for a game called *Darwin* invented by Nick Parlante—a game that has become a classic assignment for CS106B. The assignment has a four-fold purpose:

1. To give you a chance to write a large multi-module programs.
2. To illustrate the importance of modular decomposition. The entire program is broken down into a series of modules that can be developed and tested independently.
3. To stress the notion of ADTs as a mechanism for sharing data between modules without revealing the representational details.
4. To let you have fun with an application that is extremely captivating and algorithmically interesting in its own right.

The Darwin world

The Darwin program simulates a two-dimensional world divided up into small squares and populated by a number of *creatures*. Each of the creatures lives in one of the squares, faces in one of the major compass directions (North, East, South, or West) and belongs to a particular *species*, which determines how that creature behaves. For example, one possible configuration of the world is shown below:



The sample world on the previous page is populated with twenty creatures, ten of a species called *Flytrap* and ten of a species called *Rover*. In each case, the creature is identified in the graphics world with the first letter in its name. The orientation is indicated by the figure

surrounding the identifying letter; the creature points in the direction of the arrow. The behavior of each creature—which you can think of as a small robot—is controlled by a program that is particular to each species. Thus, all of the Rovers behave in the same way, as do all of the Flytraps, but the behavior of each species is different from the other.

As the simulation proceeds, every creature gets a turn. On its turn, a creature executes a short piece of its program in which it may look in front of itself to see what's there and then take some action. The possible actions are moving forward, turning left or right, or *infecting* some other creature standing immediately in front, which transforms that creature into a member of the infecting species. As soon as one of these actions is completed, the turn for that creature ends, and some other creature gets its turn. When every creature has had a turn, the process begins all over again with each creature taking a second turn, and so on. The goal of the game is to infect as many creatures as possible to increase the population of your own species.

Species programming

In order to know what to do on any particular turn, a creature executes some number of instructions in an internal program specific to its species. For example, the program for the Flytrap species is shown below:

step	instruction	comment
1	**`ifenemy 4`**	*If there is an enemy ahead, go to step 4*
2	**`left`**	*Turn left*
3	**`go 1`**	*Go back to step 1*
4	**`infect`**	*Infect the adjacent creature*
5	**`go 1`**	*Go back to step 1*

The step numbers are not part of the actual program, but are included here to make it easier to understand the program. On its turn, a Flytrap first checks to see if it is facing an enemy creature in the adjacent square. If so, the program jumps ahead to step 4 and infects the hapless creature that happened to be there. If not, the program instead goes on to step 2, in which it simply turns left. In either case, the next instruction is a **`go`** instruction that will cause the program to start over again at the beginning of the program.

Programs are executed beginning with the instruction in step 1 and ordinarily continue with each new instruction in sequence, although this order can be changed by certain instructions in the program. Each creature is responsible for remembering the number of the next step to be executed. The instructions that can be part of a Darwin program are listed below:

`hop` The creature moves forward as long as the square it is facing is empty. If moving forward would put the creature outside the boundaries of the world or would cause it to land on top of another creature, the **`hop`** instruction does nothing.

`left` The creature turns left 90 degrees to face in a new direction.

`right` The creature turns right 90 degrees.

`infect` *n* If the square immediately in front of this creature is occupied by a creature of a different species (an "enemy") that creature is infected to become the same as the infecting species. When a creature is infected, it keeps its position and orientation, but changes its internal species indicator and begins executing the same program as the infecting creature, starting at step *n*. The parameter *n* is optional. If it is missing—as it is in the program examples—the new creature should start at the beginning of its new program, so that the **`infect`** instruction with no parameter is equivalent to **`infect 1`**.

ifempty *n* If the square in front of the creature is unoccupied, update the next instruction field in the creature so that the program continues from step *n*. If that square is occupied or outside the world boundary, go on with the next instruction in sequence.

ifwall *n* If the creature is facing the border of the world (which we imagine as consisting of a huge wall) jump to step *n*; otherwise, go on with the next instruction in sequence.

ifsame *n* If the square the creature is facing is occupied by a creature of the same species, jump to step *n*; otherwise, go on with the next instruction.

ifenemy *n* If the square the creature is facing is occupied by a creature of an enemy species, jump to step *n*; otherwise, go on with the next instruction.

ifrandom *n* In order to make it possible to write some creatures capable of exercising what might be called the rudiments of "free will," this instruction jumps to step *n* half the time and continues with the next instruction the other half of the time.

go *n* This instruction always jumps to step *n*, independent of any condition.

A creature can execute any number of **if** or **go** instructions without relinquishing its turn. The turn ends only when the program executes one of the instructions **hop**, **left**, **right**, or **infect**. On subsequent turns, the program starts up from the point in the program at which it ended its previous turn.

The program for each species is stored in a file in the subfolder named **Creatures** in the assignment folder. Each file in that folder consists of the species name, followed by the steps in the species program, in order. The program ends with the end of file or a blank line. Comments may appear after the blank line or at the end of each instruction line. For example, the program file for the Flytrap creature looks like this:

```
Flytrap
ifenemy 4
left
go 1
infect
go 1

The flytrap sits in one place and spins.
It infects anything which comes in front.
Flytraps do well when they clump.
```

There are several presupplied creature files:

Food This creature spins in a square but never infects anything. Its only purpose is to serve as food for other creatures. As Nick Parlante explains, "the life of the **Food** creature is so boring that its only hope in life is to be eaten by something else so that it gets reincarnated as something more interesting."

Hop This creature just keeps hopping forward until it reaches a wall. Not very interesting, but it is useful to see if your program is working.

Flytrap This creature spins in one square, infecting any enemy creature it sees.

`Rover`	This creature walks in straight lines until it is blocked, infecting any enemy creature it sees. If it can't move forward, it turns.

You can also create your own creatures. In particular, you can design a creature for the Darwin Contest described in a separate handout.

Your assignment

Your mission in this assignment is to write the Darwin simulator and get it running. Since this is a large program, it is a more challenging task than any of the ones you have faced to date. The program is large enough that it is broken down into six separate modules that work together to solve the complete problem.

Of the modules, you are responsible for the following four:

`darwin`	This module contains the main program, which is responsible for setting up the world, populating it with creatures, and running the main loop of the simulation that gives each creature a turn. The details of these operations are generally handled by the other modules. New creatures should be created in random empty locations, pointing in random directions.
`creature`	This module defines an abstract data type representing an individual creature, along with functions for creating new creatures and for taking a turn.
`species`	This module defines an abstract data type representing a species, and provides operations for reading in a species description from a file and for working with the programs that each creature executes.
`world`	This module contains an abstraction for a two-dimensional world, into which you can place the creatures.

The following modules have been provided for you:

`geometry`	This module defines types to represent points and compass directions, which are the same as those used in the maze-solving program from Chapter 6.
`worldmap`	This module handles all of the graphics for the simulation.

Even though the program is big, the good news is that you do not have to start completely from scratch. In fact, you have the advantage of being able to start with a complete program that solves the entire assignment. This means that you get to play with a working Darwin program immediately beginning on day 1. It does not, of course, mean that your work is finished.

We provide you with the following files:

Interfaces

```
geometry.h
world.h
species.h
creature.h
worldmap.h
```

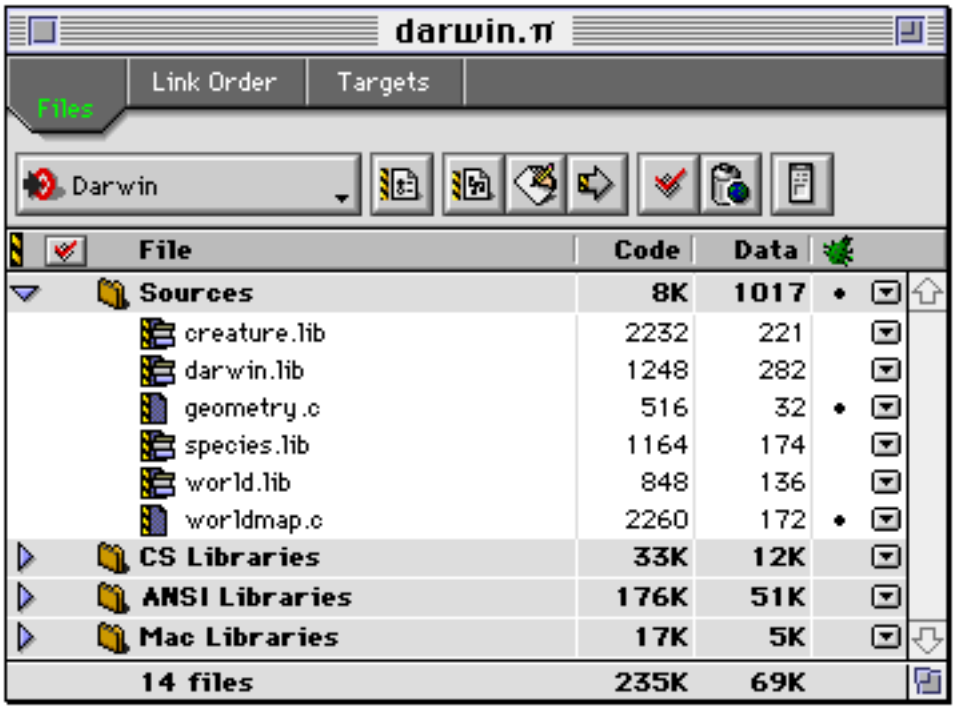
Libraries

```
darwin.lib
world.lib
species.lib
creature.lib
```

Source code

```
geometry.c
worldmap.c
```

To get started, you can use these files to build a complete project for the entire Darwin system. For example, if you are using CodeWarrior on the Mac, you would put together a project like this (PC users would have the same libraries and sources in their projects, plus CSLib.lib):



Instead of source files, the project contains library implementations for each of the modules with the exception of **`geometry.c`** and **`worldmap.c`**, which you are given in source form. Your job is to reimplement the modules **`world`**, **`species`**, **`creature`**, and **`darwin`**, probably (although not necessarily) in that order. When you have written your own implementation of any of these modules, you can remove the **`.lib`** file from the project and add your **`.c`** file in its place. The interfaces have all been given to you; your job is to write a new implementation for each of these four modules that implements the functions that are part of that interface description.

Implementation constants

In your implementation, you should use the following constants to control the operation of your program:

```
/*
 * Constants
 * ---------
 * NRows           Number of rows in Darwin world
 * NColumns        Number of columns
 * MaxSpecies      Maximum number of different species
 * MaxCreatures    Maximum number of individial creatures
 * MaxProgram      Maximum program size
 * InitialCount    Initial number of creatures per
species
 */

#define NRows           15
#define NColumns        15
#define MaxSpecies      10
#define MaxCreatures   100
#define MaxProgram     250
#define InitialCount    10
```

These constants will not all appear in the same source file, and it is up to you to determine in which module each of these constants belongs.

A Note About the Sample App

If you run the sample Darwin program without specifying any creatures with which to initially populate the board, the program may appear to "crash." In reality, the program is just carrying out the infinite game loop, and because there are no creatures on the board, it is running the loop so fast that it can't respond to keystrokes. If you ever end up in a situation like this, hit **Command-Option-Escape** (or **Ctrl-Alt-Del** on a PC) to force the application to quit.

Supplied interfaces

The remainder of this handout describes the files supplied as part of the assignment folder.

File: `geometry.h` — new types for an x-y grid

This module provides two low-level types (**`pointT`** and **`directionT`**) that are used in several of the other modules. The code for this module is provided for you.

```
/*
 * File: geometry.h
 * ----------------
 * This interface provides some extremely simple types
 * and operations that are useful for manipulating points
 * on an x-y grid.
 */

#ifndef _geometry_h
#define _geometry_h

#include "genlib.h"

/*
 * Type: pointT
 * ------------
 * The type pointT is used to encapsulate a coordinate pair
 * into a single value.  Because the record representation
 * makes good intuitive sense and adding an extra level of
 * pointers to the reference would reduce both execution and
 * storage efficiency, this type is exported in its concrete
 * form.
 */

typedef struct {
    int x, y;
} pointT;

/*
 * Type: directionT
 * ----------------
 * This type is an example of an "enumerated type" in C.  The
 * values of type directionT are simply the constants listed in
 * the braces following the enum keyword.  Thus, a variable of
 * type directionT can take on one of the four values North, East,
 * South, and West.
 */

typedef enum { North, East, South, West } directionT;

/*
 * Function: CreatePoint
 * Usage: pt = CreatePoint(x, y);
 * ------------------------------
 * This function combines the x and y coordinates into a pointT
 * structure and returns that value.
 */

pointT CreatePoint(int x, int y);
```

```
/*
 * Function: AdjacentPoint
 * Usage: newpt = AdjacentPoint(pt, dir);
 * --------------------------------------
 * This function returns the pointT that results from moving one
 * square in the indicated direction from pt.
 */

pointT AdjacentPoint(pointT pt, directionT dir);

/*
 * Functions: LeftFrom, RightFrom
 * Usage: newdir = LeftFrom(dir);
 *        newdir = RightFrom(dir);
 * ------------------------------
 * These functions return the directions that result from turning
 * left or right from the given starting direction.
 */

directionT LeftFrom(directionT dir);
directionT RightFrom(directionT dir);

#endif
```

File: `world.h` — abstraction to represent the x-y grid

This module includes the functions necessary to keep track of the creatures in a two-dimensional world. In order for the design to be general, the interface adopts the following design:

1. The world is implemented as an abstract type.
2. The contents are unspecified objects represented as **`void *`** pointers.
3. The dimensions of the world array are specified by the client and therefore must be allocated dynamically.

This design implies that the internal structure is—at least in part—a two-dimensional dynamic array of **`void *`** pointers. You should give careful thought to how you can declare and initialize such an array in C.

```
/*
 * File: world.h
 * -------------
 * This interface defines an abstraction which can be used
 * to store objects in an x/y cartesian world.  This abstraction
 * is completely independent of the graphical display, and the
 * client is responsible for any screen updates that are required.
 */

#ifndef _world_h
#define _world_h

#include "genlib.h"
#include "geometry.h"

/*
 * Type: worldADT
 * --------------
 * This abstract type stores the data for a "world," which is
 * defined to be a two-dimensional grid capable of storing
 * arbitrary objects represented as pointers whose type is
 * understood only by the client.
 */

typedef struct worldCDT *worldADT;

/*
 * Function: NewWorld
 * Usage: world = NewWorld(width, height);
 * ---------------------------------------
 * This function creates a new world consisting of width columns
 * and height rows, each of which is numbered beginning at 0.
 * A newly created world contains no objects.
 */

worldADT NewWorld(int width, int height);
```

```
/*
 * Function: FreeWorld
 * Usage: FreeWorld(world);
 * ------------------------
 * This function frees all of the storage associated with a world.
 */

void FreeWorld(worldADT world);

/*
 * Functions: WorldWidth, WorldHeight
 * Usage: width = WorldWidth(world);
 *        height = WorldHeight(world);
 * -----------------------------------
 * These functions return the width and the height of a world,
 * respectively.
 */

int WorldWidth(worldADT world);
int WorldHeight(worldADT world);

/*
 * Function: InRange
 * Usage: if (InRange(world, pt)) . . .
 * ------------------------------------
 * This function returns TRUE if the specified point pt is within
 * the boundaries  of the world.
 */

bool InRange(worldADT world, pointT pt);

/*
 * Function: SetContents
 * Usage: SetContents(world, pt, obj);
 * -----------------------------------
 * This function places the object obj into the world at the
 * position indicated by pt.
 */

void SetContents(worldADT world, pointT pt, void *obj);

/*
 * Function: GetContents
 * Usage: obj = GetContents(world, pt);
 * ------------------------------------
 * This function returns the object currently in the world at
 * position pt.
 */

void *GetContents(worldADT world, pointT pt);

#endif
```

File: `species.h` — abstraction to represent each species of creature

The individual creatures in the world are all representatives of some species class and share certain common characteristics, such as the species name and the program they execute. Rather than copy this information into each creature, this data can be recorded once as part of the description for a species and then each creature can simply include the appropriate species pointer as part of its internal data structure.

To encapsulate all of the operations operating on a species within this abstraction, this interface exports a function **`ReadSpecies`** whose job is to read a file containing the name of the creature and its program, as described in the earlier part of this assignment. To make the folder structure more manageable, the species files for each creature are stored in a subfolder named **`Creatures`**. To open a file in a subfolder, you need to concatenate the string **`":Creatures:"`** (**`"Creatures\\"`** on a PC) onto the beginning of the file name before calling **`fopen`**.

```
/*
 * File: species.h
 * ---------------
 * This interface defines the species abstraction.
 */

#ifndef _species_h
#define _species_h

#include "genlib.h"

/*
 * Type: speciesADT
 * ----------------
 * This type is the abstract data type for a species.
 */

typedef struct speciesCDT *speciesADT;

/*
 * Type: opcodeT
 * -------------
 * The type opcodeT is an enumeration of all of the legal
 * command names.
 */

typedef enum {
    Hop, Left, Right, Infect,
    IfEmpty, IfWall, IfSame, IfEnemy, IfRandom,
    Go
} opcodeT;

/*
 * Type: instructionT
 * ------------------
 * The type instructionT is used to represent an instruction
 * and consists of a pair of an operation code and an integer.
 */

typedef struct {
    opcodeT op;
    int address;
} instructionT;
```

```
/*
 * Function: ReadSpecies
 * Usage: species = ReadSpecies(filename);
 * ---------------------------------------
 * This function reads in a new species from the specified filename.
 * To find the file, the function looks in a subfolder named
 * "Creatures".  If there is no file with the indicated name in
 * that subfolder, the function returns NULL.
 */

speciesADT ReadSpecies(string filename);

/*
 * Function: SpeciesName
 * Usage: name = SpeciesName(species);
 * -----------------------------------
 * This function returns the name for an existing species.
 */

string SpeciesName(speciesADT species);

/*
 * Function: ProgramSize
 * Usage: nSteps = ProgramSize(species);
 * -------------------------------------
 * This function returns the number of instructions in the program
 * for this species.
 */

int ProgramSize(speciesADT species);

/*
 * Function: ProgramStep
 * Usage: statement = ProgramStep(species, k);
 * -------------------------------------------
 * This function returns the kth instruction in the program for
 * this species, where program steps are numbered beginning at 1.
 * Attempting to select an instruction outside the program range
 * generates an error.
 */

instructionT ProgramStep(speciesADT species, int k);

#endif
```

File: `creature.h` — abstraction to represent each individual creature

Creatures are also represented as an abstract type, which is defined by the **`creature.h`** interface below:

```
/*
 * File: creature.h
 * ----------------
 * This interface defines the creature abstraction.
 */

#ifndef _creature_h
#define _creature_h

#include "genlib.h"
#include "geometry.h"
#include "species.h"
#include "world.h"

/*
 * Type: creatureADT
 * -----------------
 * This type is the abstract data type for a creature.
 */

typedef struct creatureCDT *creatureADT;

/*
 * Function: NewCreature
 * Usage: creature = NewCreature(species, world, pt, dir);
 * -------------------------------------------------------
 * This function creates a new creature of the indicated species
 * that lives in the specified world.  The creature is initially
 * positioned at position pt facing direction dir.
 */

creatureADT NewCreature(speciesADT species, worldADT world,
                        pointT pt, directionT dir);

/*
 * Function: GetSpecies
 * Usage: species = GetSpecies(creature);
 * --------------------------------------
 * This function returns the species to which this creature
 * belongs.
 */

speciesADT GetSpecies(creatureADT creature);

/*
 * Function: TakeOneTurn
 * Usage: TakeOneTurn(creature);
 * -----------------------------
 * This function executes one turn for this creature.
 */

void TakeOneTurn(creatureADT creature);

#endif
```

File: `worldmap.h` — graphics package for the Darwin world

This module exports the functions necessary to display the creatures on the screen. The project folder contains an implementation of this interface. Thus, you do not have to write anything for this part of the assignment, although you should feel free to add embellishments to the graphics code if you have any ideas for interesting extensions.

```
/*
 * File: worldmap.h
 * ----------------
 * This interface supports the graphics for the Darwin world.
 */

#ifndef _worldmap_h
#define _worldmap_h

#include "genlib.h"
#include "geometry.h"

/*
 * Function: InitWorldMap
 * Usage: InitWorldMap(columns, rows);
 * -----------------------------------
 * This function opens and displays two windows on the screen, one
 * for the Darwin world and one for the console.  This call must be
 * made before any other calls are made using this package and
 * before any output to the standard I/O channels.  The parameters
 * columns and rows specify the size of the world, although
 * some squares will be outside of the visible display if the
 * world is made too large.
 */

void InitWorldMap(int columns, int rows);

/*
 * Function: DisplaySquare
 * Usage: DisplaySquare(sq, keychar, dir);
 * ---------------------------------------
 * This function changes the display for the indicated square
 * (the location of which is expressed as a point) so that
 * it contains the "creature" indicated by the character keychar
 * facing in the direction specified by dir.  If keychar is a
 * space, the square is displayed as empty and the direction is
 * ignored.
 */

void DisplaySquare(pointT sq, char keychar, directionT dir);

#endif
```

What to Turn In

As always, you will need to submit your source code to the cs106-overlord server. You will need to turn in printouts and a disk with a copy of the following four files: **world.c**, **species.c**, **creature.c**, and **darwin.c**.