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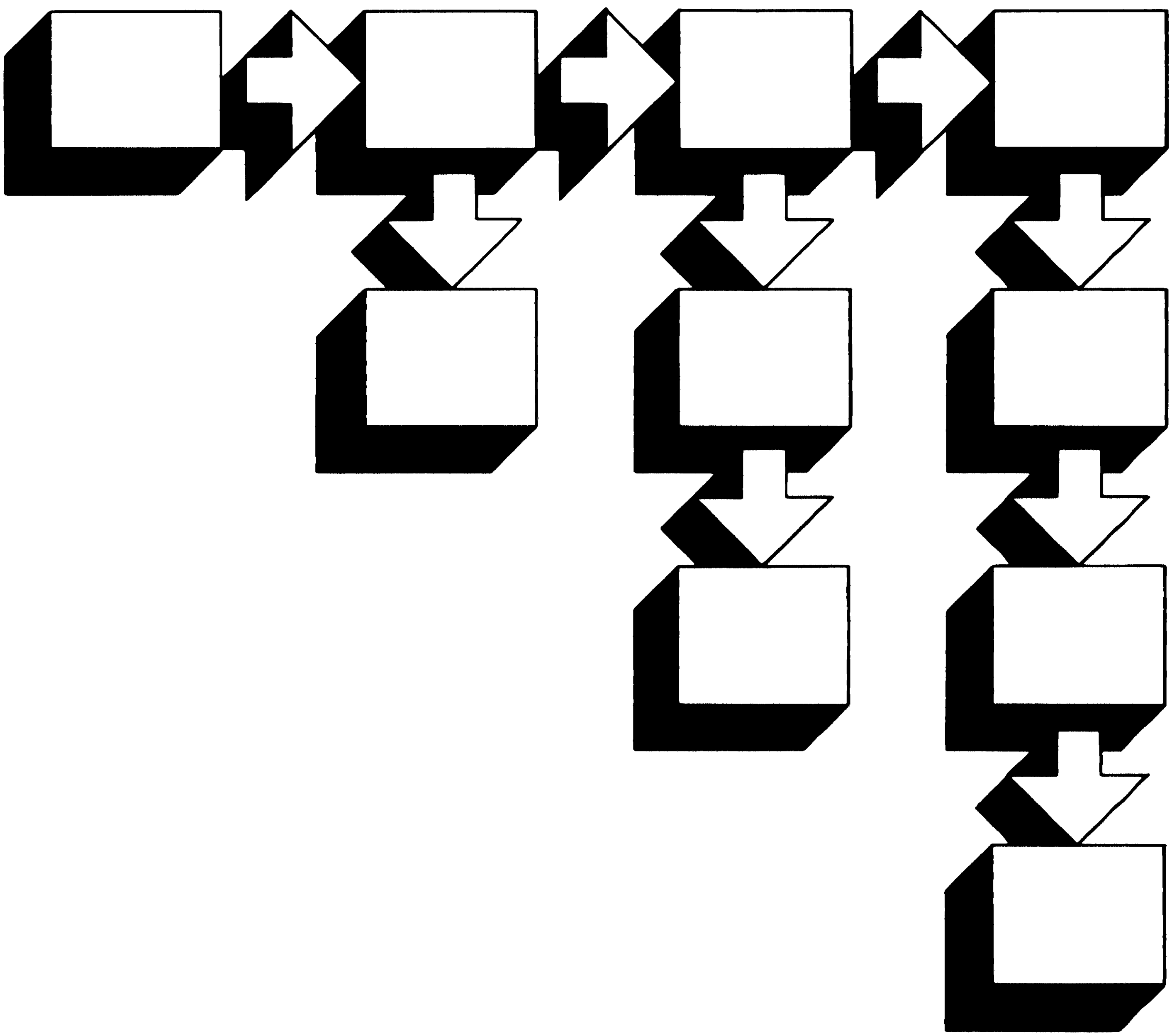
Selection and Use of General-Purpose Programming Languages — Program Examples



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Selection and Use of General-Purpose Programming Languages
Volume 2 - Program Examples

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ABSTRACT

Programming languages have been and will continue to be an important instrument for the automation of a wide variety of functions within industry and the Federal Government. Other instruments, such as program generators, application packages, query languages, and the like, are also available and their use is preferable in some circumstances.

Given that conventional programming is the appropriate technique for a particular application, the choice among the various languages becomes an important issue. There are a great number of selection criteria, not all of which depend directly on the language itself. Broadly speaking, the criteria are based on 1) the language and its implementation, 2) the application to be programmed, and 3) the user's existing facilities and software.

This study presents a survey of selection factors for the major general-purpose languages: Ada*, BASIC, C, COBOL, FORTRAN, Pascal, and PL/I. The factors covered include not only the logical operations within each language, but also the advantages and disadvantages stemming from the current computing environment, e.g., software packages, microcomputers, and standards. The criteria associated with the application and the user's facilities are explained. Finally, there is a set of program examples to illustrate the features of the various languages.

This volume includes the program examples. Volume 1 contains the discussion of language selection criteria.

Key words: Ada; alternatives to programming; BASIC; C; COBOL; FORTRAN; Pascal; PL/I; programming language features; programming languages; selection of programming language.

* Ada is a registered trademark of the U. S. Government, Ada Joint Project Office.

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1.0 INTRODUCTION

In this volume, we shall illustrate the general style of each of the languages with a program. These programs are only examples; they do not attempt to demonstrate the full capability of each language. On the other hand, the application chosen is complex enough that the programs do make significant use of several important language features, such as reading a file, interacting with a user, recursion, data abstraction, manipulation of arrays, pointers, and character strings, and some numeric calculation. Of particular note are the language features for modularizing a program of moderate size (about 1000 lines). While no application can be completely language-neutral, this variety of requirements implies a relatively unbiased example. Finally, the application deals with a well-known realm (family relationships) in order to facilitate understanding of the programs.

All of the programs solve the same problem, i.e., they accept the same input and produce output as nearly equivalent as possible. The input is a file of people, one person per record, and a series of user queries. In the file, each person's father and mother (if known), and spouse (if any) are identified. Given this information, the user may then specify any two persons in the file, and the program computes and displays the relationship (e.g., brother-in-law, second cousin) between those two. Also, based on the number and degree of common ancestors, the expected value for the proportion of common genetic material between the two is computed and displayed.

The algorithms and data structures employed are roughly equivalent, but differ in detail owing to the language differences being illustrated. Generally, user-defined names are capitalized and language-defined keywords and identifiers are written in lower-case. In all the programs a directed graph is simulated, with the vertices representing people and the edges representing different types of direct relationships. The only direct relationships are parent, child, and spouse. Starting at one vertex, a search is conducted to find the shortest path to the other vertex. The types of edges encountered along the path, together with some additional information, determine the relationship. For instance, if the shortest path between X1 and X4 is that X1 is child of X2, X2 is spouse of X3, and X3 is parent of X4, this would show that X1 and X4 are step-siblings. It is assumed that the input file has already been validated and is correct. The user's requests, however, are checked. The algorithm to determine the shortest path is adapted from [Baas78]. The overall algorithm is expressed by the pseudo-code below.

All of the programs, except the one in BASIC, have compiled and executed on at least one language processor which implements the corresponding standard or base document. The COBOL program, while conforming to both COBOL-74 and COBOL-8x, is essentially a COBOL-74 program, since it does not exploit any of the new COBOL-8x features.

Figure 1 - Algorithm for Program Examples

```
for each record in input PEOPLE file do
    establish entry in PERSON array
    for all previous entries do
        compare this entry to previous, looking for
           immediate relationships: parent, child, or spouse
        if relationship found
           establish link (edge) between these two persons
        end if
    end for
end for
graph is now built

while not request to stop
  prompt and read next request
exit while-block if request to stop
  if syntax of request OK
     search for requested persons
     if exactly one of each person found
        if 1st person = 2nd person
           display "identical to self"
        else
           find shortest path between the two persons
           if no such path
              display "unrelated"
           else
              analyze path for named relationships:
                 path initially composed of parent, child,
                    spouse edges
                 resolve child-parent and child-spouse-parent
                    to sibling
                 resolve child-child-... and parent-parent-...
                    to descendant (child*) or ancestor (parent*)
                 resolve child*-sibling-parent* to cousin,
                         child*-sibling to nephew,
                         sibling-parent* to uncle
                 display consolidated relationships
              compute proportion of common genetic material:
                 traverse ancestors of person1, zeroing out
                 traverse ancestors of person1, marking and
                    accumulating genetic contribution
                 traverse ancestors of person2, accumulating
                    overlap with person1
                 display results
           end if
        end if
     else
        display "duplicate name" or "not found"
     end if
  else
     display "invalid request"
  end if
end while
display "done"
```

Figure 2 - Input Data

This figure shows some of the input data with which the program examples were tested. The format of each record is:

Position	Contents
1-20	Name of person
21-23	Unique 3-digit identifier of person
24	Gender of person
25-27	Identifier of father (000 if unknown)
28-30	Identifier of mother (000 if unknown)
31-33	Identifier of spouse (000 if none or unknown)

Example of Input Data:

```
John Smith          001M000000002
Mary Smith          002F003000001
Wilbur Finnegan     010M000000011
Mary Finnegan       011F000000010
James Smith         020M001002022
Wilma Smith         022F010011020
Marvin Hamlisch     031M000032000
Melvin Hamlisch     033M000032000
Martha Hamlisch     032F048043034
Murgatroyd Whatsis  034M000000032
Bentley Whatsis     035M034036000
Myrna Whozat        036F000000000
Bosworth Whatsis    037M034036000
K48                 048M000000043
K43                 043F041042048
K41                 041M000000042
K42                 042F000000041
K46                 046M045000000
K45                 045M048043000
K47                 047M044000000
K44                 044M041042000
Velorus Davis       085M000000086
Goldie Beacon       083F085086082
Ross Beacon         082M000000083
Velma Davis         086F000000085
Floyd Davis         088M085084087
Cindy Davis         084F000000000
David Beacon        121M081120000
Norma Cousins       053F082083055
Carmine Cousins     051M000000052
Maria Cousins       052F000000051
James Cousins       054M051052000
C. John Cousins     055M051052053
John Cousins        073M055053074
Janet Cousins       074F140141073
Richard Cousins     077M073074000
Paul Cousins        078M073074000
Marie Cousins       079F073074000
  . . . . .           . . . . .
```

Figure 3 - Queries and Output

This figure gives some examples of the results of running the programs.

```
 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
;
 Incorrect request format: null field preceding semicolon.

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
x;x;x
 Incorrect request format: must be exactly one semicolon.

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
x;x
 First person not found.
 Second person not found.

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
   111   ;   111
 Christopher Delmonte is identical to himself.

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
G6;John Smith
 G6                    is not related to John Smith

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
Carmine Cousins;111
 Duplicate names for first person - use numeric identifier.

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
163;145
 Shortest path between identified persons:
 Linda Lackluster      is child of
 Millie Lackluster     is child of
 Anna Pittypat         is parent of
 Margaret Madison      is spouse of
 Richard Madison       is child of
 Victoria Pisces       is parent of
 Maria Gotsocks        is parent of
 Elzbieta Gotsocks
 Condensed path:
 Linda Lackluster      is niece of
 Richard Madison       is uncle of
 Elzbieta Gotsocks
 Proportion of common genetic material =  0.00000E+00
```

Figure 3 - Queries and Output (continued)

```
 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
094;145
 Shortest path between identified persons:
 Nancy Powers          is child of
 Maxine Powers         is child of
 Floyd Davis           is child of
 Velorus Davis         is parent of
 Goldie Beacon         is parent of
 Norma Cousins         is parent of
 John Cousins          is spouse of
 Janet Cousins         is child of
 Richard Madison       is child of
 Victoria Pisces       is parent of
 Maria Gotsocks        is parent of
 Elzbieta Gotsocks
 Condensed path:
 Nancy Powers          is 2nd half-cousin-in-law of
 Janet Cousins         is cousin of
 Elzbieta Gotsocks
 Proportion of common genetic material =  0.00000E+00

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
036;033
 Shortest path between identified persons:
 Myrna Whozat          is parent of
 Bentley Whatsis       is child of
 Murgatroyd Whatsis    is spouse of
 Martha Hamlisch       is parent of
 Melvin Hamlisch
 Condensed path:
 Myrna Whozat          is mother of
 Bentley Whatsis       is step-brother of
 Melvin Hamlisch
 Proportion of common genetic material =  0.00000E+00

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
031;033
 Shortest path between identified persons:
 Marvin Hamlisch       is child of
 Martha Hamlisch       is parent of
 Melvin Hamlisch
 Condensed path:
 Marvin Hamlisch       is half-brother of
 Melvin Hamlisch
 Proportion of common genetic material =  2.50000E-01
```

Figure 3 - Queries and Output (continued)

```
 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
145;090
 Shortest path between identified persons:
 Elzbieta Gotsocks     is child of
 Maria Gotsocks        is child of
 U. Pisces             is parent of
 Richard Madison       is parent of
 Janet Cousins         is spouse of
 John Cousins          is child of
 Norma Cousins         is child of
 Goldie Beacon         is child of
 Velorus Davis         is parent of
 Floyd Davis           is parent of
 Maxine Powers         is spouse of
 Tim Powers
 Condensed path:
 Elzbieta Gotsocks     is cousin-in-law of
 John Cousins          is half-cousin-in-law once removed of
 Tim Powers
 Proportion of common genetic material =  0.00000E+00

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
L6;R9
 Shortest path between identified persons:
 L6                    is child of
 L5                    is child of
 L4                    is child of
 L3                    is child of
 L2                    is child of
 L1                    is child of
 L0                    is parent of
 R1                    is parent of
 R2                    is parent of
 R3                    is parent of
 R4                    is parent of
 R5                    is parent of
 R6                    is parent of
 R7                    is parent of
 R8                    is parent of
 R9
 Condensed path:
 L6                    is 5th half-cousin 3 times removed of
 R9
 Proportion of common genetic material =  3.05176E-05
```

Figure 3 - Queries and Output (continued)

```
 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
W1;R14
 Shortest path between identified persons:
 W1                    is spouse of
 L0                    is parent of
 R1                    is parent of
 R2                    is parent of
 R3                    is parent of
 R4                    is parent of
 R5                    is parent of
 R6                    is parent of
 R7                    is parent of
 R8                    is parent of
 R9                    is parent of
 R10                   is parent of
 R11                   is parent of
 R12                   is parent of
 R13                   is parent of
 R14
 Condensed path:
 W1                    is great*12-grand-step-father of
 R14
 Proportion of common genetic material =  0.00000E+00

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
X8;L6
 Shortest path between identified persons:
 X8                    is child of
 X7                    is child of
 X6                    is child of
 X5                    is child of
 X4                    is child of
 X3                    is spouse of
 R4                    is child of
 R3                    is child of
 R2                    is child of
 R1                    is child of
 L0                    is parent of
 L1                    is parent of
 L2                    is parent of
 L3                    is parent of
 L4                    is parent of
 L5                    is parent of
 L6
 Condensed path:
 X8                    is great*3-grand-step-son of
 R4                    is 3rd half-cousin 2 times removed of
 L6
 Proportion of common genetic material =  0.00000E+00
```

Figure 3 - Queries and Output (continued)

```
 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
G5;G6
 Shortest path between identified persons:
 G5                    is parent of
 G6
 Condensed path:
 G5                    is mother of
 G6
 Proportion of common genetic material =  5.62500E-01

 Enter two person-identifiers (name or number),
 separated by semicolon. Enter "stop" to stop.
stop
 End of relation-finder.
```

2.0 ADA

```
---- first compilation-unit #1 is package of global types and objects

package RELATION_TYPES_AND_DATA is

  MAX_PERSONS         : constant integer := 300;
  NAME_LENGTH         : constant integer := 20;
  -- every PERSON has a unique 3-digit IDENTIFIER
  IDENTIFIER_LENGTH   : constant integer := 3;
  BUFFER_LENGTH       : constant integer := 60;

  subtype NAME_RANGE         is integer range 1..NAME_LENGTH;
  subtype IDENTIFIER_RANGE   is integer range 1..IDENTIFIER_LENGTH;
  subtype BUFFER_RANGE       is integer range 1..BUFFER_LENGTH;

  subtype NAME_TYPE          is string (NAME_RANGE);
  subtype BUFFER_TYPE        is string (BUFFER_RANGE) ;
  subtype MESSAGE_TYPE       is string (1..40);

  subtype INDEX_TYPE         is integer   range 0..MAX_PERSONS;
  subtype COUNTER            is integer   range 0..integer'last;
  subtype DIGIT_TYPE         is character range '0'..'9';

  type REAL                  is digits 6;
  type IDENTIFIER_TYPE       is array (IDENTIFIER_RANGE) of DIGIT_TYPE;
  -- each PERSON's record in the file identifies at most three
  -- others directly related: father, mother, and spouse
  type GIVEN_IDENTIFIERS     is (FATHER_IDENT, MOTHER_IDENT, SPOUSE_IDENT);
  type RELATIVE_ARRAY        is array (GIVEN_IDENTIFIERS) of IDENTIFIER_TYPE;

  NULL_IDENT       : constant IDENTIFIER_TYPE := "000";
  REQUEST_OK       : constant MESSAGE_TYPE    :=
    "Request OK                              ";
  REQUEST_TO_STOP  : constant BUFFER_TYPE     :=
    "stop                                                        ";

  type GENDER_TYPE          is (MALE, FEMALE);
  type RELATION_TYPE        is (PARENT, CHILD, SPOUSE, SIBLING, UNCLE,
                                    NEPHEW, COUSIN, NULL_RELATION);
  -- directed edges in the graph are of a given subtype
  subtype EDGE_TYPE         is RELATION_TYPE range PARENT..SPOUSE;
  -- A node in the graph (= PERSON) has either already been reached,
  -- is immediately adjacent to those reached, or farther away.
  type REACHED_TYPE         is (REACHED, NEARBY, NOT_SEEN);

  -- each PERSON has a linked list of adjacent nodes, called neighbors
  type NEIGHBOR_RECORD;
  type NEIGHBOR_POINTER  is access NEIGHBOR_RECORD;
  type NEIGHBOR_RECORD is
    record
      NEIGHBOR_INDEX     : INDEX_TYPE;
      NEIGHBOR_EDGE      : EDGE_TYPE;
      NEXT_NEIGHBOR      : NEIGHBOR_POINTER;
    end record;
```

```
  -- All relationships are captured in the directed graph of which
  -- each record is a node.
  type PERSON_RECORD is
    record
    -- static information - filled from PEOPLE file:
      NAME                     : NAME_TYPE;
      IDENTIFIER               : IDENTIFIER_TYPE;
      GENDER                   : GENDER_TYPE;
      -- IDENTIFIERs of immediate relatives - father, mother, spouse
      RELATIVE_IDENTIFIER      : RELATIVE_ARRAY;
      -- head of linked list of adjacent nodes
      NEIGHBOR_LIST_HEADER     : NEIGHBOR_POINTER;
    -- data used when traversing graph to resolve user request:
      DISTANCE_FROM_SOURCE     : REAL;
      PATH_PREDECESSOR         : INDEX_TYPE;
      EDGE_TO_PREDECESSOR      : EDGE_TYPE;
      REACHED_STATUS           : REACHED_TYPE;
    -- data used to compute common genetic material
      DESCENDANT_IDENTIFIER    : IDENTIFIER_TYPE;
      DESCENDANT_GENES         : REAL;
    end record;

  -- the PERSON array is the central repository of information
  -- about inter-relationships.
  PERSON            : array (INDEX_TYPE) of PERSON_RECORD;

  -- utility to truncate or fill with spaces
  procedure COERCE_STRING (SOURCE : in string; TARGET : in out string);

end RELATION_TYPES_AND_DATA;

 -- - - - - END SPECIFICATION - - BEGIN BODY - - - - - - --

package body RELATION_TYPES_AND_DATA is
  procedure COERCE_STRING (SOURCE : in string; TARGET : in out string) is
    MANY_SPACES : constant string (1..100) :=
      "                                                  " &
      "                                                  ";
  begin
    if SOURCE'length < TARGET'length then
       TARGET (TARGET'first..TARGET'first + SOURCE'length - 1) := SOURCE;
       TARGET (TARGET'first + SOURCE'length..TARGET'last) :=
         MANY_SPACES (1..TARGET'length - SOURCE'length);
    else   -- SOURCE longer than TARGET
       TARGET := SOURCE(SOURCE'first..SOURCE'first + TARGET'length - 1);
    end if;
  end COERCE_STRING;
end RELATION_TYPES_AND_DATA;
```

```
---- new compilation-unit #2: main line of execution RELATE

with RELATION_TYPES_AND_DATA, text_io, sequential_io;
use  RELATION_TYPES_AND_DATA, text_io;

procedure RELATE is

  -- this is the format of records in the file to be read in
  type FILE_GENDER        is ('M', 'F');
  type FILE_PERSON_RECORD is
    record
      NAME                : NAME_TYPE;
      IDENTIFIER          : IDENTIFIER_TYPE;
      -- 'M' for MALE and 'F' for FEMALE
      GENDER              : FILE_GENDER;
      RELATIVE_IDENTIFIER : RELATIVE_ARRAY;
    end record;

  -- Instantiate generic package for file IO.
  package PEOPLE_IO is
    new sequential_io (ELEMENT_TYPE => FILE_PERSON_RECORD);

  -- These variables are used when establishing the PERSON array
  -- from the PEOPLE file.
  PEOPLE              : PEOPLE_IO . FILE_TYPE;
  PEOPLE_RECORD       : FILE_PERSON_RECORD;
  CURRENT, NUMBER_OF_PERSONS
                      : INDEX_TYPE;
  PREVIOUS_IDENT, CURRENT_IDENT
                      : IDENTIFIER_TYPE;
  RELATIONSHIP        : GIVEN_IDENTIFIERS;

  -- These variables are used to accept and resolve requests for
  -- RELATIONSHIP information.
  BUFFER_INDEX, SEMICOLON_LOCATION
                      : BUFFER_RANGE;
  REQUEST_BUFFER      : BUFFER_TYPE;
  PERSON1_IDENT, PERSON2_IDENT
                      : NAME_TYPE;
  PERSON1_FOUND, PERSON2_FOUND
                      : COUNTER;
  ERROR_MESSAGE       : MESSAGE_TYPE;
  PERSON1_INDEX, PERSON2_INDEX
                      : INDEX_TYPE;
```

```
  -- declare procedures directly invoked from RELATE:

  procedure LINK_RELATIVES (FROM_INDEX   : in INDEX_TYPE;
                            RELATIONSHIP : in GIVEN_IDENTIFIERS;
                            TO_INDEX     : in INDEX_TYPE)
            is separate;
  procedure PROMPT_AND_READ is separate;
  procedure CHECK_REQUEST (REQUEST_STATUS     : out MESSAGE_TYPE;
                           SEMICOLON_LOCATION : out BUFFER_RANGE)
            is separate;
  procedure BUFFER_TO_PERSON (PERSON_ID     : in out NAME_TYPE;
                              START_LOCATION,
                              STOP_LOCATION : in BUFFER_RANGE)
            is separate;
  procedure SEARCH_FOR_REQUESTED_PERSONS
                (PERSON1_IDENT, PERSON2_IDENT : in  NAME_TYPE;
                 PERSON1_INDEX, PERSON2_INDEX : out INDEX_TYPE;
                 PERSON1_FOUND, PERSON2_FOUND : in out COUNTER)
            is separate;
  procedure FIND_RELATIONSHIP (TARGET_INDEX, SOURCE_INDEX : in INDEX_TYPE)
            is separate;

-- *** execution of main sequence begins here *** --

begin
  PEOPLE_IO . open (PEOPLE, PEOPLE_IO . IN_FILE, "PEOPLE.DAT");
  -- CURRENT location in array being filled
  CURRENT := 0;
  -- This loop reads in the PEOPLE file and constructs the PERSON
  -- array from it (one PERSON = one record = one array entry).
  -- As records are read in, links are constructed to represent the
  -- PARENT-CHILD or SPOUSE RELATIONSHIP.  The array then implements
  -- a directed graph which is used to satisfy subsequent user
  -- requests.  The file is assumed to be correct - no validation
  -- is performed on it.
READ_IN_PEOPLE:
  while not PEOPLE_IO . end_of_file (PEOPLE) loop
    PEOPLE_IO . read (PEOPLE, PEOPLE_RECORD);
    CURRENT := CURRENT+1;
    -- copy direct information from file to array
    PERSON (CURRENT) . NAME          := PEOPLE_RECORD . NAME;
    PERSON (CURRENT) . IDENTIFIER    := PEOPLE_RECORD . IDENTIFIER;
    if PEOPLE_RECORD . GENDER = 'M' then
       PERSON (CURRENT) . GENDER := MALE;
    else
       PERSON (CURRENT) . GENDER := FEMALE;
    end if;
    PERSON (CURRENT) . RELATIVE_IDENTIFIER :=
        PEOPLE_RECORD . RELATIVE_IDENTIFIER;
    -- Location of adjacent persons as yet undetermined
    PERSON (CURRENT) . NEIGHBOR_LIST_HEADER := null;
    -- Descendants as yet undetermined
    PERSON (CURRENT) . DESCENDANT_IDENTIFIER := NULL_IDENT;
    CURRENT_IDENT := PERSON (CURRENT) . IDENTIFIER;
```

```
    -- Compare this PERSON against all previously entered PERSONs
    -- to search for RELATIONSHIPs.
COMPARE_TO_PREVIOUS:
    for PREVIOUS in 1..CURRENT-1 loop
      PREVIOUS_IDENT    := PERSON (PREVIOUS) . IDENTIFIER;
      RELATIONSHIP      := FATHER_IDENT;
      -- Search for father, mother, or spouse relationship in
      -- either direction between this and PREVIOUS PERSON.
      -- Assume at most one RELATIONSHIP exists.
TRY_ALL_RELATIONSHIPS:
      loop
        if PERSON (CURRENT) . RELATIVE_IDENTIFIER (RELATIONSHIP) =
           PREVIOUS_IDENT
        then
           LINK_RELATIVES (CURRENT, RELATIONSHIP, PREVIOUS);
           exit TRY_ALL_RELATIONSHIPS;
        else
           if CURRENT_IDENT =
              PERSON (PREVIOUS) . RELATIVE_IDENTIFIER (RELATIONSHIP)
           then
              LINK_RELATIVES (PREVIOUS, RELATIONSHIP, CURRENT);
              exit TRY_ALL_RELATIONSHIPS;
           end if;
        end if;
        if RELATIONSHIP < SPOUSE_IDENT then
           RELATIONSHIP := GIVEN_IDENTIFIERS'succ(RELATIONSHIP);
        else
           exit TRY_ALL_RELATIONSHIPS;
        end if;
      end loop TRY_ALL_RELATIONSHIPS;
    end loop COMPARE_TO_PREVIOUS;
  end loop READ_IN_PEOPLE;
  NUMBER_OF_PERSONS := CURRENT;
  PEOPLE_IO . close (PEOPLE);

  -- PERSON array is now loaded and edges between immediate relatives
  -- (PARENT-CHILD or SPOUSE-SPOUSE) are established.

  -- While-loop accepts requests and finds RELATIONSHIP (if any)
  -- between pairs of PERSONs.
```

```
READ_AND_PROCESS_REQUEST:
  loop
    PROMPT_AND_READ;
  exit READ_AND_PROCESS_REQUEST when REQUEST_BUFFER = REQUEST_TO_STOP;
    CHECK_REQUEST (ERROR_MESSAGE, SEMICOLON_LOCATION);

    -- Syntax check of request completed.  Now either display error
    -- message or search for the two PERSONs.

    if ERROR_MESSAGE = REQUEST_OK then
               -- Request syntactically correct -
               -- search for requested PERSONs.
       BUFFER_TO_PERSON (PERSON1_IDENT, 1, SEMICOLON_LOCATION - 1);
       BUFFER_TO_PERSON (PERSON2_IDENT, SEMICOLON_LOCATION + 1, BUFFER_LENGTH);
       SEARCH_FOR_REQUESTED_PERSONS (PERSON1_IDENT, PERSON2_IDENT,
                                     PERSON1_INDEX, PERSON2_INDEX,
                                     PERSON1_FOUND, PERSON2_FOUND);
       if (PERSON1_FOUND = 1) and (PERSON2_FOUND = 1) then
          -- Exactly one match for each PERSON - proceed to
          -- determine RELATIONSHIP, if any.
          if PERSON1_INDEX = PERSON2_INDEX then
             put (" " & PERSON (PERSON1_INDEX) . NAME &
                    " is identical to ");
             if PERSON (PERSON1_INDEX) . GENDER = MALE then
                put_line("himself.");
             else
                put_line("herself.");
             end if;
          else
             FIND_RELATIONSHIP (PERSON1_INDEX, PERSON2_INDEX);
          end if;
       else   -- either not found or more than one found
          if PERSON1_FOUND = 0 then
             put_line (" First person not found.");
          elsif PERSON1_FOUND > 1 then
             put_line (" Duplicate names for first person - use" &
                       " numeric identifier.");
          end if;
          if PERSON2_FOUND = 0 then
             put_line (" Second person not found.");
          elsif PERSON2_FOUND > 1 then
             put_line (" Duplicate names for second person - use" &
                       " numeric identifier.");
          end if;
       end if;   -- processing of syntactically legal request
    else
       put_line (" Incorrect request format: " & ERROR_MESSAGE);
    end if;
  end loop READ_AND_PROCESS_REQUEST;
  put_line (" End of relation-finder.");
end RELATE;
```

```
---- new compilation-unit #3: procedures under RELATE

separate (RELATE)
procedure LINK_RELATIVES (FROM_INDEX    : in INDEX_TYPE;
                          RELATIONSHIP : in GIVEN_IDENTIFIERS;
                          TO_INDEX     : in INDEX_TYPE) is
  -- establishes cross-indexing between immediately related PERSONs.

  procedure LINK_ONE_WAY (FROM_INDEX : in INDEX_TYPE;
                          THIS_EDGE  : in EDGE_TYPE;
                          TO_INDEX   : in INDEX_TYPE) is
    -- Establishes the NEIGHBOR_RECORD from one PERSON to another

    NEW_NEIGHBOR : NEIGHBOR_POINTER;

  begin
    NEW_NEIGHBOR := new NEIGHBOR_RECORD
           '(NEIGHBOR_INDEX => TO_INDEX,
             NEIGHBOR_EDGE  => THIS_EDGE,
             NEXT_NEIGHBOR  => PERSON (FROM_INDEX) . NEIGHBOR_LIST_HEADER);
    PERSON (FROM_INDEX) . NEIGHBOR_LIST_HEADER := NEW_NEIGHBOR;
  end;

begin   -- execution of LINK_RELATIVES
  if RELATIONSHIP = SPOUSE_IDENT then
     LINK_ONE_WAY (FROM_INDEX, SPOUSE, TO_INDEX);
     LINK_ONE_WAY (TO_INDEX, SPOUSE, FROM_INDEX);
  else   -- RELATIONSHIP is father or mother
     LINK_ONE_WAY (FROM_INDEX, PARENT, TO_INDEX);
     LINK_ONE_WAY (TO_INDEX, CHILD, FROM_INDEX);
  end if;
end LINK_RELATIVES;

separate (RELATE)
procedure PROMPT_AND_READ is
  -- Issues prompt for user-request, reads in request,
  -- blank-fills buffer, and skips to next line of input.

  LAST_FILLED : natural;

begin
  put_line (" ");
  put_line (" --------------------------------------------");
  put_line (" Enter two person-identifiers (name or number),");
  put_line (" separated by semicolon. Enter ""stop"" to stop.");
  get_line (REQUEST_BUFFER, LAST_FILLED);
  COERCE_STRING (" ", REQUEST_BUFFER (LAST_FILLED+1..BUFFER_LENGTH));
end PROMPT_AND_READ;
```

```
separate (RELATE)
procedure CHECK_REQUEST (REQUEST_STATUS     : out MESSAGE_TYPE;
                         SEMICOLON_LOCATION : out BUFFER_RANGE) is
  -- Performs syntactic check on request in buffer.

  SEMICOLON_COUNT    : COUNTER;
  PERSON1_FIELD_EXISTS, PERSON2_FIELD_EXISTS
                     : boolean;

begin
  REQUEST_STATUS       := REQUEST_OK;
  SEMICOLON_LOCATION   := 1;
  PERSON1_FIELD_EXISTS := false;
  PERSON2_FIELD_EXISTS := false;
  SEMICOLON_COUNT := 0;
  for BUFFER_INDEX in BUFFER_RANGE loop
    if REQUEST_BUFFER (BUFFER_INDEX) /= ' ' then
       if REQUEST_BUFFER (BUFFER_INDEX) = ';' then
          SEMICOLON_LOCATION := BUFFER_INDEX;
          SEMICOLON_COUNT    := SEMICOLON_COUNT + 1;
       else   -- Check for non-blanks before/after semicolon.
          if SEMICOLON_COUNT < 1 then
             PERSON1_FIELD_EXISTS := true;
          else
             PERSON2_FIELD_EXISTS := true;
          end if;
       end if;
    end if;
  end loop;
  -- set REQUEST_STATUS, based on results of scan of REQUEST_BUFFER.
  if SEMICOLON_COUNT /= 1 then
     REQUEST_STATUS := "must be exactly one semicolon.           ";
  elsif not PERSON1_FIELD_EXISTS then
     REQUEST_STATUS := "null field preceding semicolon.          ";
  elsif not PERSON2_FIELD_EXISTS then
     REQUEST_STATUS := "null field following semicolon.          ";
  end if;
end CHECK_REQUEST;

separate (RELATE)
procedure BUFFER_TO_PERSON (PERSON_ID     : in out NAME_TYPE;
                            START_LOCATION,
                            STOP_LOCATION : in BUFFER_RANGE) is
  -- fills in the PERSON_ID from the designated portion
  -- of the REQUEST_BUFFER.

  FIRST_NON_BLANK : BUFFER_RANGE;

begin
  FIRST_NON_BLANK := START_LOCATION;
  while REQUEST_BUFFER (FIRST_NON_BLANK) = ' ' loop
    FIRST_NON_BLANK := FIRST_NON_BLANK + 1;
  end loop;
  COERCE_STRING (REQUEST_BUFFER (FIRST_NON_BLANK..STOP_LOCATION),
                 PERSON_ID);
end BUFFER_TO_PERSON;
```

```
separate (RELATE)
procedure SEARCH_FOR_REQUESTED_PERSONS
              (PERSON1_IDENT, PERSON2_IDENT : in  NAME_TYPE;
               PERSON1_INDEX, PERSON2_INDEX : out INDEX_TYPE;
               PERSON1_FOUND, PERSON2_FOUND : in out COUNTER) is
  -- SEARCH_FOR_REQUESTED_PERSONS scans through the PERSON array,
  -- looking for the two requested PERSONs.  Match may be by NAME
  -- or unique IDENTIFIER-number.

  THIS_IDENT         : NAME_TYPE;

begin
  PERSON1_FOUND := 0;
  PERSON2_FOUND := 0;
  PERSON1_INDEX := 0;
  PERSON2_INDEX := 0;
SCAN_ALL_PERSONS:
  for CURRENT  in 1..NUMBER_OF_PERSONS loop
      -- THIS_IDENT contains CURRENT PERSON's numeric IDENTIFIER
      -- left-justified, padded with blanks.
      COERCE_STRING (" ", THIS_IDENT);
      for IDENTIFIER_INDEX in IDENTIFIER_RANGE loop
        THIS_IDENT (IDENTIFIER_INDEX) :=
            PERSON (CURRENT) . IDENTIFIER (IDENTIFIER_INDEX);
      end loop;
      -- allow identification by name or number.
      if (PERSON1_IDENT = THIS_IDENT) or
         (PERSON1_IDENT = PERSON (CURRENT) . NAME)
      then
         PERSON1_FOUND := PERSON1_FOUND + 1;
         PERSON1_INDEX := CURRENT;
      end if;
      if (PERSON2_IDENT = THIS_IDENT) or
         (PERSON2_IDENT = PERSON (CURRENT) . NAME)
      then
         PERSON2_FOUND := PERSON2_FOUND + 1;
         PERSON2_INDEX := CURRENT;
      end if;
  end loop SCAN_ALL_PERSONS;
end SEARCH_FOR_REQUESTED_PERSONS;
```

```
separate (RELATE)
procedure FIND_RELATIONSHIP (TARGET_INDEX, SOURCE_INDEX : in INDEX_TYPE) is
  -- Finds shortest path (if any) between two PERSONs and
  -- determines their RELATIONSHIP based on immediate relations
  -- traversed in path.  PERSON array simulates a directed graph,
  -- and algorithm finds shortest path, based on following
  -- weights: PARENT-CHILD edge  = 1.0
  --          SPOUSE-SPOUSE edge = 1.8

  type SEARCH_TYPE is (SEARCHING, SUCCEEDED, FAILED);

  SEARCH_STATUS        : SEARCH_TYPE;
  THIS_NODE, ADJACENT_NODE, BEST_NEARBY_INDEX, LAST_NEARBY_INDEX
                       : INDEX_TYPE;
  NEARBY_NODE          : array (INDEX_TYPE) of INDEX_TYPE;
  THIS_EDGE            : EDGE_TYPE;
  THIS_NEIGHBOR        : NEIGHBOR_POINTER;
  RELATIONSHIP         : GIVEN_IDENTIFIERS;
  MINIMAL_DISTANCE     : REAL;

  procedure PROCESS_ADJACENT_NODE (BASE_NODE, NEXT_NODE : in INDEX_TYPE;
                                   NEXT_BASE_EDGE       : in EDGE_TYPE)
            is separate;
  procedure RESOLVE_PATH_TO_ENGLISH is separate;
  procedure COMPUTE_COMMON_GENES (INDEX1, INDEX2 : in INDEX_TYPE)
            is separate;

begin   -- execution of FIND_RELATIONSHIP
  -- initialize PERSON-array for processing -
  -- mark all nodes as not seen
  for PERSON_INDEX in 1..NUMBER_OF_PERSONS loop
    PERSON (PERSON_INDEX) . REACHED_STATUS := NOT_SEEN;
  end loop;
  THIS_NODE := SOURCE_INDEX;
  -- mark source node as REACHED
  PERSON (THIS_NODE) . REACHED_STATUS       := REACHED;
  PERSON (THIS_NODE) . DISTANCE_FROM_SOURCE := 0.0;
  -- no NEARBY nodes exist yet
  LAST_NEARBY_INDEX := 0;
  if THIS_NODE = TARGET_INDEX then
     SEARCH_STATUS := SUCCEEDED;
  else
     SEARCH_STATUS := SEARCHING;
  end if;
```

```
  -- Loop keeps processing closest-to-source, unREACHED node
  -- until target REACHED, or no more connected nodes.
SEARCH_FOR_TARGET:
  while SEARCH_STATUS = SEARCHING loop
    -- Process all nodes adjacent to THIS_NODE
    THIS_NEIGHBOR := PERSON (THIS_NODE) . NEIGHBOR_LIST_HEADER;
    while THIS_NEIGHBOR /= null loop
      PROCESS_ADJACENT_NODE (THIS_NODE,
                             THIS_NEIGHBOR . NEIGHBOR_INDEX,
                             THIS_NEIGHBOR . NEIGHBOR_EDGE);
      THIS_NEIGHBOR := THIS_NEIGHBOR . NEXT_NEIGHBOR;
    end loop;

    -- All nodes adjacent to THIS_NODE are set.  Now search for
    -- shortest-distance unREACHED (but NEARBY) node to process next.
    if LAST_NEARBY_INDEX = 0 then
       SEARCH_STATUS := FAILED;
    else   -- determine next node to process
       MINIMAL_DISTANCE := 1.0e+18;
       for PERSON_INDEX in 1..LAST_NEARBY_INDEX loop
         if PERSON (NEARBY_NODE (PERSON_INDEX)) . DISTANCE_FROM_SOURCE
            < MINIMAL_DISTANCE
         then
            BEST_NEARBY_INDEX := PERSON_INDEX;
            MINIMAL_DISTANCE  :=
               PERSON (NEARBY_NODE (PERSON_INDEX)) . DISTANCE_FROM_SOURCE;
         end if;
       end loop;
       -- establish new THIS_NODE
       THIS_NODE := NEARBY_NODE (BEST_NEARBY_INDEX);
       -- change THIS_NODE from being NEARBY to REACHED
       PERSON (THIS_NODE) . REACHED_STATUS := REACHED;
       -- remove THIS_NODE from NEARBY list
       NEARBY_NODE (BEST_NEARBY_INDEX) := NEARBY_NODE (LAST_NEARBY_INDEX);
       LAST_NEARBY_INDEX := LAST_NEARBY_INDEX - 1;
       if THIS_NODE = TARGET_INDEX then
          SEARCH_STATUS := SUCCEEDED;
       end if;
    end if;
  end loop SEARCH_FOR_TARGET;

  -- Shortest path between PERSONs now established.  Next task is
  -- to translate path to English description of RELATIONSHIP.

  if SEARCH_STATUS = FAILED then
     put_line (' ' & PERSON (TARGET_INDEX) . NAME & " is not related to " &
                     PERSON (SOURCE_INDEX) . NAME);
  else   -- success - parse path to find and display RELATIONSHIP
     RESOLVE_PATH_TO_ENGLISH;
     COMPUTE_COMMON_GENES (SOURCE_INDEX, TARGET_INDEX);
  end if;
end FIND_RELATIONSHIP;
```

```
---- new compilation-unit #4: procedures under FIND_RELATIONSHIP

  separate (RELATE . FIND_RELATIONSHIP)
  procedure PROCESS_ADJACENT_NODE (BASE_NODE, NEXT_NODE : in INDEX_TYPE;
                                   NEXT_BASE_EDGE       : in EDGE_TYPE) is
    -- NEXT_NODE is adjacent to last-REACHED node (= BASE_NODE).
    -- if NEXT_NODE already REACHED, do nothing.
    -- If previously seen, check whether path thru BASE_NODE is
    -- shorter than current path to NEXT_NODE, and if so re-link
    -- next to base.
    -- If not previously seen, link next to base node.

    WEIGHT_THIS_EDGE, DISTANCE_THRU_BASE_NODE : REAL;

    procedure LINK_NEXT_NODE_TO_BASE_NODE is
      -- link next to base by re-setting its predecessor index to
      -- point to base, note type of edge, and re-set distance
      -- as it is through base node.
    begin   -- execution of LINK_NEXT_NODE_TO_BASE_NODE
      PERSON (NEXT_NODE) . DISTANCE_FROM_SOURCE := DISTANCE_THRU_BASE_NODE;
      PERSON (NEXT_NODE) . PATH_PREDECESSOR     := BASE_NODE;
      PERSON (NEXT_NODE) . EDGE_TO_PREDECESSOR  := NEXT_BASE_EDGE;
    end LINK_NEXT_NODE_TO_BASE_NODE;

  begin  -- execution of PROCESS_ADJACENT_NODE
    if PERSON (NEXT_NODE) . REACHED_STATUS /= REACHED then
       if NEXT_BASE_EDGE = SPOUSE then
          WEIGHT_THIS_EDGE := 1.8;
       else
          WEIGHT_THIS_EDGE := 1.0;
       end if;
       DISTANCE_THRU_BASE_NODE := WEIGHT_THIS_EDGE +
           PERSON (BASE_NODE) . DISTANCE_FROM_SOURCE;
       if PERSON (NEXT_NODE) . REACHED_STATUS = NOT_SEEN then
          PERSON (NEXT_NODE) . REACHED_STATUS := NEARBY;
          LAST_NEARBY_INDEX  := LAST_NEARBY_INDEX + 1;
          NEARBY_NODE (LAST_NEARBY_INDEX) := NEXT_NODE;
          LINK_NEXT_NODE_TO_BASE_NODE;
       else   -- REACHED_STATUS = NEARBY
          if DISTANCE_THRU_BASE_NODE
             < PERSON (NEXT_NODE) . DISTANCE_FROM_SOURCE
          then
             LINK_NEXT_NODE_TO_BASE_NODE;
          end if;
       end if;
    end if;
  end PROCESS_ADJACENT_NODE;
```

```
separate (RELATE . FIND_RELATIONSHIP)
procedure RESOLVE_PATH_TO_ENGLISH is
  -- RESOLVE_PATH_TO_ENGLISH condenses the shortest path to a
  -- series of RELATIONSHIPs for which there are English
  -- descriptions.

  -- Key persons are the ones in the RELATIONSHIP path which remain
  -- after the path is condensed.

  type SIBLING_TYPE is (STEP, HALF, FULL);

  type KEY_PERSON_RECORD  (RELATION_TO_NEXT : RELATION_TYPE := PARENT) is
    record
      PERSON_INDEX    : INDEX_TYPE;
      GENERATION_GAP  : COUNTER;
      PROXIMITY       : SIBLING_TYPE;
      case RELATION_TO_NEXT is
        when COUSIN => COUSIN_RANK : COUNTER;
        when others => null;
      end case;
    end record;

  -- these variables are used to generate KEY_PERSONs
  GENERATION_COUNT          : COUNTER;
  THIS_COUSIN_RANK          : COUNTER;
  THIS_PROXIMITY            : SIBLING_TYPE;

  -- these variables are used to condense the path
  KEY_PERSON                : array (INDEX_TYPE) of KEY_PERSON_RECORD;
  KEY_RELATION, LATER_KEY_RELATION, PRIMARY_RELATION,
     NEXT_PRIMARY_RELATION : RELATION_TYPE;
  KEY_INDEX, LATER_KEY_INDEX, PRIMARY_INDEX
                            : INDEX_TYPE;
  ANOTHER_ELEMENT_POSSIBLE : boolean;

  function  FULL_SIBLING (INDEX1, INDEX2 : in INDEX_TYPE)
                        return boolean is
    -- Determines whether two PERSONs are full siblings, i.e.,
    -- have the same two parents.
  begin
    return
      PERSON (INDEX1) . RELATIVE_IDENTIFIER (FATHER_IDENT) /= NULL_IDENT and
      PERSON (INDEX1) . RELATIVE_IDENTIFIER (MOTHER_IDENT) /= NULL_IDENT and
      PERSON (INDEX1) . RELATIVE_IDENTIFIER (FATHER_IDENT) =
          PERSON (INDEX2) . RELATIVE_IDENTIFIER (FATHER_IDENT) and
      PERSON (INDEX1) . RELATIVE_IDENTIFIER (MOTHER_IDENT) =
          PERSON (INDEX2) . RELATIVE_IDENTIFIER (MOTHER_IDENT);
  end FULL_SIBLING;
```

```
    procedure CONDENSE_KEY_PERSONS (AT_INDEX : in INDEX_TYPE;
                                    GAP_SIZE : in COUNTER) is
      -- CONDENSE_KEY_PERSONS condenses superfluous entries from the
      -- KEY_PERSON array, starting at AT_INDEX.

      RECEIVE_INDEX, SEND_INDEX : INDEX_TYPE;

    begin
      RECEIVE_INDEX := AT_INDEX;
      loop
        RECEIVE_INDEX := RECEIVE_INDEX + 1;
        SEND_INDEX    := RECEIVE_INDEX + GAP_SIZE;
        KEY_PERSON (RECEIVE_INDEX) := KEY_PERSON (SEND_INDEX);
      exit when KEY_PERSON (SEND_INDEX) . RELATION_TO_NEXT = NULL_RELATION;
      end loop;
    end CONDENSE_KEY_PERSONS;

    procedure DISPLAY_RELATION (FIRST_INDEX, LAST_INDEX, PRIMARY_INDEX
                                : in INDEX_TYPE)
            is separate;

  begin   -- execution of RESOLVE_PATH_TO_ENGLISH
     put_line (" Shortest path between identified persons: ");
     THIS_NODE  := TARGET_INDEX;
     KEY_INDEX  := 1;
     -- Display path and initialize KEY_PERSON array from path elements.
TRAVERSE_SHORTEST_PATH:
     while THIS_NODE /= SOURCE_INDEX loop
       put (' ' & PERSON (THIS_NODE) . NAME & " is ");
       case PERSON (THIS_NODE) . EDGE_TO_PREDECESSOR is
         when PARENT =>
           put_line ("parent of");
           KEY_PERSON (KEY_INDEX) :=
              (PERSON_INDEX     => THIS_NODE,
               GENERATION_GAP   => 1,
               PROXIMITY        => FULL,
               RELATION_TO_NEXT => PARENT);
         when CHILD  =>
           put_line ("child of");
           KEY_PERSON (KEY_INDEX) :=
              (PERSON_INDEX     => THIS_NODE,
               GENERATION_GAP   => 1,
               PROXIMITY        => FULL,
               RELATION_TO_NEXT => CHILD);
         when SPOUSE =>
           put_line ("spouse of");
           KEY_PERSON (KEY_INDEX) :=
              (PERSON_INDEX     => THIS_NODE,
               GENERATION_GAP   => 0,
               PROXIMITY        => FULL,
               RELATION_TO_NEXT => SPOUSE);
       end case;
       KEY_INDEX := KEY_INDEX + 1;
       THIS_NODE := PERSON (THIS_NODE) . PATH_PREDECESSOR;
     end loop TRAVERSE_SHORTEST_PATH;
```

```
    put_line(' ' & PERSON (THIS_NODE) . NAME);
    KEY_PERSON (KEY_INDEX) :=
       (PERSON_INDEX      => THIS_NODE,
        GENERATION_GAP    => 0,
        PROXIMITY         => FULL,
        RELATION_TO_NEXT => NULL_RELATION);
    KEY_PERSON (KEY_INDEX + 1) :=
       (PERSON_INDEX      => 0,
        GENERATION_GAP    => 0,
        PROXIMITY         => FULL,
        RELATION_TO_NEXT => NULL_RELATION);
    -- Resolve CHILD-PARENT and CHILD-SPOUSE-PARENT relations
    -- to SIBLING relations.
    KEY_INDEX := 1;
FIND_SIBLINGS:
    while KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT /= NULL_RELATION loop
      if KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = CHILD then
         LATER_KEY_RELATION := KEY_PERSON (KEY_INDEX + 1) . RELATION_TO_NEXT;
         if LATER_KEY_RELATION = PARENT then
            -- found either full or half SIBLINGs
            if FULL_SIBLING (KEY_PERSON (KEY_INDEX)     . PERSON_INDEX,
                             KEY_PERSON (KEY_INDEX + 2) . PERSON_INDEX)
            then
               THIS_PROXIMITY := FULL;
            else
               THIS_PROXIMITY := HALF;
            end if;
            KEY_PERSON (KEY_INDEX) :=
               (PERSON_INDEX      => KEY_PERSON (KEY_INDEX) . PERSON_INDEX,
                GENERATION_GAP    => 0,
                PROXIMITY         => THIS_PROXIMITY,
                RELATION_TO_NEXT => SIBLING);
            CONDENSE_KEY_PERSONS (KEY_INDEX, 1);
         elsif (LATER_KEY_RELATION = SPOUSE) and
               (KEY_PERSON (KEY_INDEX + 2) . RELATION_TO_NEXT = PARENT)
         then -- found step-SIBLINGs
            KEY_PERSON (KEY_INDEX) :=
               (PERSON_INDEX      => KEY_PERSON (KEY_INDEX) . PERSON_INDEX,
                GENERATION_GAP    => 0,
                PROXIMITY         => STEP,
                RELATION_TO_NEXT => SIBLING);
            CONDENSE_KEY_PERSONS (KEY_INDEX, 2);
         end if;  -- LATER_KEY_RELATION = PARENT
      end if;   -- RELATION_TO_NEXT = CHILD
      KEY_INDEX := KEY_INDEX + 1;
    end loop FIND_SIBLINGS;
```

```
-- Resolve CHILD-CHILD-... and PARENT-PARENT-... relations to
-- direct descendant or ancestor relations.
KEY_INDEX := 1;
FIND_ANCESTORS_OR_DESCENDANTS:
while KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT /= NULL_RELATION loop
  if (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = CHILD) or
     (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = PARENT)
  then
     LATER_KEY_INDEX := KEY_INDEX + 1;
     while KEY_PERSON (LATER_KEY_INDEX) . RELATION_TO_NEXT =
           KEY_PERSON       (KEY_INDEX) . RELATION_TO_NEXT loop
       LATER_KEY_INDEX := LATER_KEY_INDEX + 1;
     end loop;
     GENERATION_COUNT := LATER_KEY_INDEX - KEY_INDEX;
     if GENERATION_COUNT > 1 then   -- compress generations
        KEY_PERSON (KEY_INDEX) . GENERATION_GAP := GENERATION_COUNT;
        CONDENSE_KEY_PERSONS (KEY_INDEX, GENERATION_COUNT - 1);
     end if;
  end if;    -- if RELATION_TO_NEXT = CHILD or PARENT
  KEY_INDEX := KEY_INDEX + 1;
end loop FIND_ANCESTORS_OR_DESCENDANTS;
```

```
    -- Resolve CHILD-SIBLING-PARENT to COUSIN,
    --          CHILD-SIBLING        to NEPHEW,
    --          SIBLING-PARENT       to UNCLE.
    KEY_INDEX := 1;
FIND_COUSINS_NEPHEWS_UNCLES:
    while KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT /= NULL_RELATION loop
      LATER_KEY_RELATION := KEY_PERSON (KEY_INDEX + 1) . RELATION_TO_NEXT;
      if (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = CHILD) and
         (LATER_KEY_RELATION = SIBLING)
      then   -- COUSIN or NEPHEW
         if KEY_PERSON (KEY_INDEX + 2) . RELATION_TO_NEXT = PARENT then
            -- found COUSIN
            if KEY_PERSON (KEY_INDEX)     . GENERATION_GAP <
               KEY_PERSON (KEY_INDEX + 2) . GENERATION_GAP
            then
               THIS_COUSIN_RANK :=
                   KEY_PERSON (KEY_INDEX) . GENERATION_GAP;
            else
               THIS_COUSIN_RANK :=
                   KEY_PERSON (KEY_INDEX + 2) . GENERATION_GAP;
            end if;
            KEY_PERSON (KEY_INDEX) :=
               (PERSON_INDEX     => KEY_PERSON (KEY_INDEX) . PERSON_INDEX,
                GENERATION_GAP   =>
                      abs (KEY_PERSON (KEY_INDEX)     . GENERATION_GAP -
                           KEY_PERSON (KEY_INDEX + 2) . GENERATION_GAP),
                PROXIMITY        => KEY_PERSON (KEY_INDEX + 1) . PROXIMITY,
                RELATION_TO_NEXT => COUSIN,
                COUSIN_RANK      => THIS_COUSIN_RANK);
            CONDENSE_KEY_PERSONS (KEY_INDEX, 2);
         else  -- found NEPHEW
            KEY_PERSON (KEY_INDEX) :=
               (PERSON_INDEX     => KEY_PERSON (KEY_INDEX) . PERSON_INDEX,
                GENERATION_GAP   => KEY_PERSON (KEY_INDEX) . GENERATION_GAP,
                PROXIMITY        => KEY_PERSON (KEY_INDEX + 1) . PROXIMITY,
                RELATION_TO_NEXT => NEPHEW);
            CONDENSE_KEY_PERSONS (KEY_INDEX, 1);
         end if;
      elsif KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = SIBLING and
            LATER_KEY_RELATION = PARENT
      then   -- found UNCLE
         KEY_PERSON (KEY_INDEX) :=
            (PERSON_INDEX     => KEY_PERSON (KEY_INDEX) . PERSON_INDEX,
             GENERATION_GAP   => KEY_PERSON (KEY_INDEX + 1) . GENERATION_GAP,
             PROXIMITY        => KEY_PERSON (KEY_INDEX) . PROXIMITY,
             RELATION_TO_NEXT => UNCLE);
         CONDENSE_KEY_PERSONS (KEY_INDEX, 1);
      end if;
      KEY_INDEX := KEY_INDEX + 1;
    end loop FIND_COUSINS_NEPHEWS_UNCLES;
```

```
     -- Loop below will pick out valid adjacent strings of elements
     -- to be displayed.  KEY_INDEX points to first element,
     -- LATER_KEY_INDEX to last element, and PRIMARY_INDEX to the
     -- element which determines the primary English word to be used.
     -- Associativity of adjacent elements in condensed table
     -- is based on English usage.
     KEY_INDEX := 1;
     put_line (" Condensed path:");
CONSOLIDATE_ADJACENT_PERSONS:
     while KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT /= NULL_RELATION loop
       KEY_RELATION    := KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT;
       LATER_KEY_INDEX := KEY_INDEX;
       PRIMARY_INDEX   := KEY_INDEX;
       if KEY_PERSON (KEY_INDEX + 1) . RELATION_TO_NEXT /= NULL_RELATION then
          -- seek multi-element combination
          ANOTHER_ELEMENT_POSSIBLE := true;
          if KEY_RELATION = SPOUSE then
             LATER_KEY_INDEX := LATER_KEY_INDEX + 1;
             PRIMARY_INDEX   := LATER_KEY_INDEX;
             if (KEY_PERSON (LATER_KEY_INDEX) . RELATION_TO_NEXT = SIBLING) or
                (KEY_PERSON (LATER_KEY_INDEX) . RELATION_TO_NEXT = COUSIN)
             then   -- Nothing can follow SPOUSE-SIBLING or SPOUSE-COUSIN
                ANOTHER_ELEMENT_POSSIBLE := false;
             end if;
          end if;

          -- PRIMARY_INDEX is now correctly set.  Next if-statement
          -- determines if a following SPOUSE relation should be
          -- appended to this combination or left for the next
          -- combination.
          if ANOTHER_ELEMENT_POSSIBLE and
             (KEY_PERSON (PRIMARY_INDEX + 1) . RELATION_TO_NEXT = SPOUSE)
             -- Only a SPOUSE can follow a Primary
          then
             -- check primary preceding and following SPOUSE.
             PRIMARY_RELATION      :=
                KEY_PERSON (PRIMARY_INDEX)     . RELATION_TO_NEXT;
             NEXT_PRIMARY_RELATION :=
                KEY_PERSON (PRIMARY_INDEX + 2) . RELATION_TO_NEXT;
             if (NEXT_PRIMARY_RELATION = NEPHEW   or
                 NEXT_PRIMARY_RELATION = COUSIN   or
                 NEXT_PRIMARY_RELATION = NULL_RELATION)
                or (PRIMARY_RELATION = NEPHEW)
                or ( (PRIMARY_RELATION = SIBLING  or
                      PRIMARY_RELATION = PARENT)
                   and NEXT_PRIMARY_RELATION /= UNCLE )
             then  -- append following SPOUSE with this combination.
                LATER_KEY_INDEX := LATER_KEY_INDEX + 1;
             end if;
          end if;
       end if;  -- multi-element combination
       DISPLAY_RELATION (KEY_INDEX, LATER_KEY_INDEX, PRIMARY_INDEX);
       KEY_INDEX := LATER_KEY_INDEX + 1;
     end loop CONSOLIDATE_ADJACENT_PERSONS;
     put_line (' ' & PERSON (KEY_PERSON (KEY_INDEX) . PERSON_INDEX) . NAME);
  end;  -- RESOLVE_PATH_TO_ENGLISH
```

```
---- new compilation-unit #5: procedures under RESOLVE_PATH_TO_ENGLISH

separate (RELATE . FIND_RELATIONSHIP . RESOLVE_PATH_TO_ENGLISH)
procedure DISPLAY_RELATION (FIRST_INDEX, LAST_INDEX, PRIMARY_INDEX
                            : in INDEX_TYPE) is
  -- DISPLAY_RELATION takes 1, 2, or 3 adjacent elements in the
  -- condensed table and generates the English description of
  -- the relation between the first and last + 1 elements.

  INLAW              : boolean;
  THIS_PROXIMITY     : SIBLING_TYPE;
  THIS_GENDER        : GENDER_TYPE;
  FIRST_RELATION, LAST_RELATION, PRIMARY_RELATION
                     : RELATION_TYPE;
  THIS_GENERATION_GAP, THIS_COUSIN_RANK
                     : COUNTER;

  -- need to instantiate package to display integer values
  package COUNTER_IO is
    new integer_io (COUNTER);
```

```
begin   -- execution of DISPLAY_RELATION
  FIRST_RELATION    := KEY_PERSON (FIRST_INDEX)   . RELATION_TO_NEXT;
  LAST_RELATION     := KEY_PERSON (LAST_INDEX)    . RELATION_TO_NEXT;
  PRIMARY_RELATION  := KEY_PERSON (PRIMARY_INDEX) . RELATION_TO_NEXT;
  -- set THIS_PROXIMITY
  if ((PRIMARY_RELATION = PARENT) and (FIRST_RELATION = SPOUSE)) or
     ((PRIMARY_RELATION = CHILD)  and (LAST_RELATION  = SPOUSE))
  then
     THIS_PROXIMITY := STEP;
  elsif PRIMARY_RELATION = SIBLING or
        PRIMARY_RELATION = UNCLE   or
        PRIMARY_RELATION = NEPHEW  or
        PRIMARY_RELATION = COUSIN
  then
     THIS_PROXIMITY := KEY_PERSON (PRIMARY_INDEX) . PROXIMITY;
  else
     THIS_PROXIMITY := FULL;
  end if;
  -- set THIS_GENERATION_GAP
  if PRIMARY_RELATION = PARENT or
     PRIMARY_RELATION = CHILD  or
     PRIMARY_RELATION = UNCLE  or
     PRIMARY_RELATION = NEPHEW or
     PRIMARY_RELATION = COUSIN
  then
     THIS_GENERATION_GAP := KEY_PERSON (PRIMARY_INDEX) . GENERATION_GAP;
  else
     THIS_GENERATION_GAP := 0;
  end if;
  -- set INLAW
  INLAW := false;
  if (FIRST_RELATION = SPOUSE)     and
     (PRIMARY_RELATION = SIBLING or
      PRIMARY_RELATION = CHILD   or
      PRIMARY_RELATION = NEPHEW  or
      PRIMARY_RELATION = COUSIN)
  then
     INLAW := true;
  elsif (LAST_RELATION    = SPOUSE)    and
        (PRIMARY_RELATION = SIBLING or
         PRIMARY_RELATION = PARENT  or
         PRIMARY_RELATION = UNCLE   or
         PRIMARY_RELATION = COUSIN)
  then
     INLAW := true;
  end if;
  -- set THIS_COUSIN_RANK
  if PRIMARY_RELATION = COUSIN then
     THIS_COUSIN_RANK := KEY_PERSON (PRIMARY_INDEX) . COUSIN_RANK;
  end if;
```

```
-- parameters are set - now generate display.

put (" " & PERSON (KEY_PERSON (FIRST_INDEX) . PERSON_INDEX) . NAME &
     " is ");
if PRIMARY_RELATION = PARENT or
   PRIMARY_RELATION = CHILD  or
   PRIMARY_RELATION = UNCLE  or
   PRIMARY_RELATION = NEPHEW
then
   -- display generation-qualifier
   if THIS_GENERATION_GAP >= 3 then
      put ("great");
      if THIS_GENERATION_GAP > 3 then
         put ("*");
         COUNTER_IO . put (THIS_GENERATION_GAP - 2, width => 1);
      end if;
      put ("-");
   end if;
   if THIS_GENERATION_GAP >= 2 then
      put ("grand-");
   end if;
elsif (PRIMARY_RELATION = COUSIN) and then (THIS_COUSIN_RANK > 1) then
   COUNTER_IO . put (THIS_COUSIN_RANK, width => 1);
   case THIS_COUSIN_RANK mod 10 is
     when 1      => put ("st ");
     when 2      => put ("nd ");
     when 3      => put ("rd ");
     when others => put ("th ");
   end case;
end if;

if THIS_PROXIMITY = STEP then
   put ("step-");
elsif THIS_PROXIMITY = HALF then
   put ("half-");
end if;
```

```
  THIS_GENDER := PERSON (KEY_PERSON (FIRST_INDEX) . PERSON_INDEX) . GENDER;
  case PRIMARY_RELATION is
    when PARENT  => if THIS_GENDER = MALE then put ("father");
                    else                       put ("mother");
                    end if;
    when CHILD   => if THIS_GENDER = MALE then put ("son");
                    else                       put ("daughter");
                    end if;
    when SPOUSE  => if THIS_GENDER = MALE then put ("husband");
                    else                       put ("wife");
                    end if;
    when SIBLING => if THIS_GENDER = MALE then put ("brother");
                    else                       put ("sister");
                    end if;
    when UNCLE   => if THIS_GENDER = MALE then put ("uncle");
                    else                       put ("aunt");
                    end if;
    when NEPHEW  => if THIS_GENDER = MALE then put ("nephew");
                    else                       put ("niece");
                    end if;
    when COUSIN  => put ("cousin");
    when others  => put ("null");
  end case;

  if INLAW then
     put ("-in-law");
  end if;

  if (PRIMARY_RELATION = COUSIN) and (THIS_GENERATION_GAP > 0) then
     if THIS_GENERATION_GAP > 1 then
        put (" ");
        COUNTER_IO . put (THIS_GENERATION_GAP, width => 1);
        put (" times removed");
     else
        put (" once removed");
     end if;
  end if;

  put_line (" of");
end DISPLAY_RELATION;
```

```
---- new compilation-unit #6: procedures under FIND_RELATIONSHIP

separate (RELATE . FIND_RELATIONSHIP)
procedure COMPUTE_COMMON_GENES (INDEX1, INDEX2 : in INDEX_TYPE) is
  -- COMPUTE_COMMON_GENES assumes that each ancestor contributes
  -- half of the genetic material to a PERSON.  It finds common
  -- ancestors between two PERSONs and computes the expected
  -- value of the PROPORTION of common material.

  COMMON_PROPORTION : REAL;

  package REAL_IO is
    new FLOAT_IO (REAL);

  procedure ZERO_PROPORTION (ZERO_INDEX : in INDEX_TYPE) is
    -- ZERO_PROPORTION recursively seeks out all ancestors and
    -- zeros them out.

    THIS_NEIGHBOR : NEIGHBOR_POINTER;

  begin
    PERSON (ZERO_INDEX) . DESCENDANT_GENES := 0.0;
    THIS_NEIGHBOR := PERSON (ZERO_INDEX) . NEIGHBOR_LIST_HEADER;
    while THIS_NEIGHBOR /= null loop
      if THIS_NEIGHBOR . NEIGHBOR_EDGE = PARENT then
        ZERO_PROPORTION (THIS_NEIGHBOR . NEIGHBOR_INDEX);
      end if;
      THIS_NEIGHBOR := THIS_NEIGHBOR . NEXT_NEIGHBOR;
    end loop;
  end ZERO_PROPORTION;

  procedure MARK_PROPORTION (MARKER       : in IDENTIFIER_TYPE;
                             PROPORTION   : in REAL;
                             MARKED_INDEX : in INDEX_TYPE) is
    -- MARK_PROPORTION recursively seeks out all ancestors and
    -- marks them with the sender's PROPORTION of shared
    -- genetic material.  This PROPORTION is diluted by one-half
    -- for each generation.

    THIS_NEIGHBOR : NEIGHBOR_POINTER;

  begin
    PERSON (MARKED_INDEX) . DESCENDANT_IDENTIFIER := MARKER;
    PERSON (MARKED_INDEX) . DESCENDANT_GENES      :=
       PERSON (MARKED_INDEX) . DESCENDANT_GENES + PROPORTION;
    THIS_NEIGHBOR := PERSON (MARKED_INDEX) . NEIGHBOR_LIST_HEADER;
    while THIS_NEIGHBOR /= null loop
      if THIS_NEIGHBOR . NEIGHBOR_EDGE = PARENT then
        MARK_PROPORTION (MARKER, PROPORTION / 2.0,
                         THIS_NEIGHBOR . NEIGHBOR_INDEX);
      end if;
      THIS_NEIGHBOR := THIS_NEIGHBOR . NEXT_NEIGHBOR;
    end loop;
  end MARK_PROPORTION;
```

```
  procedure CHECK_COMMON_PROPORTION
            (COMMON_PROPORTION : in out REAL;
             MATCH_IDENTIFIER  : in     IDENTIFIER_TYPE;
             PROPORTION        : in     REAL;
             ALREADY_COUNTED   : in     REAL;
             CHECK_INDEX       : in     INDEX_TYPE) is
    -- CHECK_COMMON_PROPORTION searches all the ancestors of
    -- CHECK_INDEX to see if any have been marked, and if so
    -- adds the appropriate amount to COMMON_PROPORTION.

    THIS_NEIGHBOR     : NEIGHBOR_POINTER;
    THIS_CONTRIBUTION : REAL;

  begin
    if PERSON (CHECK_INDEX) . DESCENDANT_IDENTIFIER = MATCH_IDENTIFIER then
       -- Increment COMMON_PROPORTION by the contribution of
       -- this common ancestor, but discount for the contribution
       -- of less remote ancestors already counted.
       THIS_CONTRIBUTION := PERSON (CHECK_INDEX) . DESCENDANT_GENES
                            * PROPORTION;
       COMMON_PROPORTION := COMMON_PROPORTION
          + THIS_CONTRIBUTION - ALREADY_COUNTED;
    else
       THIS_CONTRIBUTION := 0.0;
    end if;
    THIS_NEIGHBOR := PERSON (CHECK_INDEX) . NEIGHBOR_LIST_HEADER;
    while THIS_NEIGHBOR /= null loop
      if THIS_NEIGHBOR . NEIGHBOR_EDGE = PARENT then
         CHECK_COMMON_PROPORTION (COMMON_PROPORTION,
               MATCH_IDENTIFIER, PROPORTION / 2.0,
               THIS_CONTRIBUTION / 4.0,
               THIS_NEIGHBOR . NEIGHBOR_INDEX);
      end if;
      THIS_NEIGHBOR := THIS_NEIGHBOR . NEXT_NEIGHBOR;
    end loop;
  end CHECK_COMMON_PROPORTION;

begin    -- COMPUTE_COMMON_GENES
  -- First zero out all ancestors to allow adding.  This is necessary
  -- because there might be two paths to an antestor.
  ZERO_PROPORTION (INDEX1);
  -- now mark with shared PROPORTION
  MARK_PROPORTION (PERSON (INDEX1) . IDENTIFIER, 1.0, INDEX1);
  COMMON_PROPORTION := 0.0;
  CHECK_COMMON_PROPORTION (COMMON_PROPORTION,
     PERSON (INDEX1) . IDENTIFIER, 1.0, 0.0, INDEX2);
  put (" Proportion of common genetic material = ");
  REAL_IO . put (COMMON_PROPORTION, fore => 1, aft => 5, exp => 3);
  put_line (" ");
end COMPUTE_COMMON_GENES;
```

3.0 BASIC

Because of the unavailability of a standard implementation, the BASIC program could not be tested directly. However, a syntactically non-standard version, which is believed to be logically equivalent, was tested.

```
10000 ! ---- program-unit number 1 ----
10010 !
10020 program RELATE
10030 !
10040 !  declare subs to be used by this program-unit
10050 !
10060 declare external sub FIND_RELATIONSHIP
10070 declare sub LINK_RELATIVES, LINK_ONE_WAY, PROMPT_AND_READ
10080 declare sub CHECK_REQUEST, SEARCH_FOR_REQUESTED_PERSONS
10090 !
10100 option base 1
10110 !
10120 !  Define global objects
10130 !
10140 data 300
10150 read MAX_PERSONS
10160 !
10170 data  1, 2         ! for truth values
10180 read  TRUE, FALSE
10190 !
10200 !  each PERSON's record in the file identifies at most three
10210 !  others directly related: father, mother, and spouse
10220 data 1, 2, 3
10230 read FATHER_IDENT, MOTHER_IDENT, SPOUSE_IDENT
10240 !
10250 data M, F
10260 read MALE$, FEMALE$
10270 !
10280 data 000
10290 read NULL_IDENT$
10300 !
10310 data 1, 2, 3, 4, 5, 6, 7, 8
10320 read PARENT, CHILD, SPOUSE, SIBLING, UNCLE, NEPHEW
10325 read COUSIN, NULL_RELATION
10330 !
10340 !  A node in the graph (= PERSON) has either already been reached,
10350 !  is immediately adjacent to those reached, or farther away.
10360 data 1, 2, 3
10370 read REACHED, NEARBY, NOT_SEEN
10380 !
```

```
10390 !  The following data arrays are the central repository of information
10400 !  about inter-relationships.  All relationships are captured in the
10410 !  directed graph of which each record is a node.
10420 !
10430 !    static information - filled from PEOPLE file:
10440 dim  NAME$ (300), IDENTIFIER$ (300), GENDER$ (300)
10450 !
10460 !    IDENTIFIER$s of immediate relatives - father, mother, spouse
10470 dim  RELATIVE_IDENTIFIER$ (300,3)
10480 !
10490 !    pointers to immediate neighbors in graph
10500 dim  NEIGHBOR_COUNT (300)
10505 dim  NEIGHBOR_INDEX (300,20), NEIGHBOR_EDGE (300,20)
10510 !
10520 !    data used when traversing graph to resolve user request:
10530 dim  DISTANCE_FROM_SOURCE (300), PATH_PREDECESSOR (300)
10540 dim  EDGE_TO_PREDECESSOR  (300), REACHED_STATUS   (300)
10550 !
10560 !    data used to compute common genetic material
10570 dim  DESCENDANT_IDENTIFIER$ (300), DESCENDANT_GENES (300)
10580 !
10590 data  stop, Request OK
10600 read  REQUEST_TO_STOP$, REQUEST_OK$
10610 !
10620 ! end initialization
10630 !
```

```
10640 ! begin main line of execution
10650 !
10660 open #1: name "PEOPLE.DAT", access input, rectype native,     &
&             organization sequential
10670 !
10680 !  This loop reads in the PEOPLE file and constructs the person
10690 !  array from it (one person = one set of array entries).
10700 !  As records are read in, links are constructed to represent the
10710 !  PARENT-CHILD or SPOUSE RELATIONSHIP.  The array then implements
10720 !  a directed graph which is used to satisfy subsequent user
10730 !  requests.  The file is assumed to be correct - no validation
10740 !  is performed on it.
10750 !
10760 for CURRENT = 1 to MAX_PERSONS
10770    read #1, if missing then exit for,                               &
&              with "string*20, string*3, string*1, 3 of string*3":  &
&          NAME$ (CURRENT), IDENTIFIER$ (CURRENT), GENDER$ (CURRENT),  &
&          RELATIVE_IDENTIFIER$ (CURRENT, FATHER_IDENT),              &
&          RELATIVE_IDENTIFIER$ (CURRENT, MOTHER_IDENT),              &
&          RELATIVE_IDENTIFIER$ (CURRENT, SPOUSE_IDENT)
10780    let NAME$ (CURRENT) = rtrim$ (NAME$ (CURRENT))
10790    !  Location of adjacent persons as yet undetermined
10800    let NEIGHBOR_COUNT (CURRENT) = 0
10810    !  Descendants as yet undetermined
10820    let DESCENDANT_IDENTIFIER$ (CURRENT) = NULL_IDENT$
10830    let CURRENT_IDENT$ = IDENTIFIER$ (CURRENT)
10840    !  Compare this PERSON against all previously entered PERSONs
10850    !  to search for RELATIONSHIPs.
10860    for PREVIOUS = 1 to CURRENT - 1
10870       let PREVIOUS_IDENT$ = IDENTIFIER$ (PREVIOUS)
10880       !  Search for father, mother, or spouse relationship in
10890       !  either direction between this and PREVIOUS person.
10900       !  Assume at most one RELATIONSHIP exists.
10910       for RELATIONSHIP = FATHER_IDENT to SPOUSE_IDENT
10920          if RELATIVE_IDENTIFIER$ (CURRENT, RELATIONSHIP)      &
&                  = PREVIOUS_IDENT$ then
10930             call LINK_RELATIVES (CURRENT, RELATIONSHIP, PREVIOUS)
10940             exit for
10950          elseif RELATIVE_IDENTIFIER$ (PREVIOUS, RELATIONSHIP)  &
&                     = CURRENT_IDENT$ then
10960             call LINK_RELATIVES (PREVIOUS, RELATIONSHIP, CURRENT)
10970             exit for
10980          end if
10990       next RELATIONSHIP
11000    next PREVIOUS
11010 next CURRENT
11020 let NUMBER_OF_PERSONS = CURRENT - 1
11030 close #1
11040 !
11050 !  Person arrays are now loaded and edges between immediate relatives
11060 !  (PARENT-CHILD or SPOUSE-SPOUSE) are established.
11070 !
```

```
11080 !  Do-loop accepts requests and finds relationship (if any)
11090 !  between pairs of PERSONs.
11110 do
11120    call PROMPT_AND_READ
11130    if REQUEST_BUFFER$ = REQUEST_TO_STOP$ then exit do
11140    call CHECK_REQUEST (ERROR_MESSAGE$, PERSON1_IDENT$, PERSON2_IDENT$)
11150    !
11160    !    Syntax check of request completed.  Now either display error
11170    !    message or search for the two PERSONs.
11180    !
11190    if ERROR_MESSAGE$ = REQUEST_OK$ then
11200       !  request syntactically correct
11210       call SEARCH_FOR_REQUESTED_PERSONS(PERSON1_IDENT$, PERSON2_IDENT$, &
&                                         PERSON1_INDEX,  PERSON2_INDEX,  &
&                                         PERSON1_FOUND,  PERSON2_FOUND)
11220       if PERSON1_FOUND = 1 and PERSON2_FOUND = 1 then
11230       !  Exactly one match for each PERSON - proceed to
11240       !  determine RELATIONSHIP, if any.
11250          if PERSON1_INDEX = PERSON2_INDEX then
11260             print " "; NAME$ (PERSON1_INDEX); " is identical to ";
11270             if GENDER$ (PERSON1_INDEX) = MALE$ then
11280                print "himself."
11290             else
11300                print "herself."
11310             end if
11320          else
11330             call FIND_RELATIONSHIP                                     &
&                    (PERSON1_INDEX, PERSON2_INDEX, NUMBER_OF_PERSONS,    &
&                     NAME$, IDENTIFIER$, GENDER$, RELATIVE_IDENTIFIER$, &
&                     NEIGHBOR_COUNT, NEIGHBOR_INDEX, NEIGHBOR_EDGE,     &
&                     DISTANCE_FROM_SOURCE, PATH_PREDECESSOR,            &
&                     EDGE_TO_PREDECESSOR , REACHED_STATUS,              &
&                     DESCENDANT_IDENTIFIER$, DESCENDANT_GENES)
11340          end if
11350       else   !  either not found or more than one found
11360          if PERSON1_FOUND = 0 then
11370             print " First person not found."
11380          elseif PERSON1_FOUND > 1 then
11390             print " Duplicate names for first person -";
11400             print " use numeric identifier."
11410          end if
11420          if PERSON2_FOUND = 0 then
11430             print " Second person not found."
11440          elseif PERSON2_FOUND > 1 then
11450             print " Duplicate names for second person -";
11460             print " use numeric identifier."
11470          end if
11480       end if
11490    else
11500       print " Incorrect request format: "; ERROR_MESSAGE$
11510    end if
11520 loop
11530 print " End of relation-finder."
11540 stop
11550 !
11560 ! end of main line of execution; internal subs follow
```

```
11570 !
11580 sub LINK_RELATIVES (FROM_INDEX, RELATIONSHIP, TO_INDEX)
11590 !   establishes cross-indexing between immediately related PERSONs.
11600 !
11610 if RELATIONSHIP = SPOUSE_IDENT then
11620    call LINK_ONE_WAY (FROM_INDEX, SPOUSE, TO_INDEX)
11630    call LINK_ONE_WAY (TO_INDEX,   SPOUSE, FROM_INDEX)
11640 else  !  RELATIONSHIP is father or mother
11650    call LINK_ONE_WAY (FROM_INDEX, PARENT, TO_INDEX)
11660    call LINK_ONE_WAY (TO_INDEX,   CHILD,  FROM_INDEX)
11670 end if
11680 end sub
11690 !
11700 sub LINK_ONE_WAY (FROM_INDEX, THIS_EDGE, TO_INDEX)
11710 !   Establishes the neighbor entries from one person to another
11720 !
11730 let NEXT_NEIGHBOR = NEIGHBOR_COUNT (FROM_INDEX) + 1
11740 let NEIGHBOR_COUNT (FROM_INDEX) = NEXT_NEIGHBOR
11750 let NEIGHBOR_INDEX (FROM_INDEX, NEXT_NEIGHBOR) = TO_INDEX
11760 let NEIGHBOR_EDGE  (FROM_INDEX, NEXT_NEIGHBOR) = THIS_EDGE
11770 end sub
11780 !
11790 sub PROMPT_AND_READ
11800 !  Issues prompt for user-request, reads in request,
11810 !  blank-fills buffer, and skips to next line of input.
11820 !
11830 print
11840 print " ---------------------------------------------"
11850 print " Enter two person-identifiers (name or number),"
11860 print " separated by semicolon. Enter ""stop"" to stop."
11870 line input REQUEST_BUFFER$
11880 end sub
11890 !
11900 sub CHECK_REQUEST (REQUEST_STATUS$, PERSON1_IDENT$, PERSON2_IDENT$)
11910 !   Performs syntactic check on request in buffer
11920 !   and fills in identifiers of the two requested persons.
11930 !
11940 let SEMICOLON_LOCATION = pos (REQUEST_BUFFER$, ";")
11950 let PERSON1_IDENT$ = ltrim$ (rtrim$   &
&         (REQUEST_BUFFER$ (1 : SEMICOLON_LOCATION - 1)))
11960 let PERSON2_IDENT$ = ltrim$ (rtrim$   &
&         (REQUEST_BUFFER$ (SEMICOLON_LOCATION + 1 : len (REQUEST_BUFFER$))))
11970 if SEMICOLON_LOCATION  = 0 or pos (PERSON2_IDENT$, ";") <> 0 then
11980    let REQUEST_STATUS$ = "must be exactly one semicolon."
11990 elseif PERSON1_IDENT$  = "" then
12000    let REQUEST_STATUS$ = "null field preceding semicolon."
12010 elseif PERSON2_IDENT$  = "" then
12020    let REQUEST_STATUS$ = "null field following semicolon."
12030 else
12040    let REQUEST_STATUS$ = REQUEST_OK$
12050 end if
12060 end sub
12070 !
```

```
12080 sub SEARCH_FOR_REQUESTED_PERSONS (PERSON1_IDENT$, PERSON2_IDENT$,  &
&                                       PERSON1_INDEX,  PERSON2_INDEX,   &
&                                       PERSON1_FOUND,  PERSON2_FOUND)
12090 !   SEARCH_FOR_REQUESTED_PERSONS scans through the PERSON array,
12100 !   looking for the two requested PERSONs.  Match may be by NAME
12110 !   or unique IDENTIFIER-number
12120 !
12130 let PERSON1_FOUND = 0
12140 let PERSON2_FOUND = 0
12150 let PERSON1_INDEX = 0
12160 let PERSON2_INDEX = 0
12170 for CURRENT = 1 to NUMBER_OF_PERSONS
12180    !  allow identification by name or identifier
12190    if IDENTIFIER$ (CURRENT) = PERSON1_IDENT$  &
&              or NAME$ (CURRENT) = PERSON1_IDENT$ then
12200       let PERSON1_INDEX = CURRENT
12210       let PERSON1_FOUND = PERSON1_FOUND + 1
12220    end if
12230    if IDENTIFIER$ (CURRENT) = PERSON2_IDENT$  &
&              or NAME$ (CURRENT) = PERSON2_IDENT$ then
12240       let PERSON2_INDEX = CURRENT
12250       let PERSON2_FOUND = PERSON2_FOUND + 1
12260    end if
12270 next CURRENT
12280 end sub
12290 end   ! of main program unit - external procedures follow
12300 !
```

```
12310 ! ---- program-unit number 2 ----
12320 !
12330 external sub FIND_RELATIONSHIP                                           &
&        (TARGET_INDEX, SOURCE_INDEX, NUMBER_OF_PERSONS,                      &
&         NAME$ (), IDENTIFIER$ (), GENDER$ (), RELATIVE_IDENTIFIER$ (,),     &
&         NEIGHBOR_COUNT (), NEIGHBOR_INDEX (,), NEIGHBOR_EDGE (,),           &
&         DISTANCE_FROM_SOURCE (), PATH_PREDECESSOR (),                       &
&         EDGE_TO_PREDECESSOR  (), REACHED_STATUS (),                         &
&         DESCENDANT_IDENTIFIER$ (), DESCENDANT_GENES ())
12340 !
12350 !      Finds shortest path (if any) between two PERSONs and
12360 !      determines their RELATIONSHIP based on immediate relations
12370 !      traversed in path.  PERSON array simulates a directed graph,
12380 !      and algorithm finds shortest path, based on following
12390 !      weights: PARENT-CHILD edge  = 1.0
12400 !               SPOUSE-SPOUSE edge = 1.8
12410 !
12420 !  declare subs and functions to be used by this program-unit
12430 !
12440 declare external sub COMPUTE_COMMON_GENES
12450 declare sub PROCESS_ADJACENT_NODE, LINK_NEXT_NODE_TO_BASE_NODE
12460 declare sub RESOLVE_PATH_TO_ENGLISH, CONDENSE_KEY_PERSONS
12465 declare sub DISPLAY_RELATION
12470 declare function SIBLING_PROXIMITY
12480 !
12483 option base 1
12487 !
12490 !  Define global objects
12500 !
12510 data 300
12520 read MAX_PERSONS
12530 !
12540 data  1, 2        ! for truth values
12550 read  TRUE, FALSE
12560 !
12570 !  each PERSON's record in the file identifies at most three
12580 !  others directly related: father, mother, and spouse
12590 data 1, 2, 3
12600 read FATHER_IDENT, MOTHER_IDENT, SPOUSE_IDENT
12610 !
12620 data M, F
12630 read MALE$, FEMALE$
12640 !
12650 data 000
12660 read NULL_IDENT$
12670 !
12680 data 1, 2, 3, 4, 5, 6, 7, 8
12690 read PARENT, CHILD, SPOUSE, SIBLING, UNCLE, NEPHEW
12695 read COUSIN, NULL_RELATION
12700 !
12710 !  A node in the graph (= PERSON) has either already been reached,
12720 !  is immediately adjacent to those reached, or farther away.
12730 data 1, 2, 3
12740 read REACHED, NEARBY, NOT_SEEN
12750 !
```

```
12760 data 1, 2, 3    !  values for search status
12770 read SEARCHING, SUCCEEDED, FAILED
12780 !
12790 data 1, 2, 3    !  values for sibling proximity
12800 read STEP, HALF, FULL
12810 !
12820 !    The following arrays contain information on key persons.
12830 !    Key persons are the ones in the RELATIONSHIP path which remain
12840 !    after the path is condensed.
12850 !
12860 dim  RELATION_TO_NEXT (300), PERSON_INDEX (300), GENERATION_GAP (300)
12870 dim  PROXIMITY (300), COUSIN_RANK (300)
12880 !
12890 !    keeps track of current NEARBY nodes in graph search
12900 dim  NEARBY_NODE (300)
12910 !
12920 !  begin main line of execution of FIND_RELATIONSHIP
12930 !
12940 !    initialize PERSON-array for processing -
12950 !    mark all nodes as not seen
12960 for THIS_NODE = 1 to NUMBER_OF_PERSONS
12970    let REACHED_STATUS (THIS_NODE) = NOT_SEEN
12980 next THIS_NODE
12990 !
13000 let THIS_NODE = SOURCE_INDEX
13010 !    mark source node as REACHED
13020 let REACHED_STATUS       (THIS_NODE) = REACHED
13030 let DISTANCE_FROM_SOURCE (THIS_NODE) = 0
13040 !    no nearby nodes exist yet
13050 let LAST_NEARBY_INDEX = 0
13060 if THIS_NODE = TARGET_INDEX then
13070    let SEARCH_STATUS = SUCCEEDED
13080 else
13090    let SEARCH_STATUS = SEARCHING
13100 end if
13110 !
```

```
13120 !    Loop keeps processing closest-to-source, unREACHED node
13130 !    until target REACHED, or no more connected nodes.
13140 do while SEARCH_STATUS = SEARCHING
13150    !    Process all nodes adjacent to THIS_NODE
13160    for THIS_NEIGHBOR = 1 to NEIGHBOR_COUNT (THIS_NODE)
13170       call PROCESS_ADJACENT_NODE (THIS_NODE,                      &
&                      NEIGHBOR_INDEX (THIS_NODE, THIS_NEIGHBOR),       &
&                      NEIGHBOR_EDGE  (THIS_NODE, THIS_NEIGHBOR))
13180    next THIS_NEIGHBOR
13190    !    All nodes adjacent to THIS_NODE are set.  Now search for
13200    !    shortest-distance unREACHED (but NEARBY) node to process next.
13210    if LAST_NEARBY_INDEX = 0 then
13220       let SEARCH_STATUS = FAILED
13230    else  !  determine next node to process
13240       let MINIMAL_DISTANCE = 1.0E+18
13250       !  now find closest unreached node
13260       for THIS_NEARBY_INDEX = 1 to LAST_NEARBY_INDEX
13270          let NEXT_NODE = NEARBY_NODE (THIS_NEARBY_INDEX)
13280          if DISTANCE_FROM_SOURCE (NEXT_NODE) < MINIMAL_DISTANCE then
13290             let BEST_NEARBY_INDEX = THIS_NEARBY_INDEX
13300             let MINIMAL_DISTANCE  = DISTANCE_FROM_SOURCE (NEXT_NODE)
13310          end if
13320       next THIS_NEARBY_INDEX
13330       !   establish new THIS_NODE
13340       let THIS_NODE = NEARBY_NODE (BEST_NEARBY_INDEX)
13350       !   change THIS_NODE from being NEARBY to REACHED
13360       let REACHED_STATUS (THIS_NODE) = REACHED
13370       !   remove THIS_NODE from NEARBY list
13380       let NEARBY_NODE (BEST_NEARBY_INDEX) =           &
&               NEARBY_NODE (LAST_NEARBY_INDEX)
13390       let LAST_NEARBY_INDEX = LAST_NEARBY_INDEX - 1
13400       if THIS_NODE = TARGET_INDEX then let SEARCH_STATUS = SUCCEEDED
13410    end if
13420 loop
13430 !
13440 !    Shortest path between PERSONs now established.  Next task is
13450 !    to translate path to English description of RELATIONSHIP.
13460 if SEARCH_STATUS = FAILED then
13470    print " "; NAME$ (TARGET_INDEX); " is not related to ";          &
&                NAME$ (SOURCE_INDEX)
13480 else
13490 !  success - parse path to find and display RELATIONSHIP
13500    call RESOLVE_PATH_TO_ENGLISH
13510    call COMPUTE_COMMON_GENES    (SOURCE_INDEX, TARGET_INDEX,          &
&         IDENTIFIER$, NEIGHBOR_COUNT, NEIGHBOR_INDEX, NEIGHBOR_EDGE,   &
&         DESCENDANT_IDENTIFIER$, DESCENDANT_GENES)
13520 end if
13530 exit sub
13540 !
13550 !  end of main line of execution of FIND_RELATIONSHIP
13560 !
```

```
13570 sub PROCESS_ADJACENT_NODE (BASE_NODE, NEXT_NODE, NEXT_BASE_EDGE)
13580 !    NEXT_NODE is adjacent to last-REACHED node (= BASE_NODE).
13590 !    if NEXT_NODE already REACHED, do nothing.
13600 !    If previously seen, check whether path thru BASE_NODE is
13610 !    shorter than current path to NEXT_NODE, and if so re-link
13620 !    next to base.
13630 !    If not previously seen, link next to base node.
13640 !
13650 if NEXT_BASE_EDGE = SPOUSE then
13660    let WEIGHT_THIS_EDGE = 1.8
13670 else
13680    let WEIGHT_THIS_EDGE = 1.0
13690 end if
13700 !
13710 if REACHED_STATUS (NEXT_NODE) <> REACHED then
13720    let DISTANCE_THRU_BASE_NODE                                    &
&           = WEIGHT_THIS_EDGE + DISTANCE_FROM_SOURCE (BASE_NODE)
13740    if REACHED_STATUS (NEXT_NODE) = NOT_SEEN then
13750       let REACHED_STATUS (NEXT_NODE) = NEARBY
13760       let LAST_NEARBY_INDEX = LAST_NEARBY_INDEX + 1
13770       let NEARBY_NODE (LAST_NEARBY_INDEX) = NEXT_NODE
13780       !    link next to base by re-setting its predecessor index to
13790       !    point to base, note type of edge, and re-set distance
13800       !    as it is through base node.
13810       let DISTANCE_FROM_SOURCE (NEXT_NODE) = DISTANCE_THRU_BASE_NODE
13820       let PATH_PREDECESSOR     (NEXT_NODE) = BASE_NODE
13830       let EDGE_TO_PREDECESSOR  (NEXT_NODE) = NEXT_BASE_EDGE
13840    else    !    REACHED_STATUS = NEARBY
13850       if DISTANCE_THRU_BASE_NODE < DISTANCE_FROM_SOURCE (NEXT_NODE) then
13860          !    link next to base by re-setting its predecessor index to
13870          !    point to base, note type of edge, and re-set distance
13880          !    as it is through base node.
13890          let DISTANCE_FROM_SOURCE (NEXT_NODE) = DISTANCE_THRU_BASE_NODE
13900          let PATH_PREDECESSOR     (NEXT_NODE) = BASE_NODE
13910          let EDGE_TO_PREDECESSOR  (NEXT_NODE) = NEXT_BASE_EDGE
13920       end if
13930    end if
13940 end if
13950 end sub
13960 !
```

```
13970 sub RESOLVE_PATH_TO_ENGLISH
13980 !    RESOLVE_PATH_TO_ENGLISH condenses the shortest path to a
13990 !    series of RELATIONSHIPs for which there are English
14000 !    descriptions.
14010 !
14020 !    Key persons are the ones in the RELATIONSHIP path which remain
14030 !    after the path is condensed.
14040 !
14050 print " Shortest path between identified persons: "
14060 let THIS_NODE = TARGET_INDEX
14070 !    print path and initialize KEY_PERSON array from path elements,
14080 !    as shortest path is traversed.
14090 let KEY_INDEX = 1
14100 do until THIS_NODE = SOURCE_INDEX
14110    let PERSON_INDEX     (KEY_INDEX) = THIS_NODE
14120    let PROXIMITY        (KEY_INDEX) = FULL
14130    let RELATION_TO_NEXT (KEY_INDEX) = EDGE_TO_PREDECESSOR (THIS_NODE)
14140    print "  "; NAME$ (THIS_NODE); tab(23); "is ";
14150    if EDGE_TO_PREDECESSOR (THIS_NODE) = SPOUSE then
14160       let GENERATION_GAP (KEY_INDEX) = 0
14170       print "spouse of"
14180    else
14190       let GENERATION_GAP (KEY_INDEX) = 1
14200       if EDGE_TO_PREDECESSOR (THIS_NODE) = PARENT then
14210          print "parent of"
14220       else  !   edge is child-type
14230          print "child of"
14240       end if
14250    end if
14260    let KEY_INDEX = KEY_INDEX + 1
14270    let THIS_NODE = PATH_PREDECESSOR (THIS_NODE)
14280 loop
14290 print "  "; NAME$ (THIS_NODE)
14300 let PERSON_INDEX     (KEY_INDEX)     = THIS_NODE
14310 let RELATION_TO_NEXT (KEY_INDEX)     = NULL_RELATION
14320 let RELATION_TO_NEXT (KEY_INDEX + 1) = NULL_RELATION
14330 !
```

```
14340 !    Resolve CHILD-PARENT and CHILD-SPOUSE-PARENT relations
14350 !    to SIBLING relations.
14360 let KEY_INDEX = 1
14370 do until RELATION_TO_NEXT (KEY_INDEX) = NULL_RELATION
14380    if RELATION_TO_NEXT (KEY_INDEX) = CHILD then
14390       let LATER_KEY_RELATION = RELATION_TO_NEXT (KEY_INDEX + 1)
14400       if LATER_KEY_RELATION = PARENT then
14410          !   found either full or half SIBLINGs
14420          let GENERATION_GAP    (KEY_INDEX) = 0
14430          let RELATION_TO_NEXT (KEY_INDEX) = SIBLING
14440          let PROXIMITY         (KEY_INDEX) =                    &
&                  SIBLING_PROXIMITY (PERSON_INDEX (KEY_INDEX),        &
&                                    PERSON_INDEX (KEY_INDEX + 2))
14450          call CONDENSE_KEY_PERSONS (KEY_INDEX, 1)
14460       else
14470          if LATER_KEY_RELATION = SPOUSE and                     &
&                RELATION_TO_NEXT (KEY_INDEX + 2) = PARENT then
14480             !   found step-siblings
14490             let GENERATION_GAP   (KEY_INDEX) = 0
14500             let RELATION_TO_NEXT (KEY_INDEX) = SIBLING
14510             let PROXIMITY        (KEY_INDEX) = STEP
14520             call CONDENSE_KEY_PERSONS (KEY_INDEX, 2)
14530          end if
14540       end if
14550    end if
14560    let KEY_INDEX = KEY_INDEX + 1
14570 loop
14580 !
14590 !    Resolve CHILD-CHILD-... and PARENT-PARENT-... relations to
14600 !    direct descendant or ancestor relations.
14610 let KEY_INDEX = 1
14620 do until RELATION_TO_NEXT (KEY_INDEX) = NULL_RELATION
14630    if RELATION_TO_NEXT (KEY_INDEX) = CHILD or              &
&         RELATION_TO_NEXT (KEY_INDEX) = PARENT then
14640       let LATER_KEY_INDEX = KEY_INDEX + 1
14650       do while RELATION_TO_NEXT (LATER_KEY_INDEX)          &
&               = RELATION_TO_NEXT       (KEY_INDEX)
14660          let LATER_KEY_INDEX = LATER_KEY_INDEX + 1
14670       loop
14680       let GENERATION_COUNT = LATER_KEY_INDEX - KEY_INDEX
14690       if GENERATION_COUNT > 1  then    !    compress generations
14700          let GENERATION_GAP (KEY_INDEX) = GENERATION_COUNT
14710          call CONDENSE_KEY_PERSONS (KEY_INDEX, GENERATION_COUNT - 1)
14720       end if
14730    end if
14740    let KEY_INDEX = KEY_INDEX + 1
14750 loop
14760 !
```

```
14770 !    Resolve CHILD-SIBLING-PARENT to COUSIN,
14780 !            CHILD-SIBLING        to NEPHEW,
14790 !            SIBLING-PARENT       to UNCLE.
14800 let KEY_INDEX = 1
14810 do until RELATION_TO_NEXT (KEY_INDEX) = NULL_RELATION
14820    let LATER_KEY_RELATION = RELATION_TO_NEXT (KEY_INDEX + 1)
14830    if RELATION_TO_NEXT (KEY_INDEX) = CHILD                      &
&                 and LATER_KEY_RELATION = SIBLING then
14840       !  found COUSIN or NEPHEW
14850       if RELATION_TO_NEXT (KEY_INDEX + 2) = PARENT then
14860          !  found cousin
14870          let GAP1 = GENERATION_GAP (KEY_INDEX)
14880          let GAP2 = GENERATION_GAP (KEY_INDEX + 2)
14890          let COUSIN_RANK      (KEY_INDEX) = min (GAP1,  GAP2)
14900          let GENERATION_GAP   (KEY_INDEX) = abs (GAP1 - GAP2)
14910          let PROXIMITY        (KEY_INDEX) = PROXIMITY (KEY_INDEX + 1)
14920          let RELATION_TO_NEXT (KEY_INDEX) = COUSIN
14930          call CONDENSE_KEY_PERSONS (KEY_INDEX, 2)
14940       else   !   found NEPHEW
14950          let PROXIMITY        (KEY_INDEX) = PROXIMITY (KEY_INDEX + 1)
14960          let RELATION_TO_NEXT (KEY_INDEX) = NEPHEW
14970          call CONDENSE_KEY_PERSONS (KEY_INDEX, 1)
14980       end if
14990    else
15000       if RELATION_TO_NEXT (KEY_INDEX) = SIBLING            &
&                    and LATER_KEY_RELATION = PARENT then
15010          !   found UNCLE
15020          let GENERATION_GAP   (KEY_INDEX) =                &
&                 GENERATION_GAP   (KEY_INDEX + 1)
15030          let RELATION_TO_NEXT (KEY_INDEX) = UNCLE
15040          call CONDENSE_KEY_PERSONS (KEY_INDEX, 1)
15050       end if
15060    end if
15070    let KEY_INDEX = KEY_INDEX + 1
15080 loop
15090 !
```

```
15100 !     Loop below will pick out valid adjacent strings of elements
15110 !     to be printed.  KEY_INDEX points to first element,
15120 !     LATER_KEY_INDEX to last element, and PRIMARY_INDEX to the
15130 !     element which determines the primary English word to be used.
15140 !     Associativity of adjacent elements in condensed table
15150 !     is based on English usage.
15160 print " Condensed path:"
15170 let KEY_INDEX = 1
15180 do until RELATION_TO_NEXT (KEY_INDEX) = NULL_RELATION
15190    let KEY_RELATION = RELATION_TO_NEXT (KEY_INDEX)
15200    let LATER_KEY_INDEX, PRIMARY_INDEX = KEY_INDEX
15210    if RELATION_TO_NEXT (KEY_INDEX + 1) <> NULL_RELATION then
15220       !   seek multi-element combination
15230       let ANOTHER_ELEMENT_POSSIBLE = TRUE
15240       if KEY_RELATION = SPOUSE then
15250          let LATER_KEY_INDEX = LATER_KEY_INDEX + 1
15260          let PRIMARY_INDEX   = LATER_KEY_INDEX
15270          if RELATION_TO_NEXT (LATER_KEY_INDEX) = SIBLING or        &
&                RELATION_TO_NEXT (LATER_KEY_INDEX) = COUSIN     then
15280             !   nothing can follow spouse-sibling or spouse-cousin
15290             let ANOTHER_ELEMENT_POSSIBLE = FALSE
15300          end if
15310       end if
15320       !    PRIMARY_INDEX is now correctly set.  Next if-statement
15330       !    determines if a following SPOUSE relation should be
15340       !    appended to this combination or left for the next
15350       !    combination.
15360       if RELATION_TO_NEXT (PRIMARY_INDEX + 1) = SPOUSE and          &
&            ANOTHER_ELEMENT_POSSIBLE = TRUE  then
15370          !   Only a SPOUSE can follow a Primary
15380          !   check primary preceding and following SPOUSE.
15390          let PRIMARY_RELATION      = RELATION_TO_NEXT (PRIMARY_INDEX)
15400          let NEXT_PRIMARY_RELATION = RELATION_TO_NEXT (PRIMARY_INDEX + 2)
15410          if (NEXT_PRIMARY_RELATION = NEPHEW   or            &
&               NEXT_PRIMARY_RELATION = COUSIN   or            &
&               NEXT_PRIMARY_RELATION = NULL_RELATION)         &
&             or (PRIMARY_RELATION = NEPHEW)                   &
&             or ( (PRIMARY_RELATION = SIBLING  or             &
&                   PRIMARY_RELATION = PARENT)                 &
&                and NEXT_PRIMARY_RELATION <> UNCLE )  then
15420             !   append following SPOUSE with this combination
15430             let LATER_KEY_INDEX = LATER_KEY_INDEX + 1
15440          end if
15450       end if
15460    end if    !   multi-element combination
15470    call DISPLAY_RELATION (KEY_INDEX, LATER_KEY_INDEX, PRIMARY_INDEX)
15480    let KEY_INDEX = LATER_KEY_INDEX + 1
15490 loop
15500 !
15510 print " "; NAME$ (PERSON_INDEX (KEY_INDEX))
15520 end sub
15530 !  end of RESOLVE_PATH_TO_ENGLISH
15540 !
```

```
15550 function SIBLING_PROXIMITY (INDEX1, INDEX2)
15560 !  Determines whether two PERSONs are full siblings, i.e.,
15570 !  have the same two parents.
15580 if RELATIVE_IDENTIFIER$ (INDEX1, FATHER_IDENT) <> NULL_IDENT$ and     &
&        RELATIVE_IDENTIFIER$ (INDEX1, MOTHER_IDENT) <> NULL_IDENT$ and     &
&        RELATIVE_IDENTIFIER$ (INDEX1, FATHER_IDENT) =                      &
&        RELATIVE_IDENTIFIER$ (INDEX2, FATHER_IDENT)                and     &
&        RELATIVE_IDENTIFIER$ (INDEX1, MOTHER_IDENT) =                      &
&        RELATIVE_IDENTIFIER$ (INDEX2, MOTHER_IDENT)                        then
15590    let SIBLING_PROXIMITY = FULL
15600 else
15610    let SIBLING_PROXIMITY = HALF
15620 end if
15630 end function   !  SIBLING_PROXIMITY
15640 !
15650 sub CONDENSE_KEY_PERSONS (AT_INDEX, GAP_SIZE)
15660 !   CONDENSE_KEY_PERSONS condenses superfluous entries from the
15670 !   key person array entries, starting at AT_INDEX
15680 let RECEIVE_INDEX = AT_INDEX
15690 do
15700    let RECEIVE_INDEX = RECEIVE_INDEX + 1
15710    let SEND_INDEX    = RECEIVE_INDEX + GAP_SIZE
15720    let RELATION_TO_NEXT (RECEIVE_INDEX) = RELATION_TO_NEXT (SEND_INDEX)
15730    let PERSON_INDEX     (RECEIVE_INDEX) = PERSON_INDEX     (SEND_INDEX)
15740    let GENERATION_GAP   (RECEIVE_INDEX) = GENERATION_GAP   (SEND_INDEX)
15750    let PROXIMITY        (RECEIVE_INDEX) = PROXIMITY        (SEND_INDEX)
15760    let COUSIN_RANK      (RECEIVE_INDEX) = COUSIN_RANK      (SEND_INDEX)
15770 loop until RELATION_TO_NEXT (SEND_INDEX) = NULL_RELATION
15780 end sub
15790 !
15800 sub DISPLAY_RELATION (FIRST_INDEX, LAST_INDEX, PRIMARY_INDEX)
15810 !   DISPLAY_RELATION takes 1, 2, or 3 adjacent elements in the
15820 !   condensed table and generates the English description of
15830 !   the relation between the first and last + 1 elements.
15840 !
15850 let FIRST_RELATION   = RELATION_TO_NEXT (FIRST_INDEX)
15860 let LAST_RELATION    = RELATION_TO_NEXT (LAST_INDEX)
15870 let PRIMARY_RELATION = RELATION_TO_NEXT (PRIMARY_INDEX)
15880 !
15890 !  set THIS_PROXIMITY
15900 if (PRIMARY_RELATION = PARENT and FIRST_RELATION = SPOUSE) or     &
&        (PRIMARY_RELATION = CHILD  and LAST_RELATION  = SPOUSE) then
15910    let THIS_PROXIMITY = STEP
15920 else
15930    if PRIMARY_RELATION = SIBLING or          &
&          PRIMARY_RELATION = UNCLE   or          &
&          PRIMARY_RELATION = NEPHEW  or          &
&          PRIMARY_RELATION = COUSIN     then
15940       let THIS_PROXIMITY = PROXIMITY (PRIMARY_INDEX)
15950    else
15960       let THIS_PROXIMITY = FULL
15970    end if
15980 end if
15990 !
```

```
16000 !  set THIS_GENERATION_GAP
16010 if PRIMARY_RELATION = PARENT or          &
&        PRIMARY_RELATION = CHILD  or          &
&        PRIMARY_RELATION = UNCLE  or          &
&        PRIMARY_RELATION = NEPHEW or          &
&        PRIMARY_RELATION = COUSIN    then
16020    let THIS_GENERATION_GAP = GENERATION_GAP (PRIMARY_INDEX)
16030 else
16040    let THIS_GENERATION_GAP = 0
16050 end if
16060 !
16070 !  set INLAW
16080 if (FIRST_RELATION = SPOUSE) and            &
&         (PRIMARY_RELATION = SIBLING or        &
&          PRIMARY_RELATION = CHILD   or        &
&          PRIMARY_RELATION = NEPHEW  or        &
&          PRIMARY_RELATION = COUSIN)    then
16090    let INLAW = TRUE
16100 else
16110    if (LAST_RELATION = SPOUSE) and                      &
&              (PRIMARY_RELATION = SIBLING or                &
&               PRIMARY_RELATION = PARENT  or                &
&               PRIMARY_RELATION = UNCLE   or                &
&               PRIMARY_RELATION = COUSIN)    then
16120       let INLAW = TRUE
16130    else
16140       let INLAW = FALSE
16150    end if
16160 end if
16170 !
16180 !  set THIS_COUSIN_RANK
16190 if PRIMARY_RELATION = COUSIN then
16200    let THIS_COUSIN_RANK = COUSIN_RANK (PRIMARY_INDEX)
16210 else
16220    let THIS_COUSIN_RANK = 0
16230 end if
16240 !
16250 !    parameters are set - now generate display.
16260 !
16270 print " "; NAME$ (PERSON_INDEX (FIRST_INDEX)); tab(23); "is ";
16280 if PRIMARY_RELATION = PARENT or               &
&        PRIMARY_RELATION = CHILD  or               &
&        PRIMARY_RELATION = UNCLE  or               &
&        PRIMARY_RELATION = NEPHEW then
16290    !  print generation-qualifier
16300    if THIS_GENERATION_GAP >= 3 then
16310       print "great";
16320       if THIS_GENERATION_GAP > 3 then
16330          print "*"; str$ (THIS_GENERATION_GAP - 2);
16340       end if
16350       print "-";
16360    end if
16370    if THIS_GENERATION_GAP >= 2 then print "grand-";
```

```
16380 elseif PRIMARY_RELATION = COUSIN and THIS_COUSIN_RANK > 1 then
16390    print str$ (THIS_COUSIN_RANK);
16400    select case mod (THIS_COUSIN_RANK, 10)
16410       case 1
16420          print "st ";
16430       case 2
16440          print "nd ";
16450       case 3
16460          print "rd ";
16470       case else
16480          print "th ";
16490    end select
16500 end if
16510 !
16520 if THIS_PROXIMITY = STEP then
16530    print "step-";
16540 elseif THIS_PROXIMITY = HALF then
16550    print "half-";
16560 end if
16570 !
16580 let THIS_GENDER$ = GENDER$ (PERSON_INDEX (FIRST_INDEX))
16590 select case PRIMARY_RELATION
16600   case 1    !    PARENT
16610     if THIS_GENDER$ = MALE$ then print "father";  else print "mother";
16620   case 2    !    CHILD
16630     if THIS_GENDER$ = MALE$ then print "son";     else print "daughter";
16640   case 3    !    SPOUSE
16650     if THIS_GENDER$ = MALE$ then print "husband"; else print "wife";
16660   case 4    !    SIBLING
16670     if THIS_GENDER$ = MALE$ then print "brother"; else print "sister";
16680   case 5    !    UNCLE
16690     if THIS_GENDER$ = MALE$ then print "uncle";   else print "aunt";
16700   case 6    !    NEPHEW
16710     if THIS_GENDER$ = MALE$ then print "nephew";  else print "niece";
16720   case 7    !    COUSIN
16730     print "cousin";
16740   case else
16750     print "null";
16760 end select
16770 !
16780 if INLAW = TRUE then print "-in-law";
16790 !
16800 if PRIMARY_RELATION = COUSIN and THIS_GENERATION_GAP > 0 then
16810    if THIS_GENERATION_GAP > 1 then
16820       print THIS_GENERATION_GAP; "times removed";
16830    else
16840       print " once removed";
16850    end if
16860 end if
16870 !
16880 print " of"
16890 !
16900 end sub  !  end of internal sub DISPLAY_RELATION
16910 end sub  !  end of external sub FIND_RELATIONSHIP
16920 !
```

```
16930 ! ---- program-unit number 3 ----
16940 !
16950 external sub COMPUTE_COMMON_GENES (INDEX1, INDEX2, IDENTIFIER$ (),     &
&          NEIGHBOR_COUNT (), NEIGHBOR_INDEX (,), NEIGHBOR_EDGE (,),        &
&          DESCENDANT_IDENTIFIER$ (), DESCENDANT_GENES ())
16960 !
16970 !     COMPUTE_COMMON_GENES assumes that each ancestor contributes
16980 !     half of the genetic material to a person.  It finds common
16990 !     ancestors between two persons and computes the expected
17000 !     value of the PROPORTION of common material.
17010 !
17020 declare sub ZERO_PROPORTION, MARK_PROPORTION, CHECK_COMMON_PROPORTION
17030 !
17035 option base 1
17040 !
17045 data 1, 2, 3, 4, 5, 6, 7, 8
17050 read PARENT, CHILD, SPOUSE, SIBLING, UNCLE, NEPHEW
17055 read COUSIN, NULL_RELATION
17057 !
17060 !    Begin main line of execution of COMPUTE_COMMON_GENES
17065 !
17070 !    First zero out all ancestors to allow adding.  This is necessary
17075 !    because there might be two paths to an ancestor.
17080 call ZERO_PROPORTION (INDEX1, 0)
17090 !    now mark with shared PROPORTION
17100 call MARK_PROPORTION (IDENTIFIER$ (INDEX1), 1.0, INDEX1, 0)
17110 let  COMMON_PROPORTION = 0.0
17120 call CHECK_COMMON_PROPORTION (COMMON_PROPORTION,                    &
&                                   IDENTIFIER$ (INDEX1), 1.0, 0.0, INDEX2, 0)
17130 print using " Proportion of common genetic material = #.#####^^^^":  &
&                    COMMON_PROPORTION
17140 !
17150 !    End main line of execution of COMPUTE_COMMON_GENES
17160 !
17170 sub ZERO_PROPORTION (ZERO_INDEX, THIS_NEIGHBOR)
17180     !  ZERO_PROPORTION recursively seeks out all ancestors and
17190     !  zeros them out
17200 let DESCENDANT_GENES (ZERO_INDEX) = 0.0
17210 for THIS_NEIGHBOR = 1 to NEIGHBOR_COUNT (ZERO_INDEX)
17220    if NEIGHBOR_EDGE (ZERO_INDEX, THIS_NEIGHBOR) = PARENT then
17230       call ZERO_PROPORTION                                         &
&                    (NEIGHBOR_INDEX (ZERO_INDEX, THIS_NEIGHBOR), 0)
17240    end if
17250 next THIS_NEIGHBOR
17260 end sub    !   ZERO_PROPORTION
17270 !
```

```
17280 sub MARK_PROPORTION (MARKER$, PROPORTION, MARKED_INDEX, THIS_NEIGHBOR)
17290     !  MARK_PROPORTION recursively seeks out all ancestors and
17300     !  marks them with the sender's PROPORTION of shared
17310     !  genetic material.  This PROPORTION is diluted by one-half
17320     !  for each generation
17330 let DESCENDANT_IDENTIFIER$ (MARKED_INDEX) = MARKER$
17340 let DESCENDANT_GENES       (MARKED_INDEX) =                        &
&       DESCENDANT_GENES       (MARKED_INDEX) + PROPORTION
17350 for THIS_NEIGHBOR = 1 to NEIGHBOR_COUNT (MARKED_INDEX)
17360    if NEIGHBOR_EDGE (MARKED_INDEX, THIS_NEIGHBOR) = PARENT then
17370       call MARK_PROPORTION (MARKER$, PROPORTION / 2.0,             &
&                NEIGHBOR_INDEX (MARKED_INDEX, THIS_NEIGHBOR), 0)
17380    end if
17390 next THIS_NEIGHBOR
17400 end sub    !   MARK_PROPORTION
17410 !
17420 sub CHECK_COMMON_PROPORTION (COMMON_PROPORTION, MATCH_IDENTIFIER$,   &
&       PROPORTION, ALREADY_COUNTED, CHECK_INDEX, THIS_NEIGHBOR)
17430     !  CHECK_COMMON_PROPORTION searches all the ancestors of
17440     !  CHECK_INDEX to see if any have been marked, and if so
17450     !  adds the appropriate amount to COMMON_PROPORTION
17460 if DESCENDANT_IDENTIFIER$ (CHECK_INDEX) = MATCH_IDENTIFIER$ then
17470    !  Increment COMMON_PROPORTION by the contribution of
17480    !  this common ancestor, but discount for the contribution
17490    !  of less remote ancestors already counted
17500    let THIS_CONTRIBUTION = DESCENDANT_GENES (CHECK_INDEX) * PROPORTION
17510    let COMMON_PROPORTION = COMMON_PROPORTION              &
&           + THIS_CONTRIBUTION - ALREADY_COUNTED
17520 else
17530    let THIS_CONTRIBUTION = 0.0
17540 end if
17550 for THIS_NEIGHBOR = 1 to NEIGHBOR_COUNT (CHECK_INDEX)
17560    if NEIGHBOR_EDGE (CHECK_INDEX, THIS_NEIGHBOR) = PARENT then
17570       call CHECK_COMMON_PROPORTION (COMMON_PROPORTION,          &
&                MATCH_IDENTIFIER$, PROPORTION / 2.0,               &
&                THIS_CONTRIBUTION / 4.0,                           &
&                NEIGHBOR_INDEX (CHECK_INDEX, THIS_NEIGHBOR), 0)
17610    end if
17620 next THIS_NEIGHBOR
17630 !
17640 end sub    !   end of internal sub CHECK_COMMON_PROPORTION
17650 end sub    !   end of external sub COMPUTE_COMMON_GENES
```

4.0 C

The identifiers NULL and FILE are capitalized, even though they are supplied by the standard run-time library, because identifiers in C are case-sensitive, e.g., "null" is not equivalent to "NULL".

```
/* Bring in standard routines for run-time support */

#include <stdio.h>

/* Global types and objects */

  typedef short int        BOOLEAN;
#define TRUE               1
#define FALSE              0
#define EQUALS             0

#define NULL_ID            "000"
#define NULL_CHR           '\0'

#define MAX_PERS           300
#define NAME_LEN           20
  /* every PERSON has a unique 3-digit IDENT */
#define ID_LEN             3
#define BUF_LEN            60

/* Use "+ 1" when treating type as variable-length - extra character
   used to hold NULL_CHR termination character. */
  typedef char  NAME_TYP  [NAME_LEN + 1];
  typedef char  BUF_TYPE  [BUF_LEN + 1];
  typedef char  MSG_TYPE  [40 + 1];
  typedef char  ID_TYPE   [ID_LEN + 1];

  typedef int   INDX_TYP, COUNTER;

  /* each PERSON's record in the file identifies at most thre
     others directly related: father, mother, and spouse */
  typedef short int     GIVEN_ID;
#define  FATHR_ID       0
#define  MOTHR_ID       1
#define  SPOUS_ID       2
#define  MAX_GVEN       3

  typedef ID_TYPE       REL_ARRY [MAX_GVEN];

#define REQ_OK          "Request OK"
#define REQ_STOP        "stop"

  typedef char          GNDR_TYP;
#define MALE            'M'
#define FEMALE          'F'
```

```
  typedef unsigned int  REL_TYPE;
  /* Values defined as octal powers of two to facilitate comparisons
     of one relation with several possibilities.  */
#define PARENT          0001
#define CHILD           0002
#define SPOUSE          0004
#define SIBLING         0010
#define UNCLE           0020
#define NEPHEW          0040
#define COUSIN          0100
#define NULL_REL        0200

  /* directed edges in the graph are of a given type */
  typedef REL_TYPE      EDG_TYPE;

  /* A node in the graph (= PERSON) has either already been reached,
     is immediately adjacent to those reached, or farther away. */
  typedef short int     REACH_TY;
#define REACHED         1
#define NEARBY          2
#define NOT_SEEN        3

  /* each PERSON has a linked list of adjacent nodes, called neighbors */
  typedef struct        NBR_NODE
    { INDX_TYP          NBR_DEX;
      EDG_TYPE          NBR_EDGE;
      struct NBR_NODE  *NEXT_NBR;
    }
    NBR_REC, *NBR_PTR;

  /* All relationships are captured in the directed graph of which
     each record is a node. */
  typedef struct
    {
    /* static information - filled from PEOPLE file: */
      NAME_TYP        NAME;
      ID_TYPE         IDENT;
      GNDR_TYP        GENDER;
      /* IDENTs of immediate relatives - father, mother, spouse */
      REL_ARRY        REL_ID;
      /* head of linked list of adjacent nodes */
      NBR_PTR         NBR_HDR;
    /* data used when traversing graph to resolve user request: */
      float           DIST_SRC;
      INDX_TYP        PATHPRED;
      EDG_TYPE        EDG_PRED;
      REACH_TY        REACH_ST;
    /* data used to compute common genetic material */
      ID_TYPE         DSC_ID;
      float           DSC_GENE;
    }
    PERS_REC;
```

```
  /* the PERSON array is the central repository of information
     about inter-relationships. */
  PERS_REC             PERSON [MAX_PERS];
  INDX_TYP             NUM_PERS;

  /* Key persons are the ones in the REL_SHIP path which remain
     after the path is condensed. */

  typedef short int    SIB_TYPE;
#define STEP           1
#define HALF           2
#define FULL           3

  typedef struct
    { REL_TYPE         REL_NEXT;
      INDX_TYP         PERS_DEX;
      COUNTER          GEN_GAP;
      SIB_TYPE         PROXIMTY;
      COUNTER          CUZ_RANK;
    }
    KEY_REC;

/*********** Main line of execution RELATE  ***********/

main ()

{ /* These variables are used when establishing the PERSON array
     from the PEOPLE file. */
  FILE                    *fopen(), *PEOPLE;
  register INDX_TYP       CURRENT, PREVIOUS;
  ID_TYPE                 PREV_ID, CUR_ID;
  GIVEN_ID                REL_SHIP;
  char                    INP_BUF [100];

  /* These variables are used to accept and resolve requests for
     REL_SHIP information. */
  COUNTER                 SEMI_LOC;
  BUF_TYPE                REQ_BUF;
  BUF_TYPE                P1_IDENT, P2_IDENT;
  COUNTER                 P1_FOUND, P2_FOUND;
  MSG_TYPE                ERR_MSG;
  INDX_TYP                P1_INDEX, P2_INDEX;
```

```
/* *** execution of main sequence begins here *** */

  PEOPLE = fopen("PEOPLE.DAT", "r");
  /* This loop reads in the PEOPLE file and constructs the PERSON
     array from it (one PERSON == one record == one array entry).
     As records are read in, links are constructed to represent the
     PARENT-CHILD or SPOUSE REL_SHIP.  The array then implements
     a directed graph which is used to satisfy subsequent user
     requests.  The file is assumed to be correct - no validation
     is performed on it. */
READ_PEO:
  for (CURRENT = 0; ; CURRENT++)
    {
    /* copy direct information from file to array */
    if (FXD_GETC (PERSON [CURRENT] . NAME, PEOPLE, NAME_LEN)
           == EOF)
  break;
    FXD_GETC (PERSON [CURRENT] . IDENT, PEOPLE, ID_LEN);
    FXD_GETC (&(PERSON [CURRENT] . GENDER),  PEOPLE, 1);
    for (REL_SHIP = FATHR_ID; REL_SHIP < MAX_GVEN; REL_SHIP++)
        FXD_GETC (PERSON [CURRENT] . REL_ID [REL_SHIP], PEOPLE, ID_LEN);
    /* flush remainder of record */
    fgets (INP_BUF, 100, PEOPLE);
    /* Location of adjacent persons as yet undetermined */
    PERSON [CURRENT] . NBR_HDR = NULL;
    /* Descendants as yet undetermined */
    strcpy (PERSON [CURRENT] . DSC_ID, NULL_ID);
    /* Compare this PERSON against all previously entered PERSONs
       to search for REL_SHIPs. */
    strcpy (CUR_ID, PERSON [CURRENT] . IDENT);
CMP_PREV:
    for (PREVIOUS = 0; PREVIOUS < CURRENT; PREVIOUS++)
      {
      strcpy (PREV_ID, PERSON [PREVIOUS] . IDENT);
      /* Search for father, mother, or spouse relationship in
         either direction between this and PREVIOUS PERSON.
         Assume at most one REL_SHIP exists. */
TRY_RELS:
      for (REL_SHIP = FATHR_ID; REL_SHIP < MAX_GVEN; REL_SHIP++)
        {
        if (STREQ (PREV_ID,PERSON [CURRENT] . REL_ID [REL_SHIP]))
          {
            LINK_REL (CURRENT, REL_SHIP, PREVIOUS);
      break;
          }
        else
           if (STREQ (CUR_ID, PERSON [PREVIOUS] . REL_ID [REL_SHIP]))
             {
              LINK_REL (PREVIOUS, REL_SHIP, CURRENT);
      break;
             }
        }  /* end TRY_RELS */
      }  /* end CMP_PREV */
    }  /* end READ_PEO */
  NUM_PERS = CURRENT;
  fclose (PEOPLE);
```

```
  /* PERSON array is now loaded and edges between immediate relatives
     (PARENT-CHILD or SPOUSE-SPOUSE) are established.

     While-loop accepts requests and finds REL_SHIP (if any)
     between pairs of PERSONs. */

PROC_REQ:
  while (TRUE)
    {
    PROMPT (REQ_BUF);
    if (STREQ (REQ_BUF, REQ_STOP))
  break;
    SEMI_LOC = CHK_RQST (REQ_BUF, ERR_MSG);

    /* Syntax check of request completed.  Now either display error
       message or search for the two PERSONs. */

    if (STREQ (ERR_MSG, REQ_OK))
      {  /* Request syntactically correct - search for requested PERSONs. */
       REQ_BUF [SEMI_LOC] = NULL_CHR;
       BUF_PERS (REQ_BUF, 0, P1_IDENT);
       BUF_PERS (REQ_BUF, SEMI_LOC + 1, P2_IDENT);
       SEEK_PER (P1_IDENT, P2_IDENT, & P1_INDEX, & P2_INDEX,
                                     & P1_FOUND, & P2_FOUND);
       if (P1_FOUND == 1 && P2_FOUND == 1)
          /* Exactly one match for each PERSON - proceed to
             determine REL_SHIP, if any. */
          if (P1_INDEX == P2_INDEX)
             printf (" %ls is identical to %8s \n",
                     PERSON [P1_INDEX] . NAME,
                     (PERSON [P1_INDEX] . GENDER == MALE) ?
                        "himself." : "herself.");
          else
             FIND_REL (P1_INDEX, P2_INDEX);
       else    /* either not found or more than one found */
          if (P1_FOUND == 0)
             printf (" First person not found.\n");
          else if (P1_FOUND > 1)
                  {
                   printf (" Duplicate names for first person -");
                   printf (" use numeric identifier.\n");
                  }
          if (P2_FOUND == 0)
             printf (" Second person not found.\n");
          else if (P2_FOUND > 1)
                  {
                   printf (" Duplicate names for second person -");
                   printf (" use numeric identifier.\n");
                  }
      }  /* end processing of syntactically legal request */
    else
       printf (" Incorrect request format: %ls \n", ERR_MSG);
    }  /* end PROC_REQ loop */
  printf (" End of relation-finder. \n");
}
/* End of main line of RELATE */
```

```
/* procedures under RELATE */

FXD_GETC (RECEIVER, SENDING, GET_LEN)

char          *RECEIVER;
FILE          *SENDING;
int            GET_LEN;

{ register int CHAR_CNT;

  for (CHAR_CNT = 0;
       CHAR_CNT++ < GET_LEN && (*RECEIVER++ = getc (SENDING)) != EOF ; ) ;
  if (CHAR_CNT >= GET_LEN)
    {
     *RECEIVER = NULL_CHR;
     return !EOF;
    }
  else
     return EOF;
}

STREQ (STRING1, STRING2)
/* compare for equality, ignore trailing spaces */

  register char *STRING1, *STRING2;

{ register char *LONGER;

  for ( ; *STRING1 == *STRING2; STRING1++, STRING2++)
      if (*STRING1 == NULL_CHR)
         return TRUE;
  if (*STRING1 == NULL_CHR)
     LONGER = STRING2;
  else
     if (*STRING2 == NULL_CHR)
        LONGER = STRING1;
     else
        return FALSE;
  for ( ; *LONGER++ == ' '; ) ;
  return (*--LONGER == NULL_CHR);
}
```

```
LINK_REL (FROM_DEX, REL_SHIP, TO_INDEX)
  /* establishes cross-indexing between immediately related PERSONs. */
  register INDX_TYP    FROM_DEX, TO_INDEX;
  register GIVEN_ID    REL_SHIP;

{ /* execution of LINK_REL */
  if (REL_SHIP == SPOUS_ID)
    {
     LINK_ONE (FROM_DEX, SPOUSE, TO_INDEX);
     LINK_ONE (TO_INDEX, SPOUSE, FROM_DEX);
    }
  else   /* REL_SHIP is father or mother */
    {
     LINK_ONE (FROM_DEX, PARENT, TO_INDEX);
     LINK_ONE (TO_INDEX, CHILD, FROM_DEX);
    }
}

LINK_ONE (FROM_DEX, THIS_EDG, TO_INDEX)
  /* Establishes the NBR_REC from one PERSON to another */

  INDX_TYP             FROM_DEX, TO_INDEX;
  EDG_TYPE             THIS_EDG;

{ register NBR_PTR   NEW_NBR;

  NEW_NBR = (NBR_REC * ) calloc(1, sizeof(NBR_REC));
  NEW_NBR -> NBR_DEX    = TO_INDEX;
  NEW_NBR -> NBR_EDGE   = THIS_EDG;
  NEW_NBR -> NEXT_NBR   = PERSON [FROM_DEX] . NBR_HDR;
  PERSON [FROM_DEX] . NBR_HDR = NEW_NBR;
}

PROMPT (REQ_BUF)
  /* Issues prompt for user-request, reads in request,
     blank-fills buffer, and skips to next line of input. */

  BUF_TYPE             REQ_BUF;

{
  printf (" \n");
  printf (" ----------------------------------------------\n");
  printf (" Enter two person-identifiers (name or number),\n");
  printf (" separated by semicolon. Enter \"stop\" to stop.\n");
  fgets  (REQ_BUF, BUF_LEN, stdin);
  for ( ; *REQ_BUF++ != '\n' ; ) ;
  *--REQ_BUF = '\0';
}
```

```
CHK_RQST (REQ_BUF, REQ_STAT)
  /* Performs syntactic check on request in buffer. */

  BUF_TYPE            REQ_BUF;
  MSG_TYPE            REQ_STAT;

{ COUNTER             SEMI_LOC   = 1,
                      SEMI_CNT   = 0;
  register COUNTER    BUF_DEX;

  BOOLEAN             P1_EXIST = FALSE,
                      P2_EXIST = FALSE;

  strcpy (REQ_STAT, REQ_OK);
  for (BUF_DEX = 0; BUF_DEX < BUF_LEN && REQ_BUF [BUF_DEX]; BUF_DEX++)
    {
    if (REQ_BUF [BUF_DEX] != ' ')
       if (REQ_BUF [BUF_DEX] == ';')
         {
          SEMI_LOC = BUF_DEX;
          SEMI_CNT    = SEMI_CNT + 1;
         }
       else   /* Check for non-blanks before/after semicolon. */
          if (SEMI_CNT < 1)
             P1_EXIST = TRUE;
          else
             P2_EXIST = TRUE;
    }

  /* set REQ_STAT, based on results of scan of REQ_BUF. */
  if (SEMI_CNT != 1)
     strcpy (REQ_STAT, "must be exactly one semicolon.");
  else if ( ! P1_EXIST)
     strcpy (REQ_STAT, "null field preceding semicolon.");
  else if ( ! P2_EXIST)
     strcpy (REQ_STAT, "null field following semicolon.");
  return SEMI_LOC;
}

BUF_PERS (REQ_BUF, BUF_DEX, PERS_ID)
  /* fills in the PERS_ID from the designated portion
     of the REQ_BUF, deleting leading blanks. */

  BUF_TYPE            REQ_BUF;
  register COUNTER    BUF_DEX;
  NAME_TYP            PERS_ID;

{
  for ( ; REQ_BUF [BUF_DEX++] == ' '; ) ;
  strcpy (PERS_ID, &REQ_BUF [--BUF_DEX] );
}
```

```
SEEK_PER  (P1_IDENT, P2_IDENT, P1_INDEX, P2_INDEX,
                              P1_FOUND, P2_FOUND)
  /* SEEK_PER scans through the PERSON array,
     looking for the two requested PERSONs.  Match may be by NAME
     or unique IDENT-number. */

  BUF_TYPE             P1_IDENT, P2_IDENT;
  INDX_TYP            *P1_INDEX, *P2_INDEX;
  COUNTER             *P1_FOUND, *P2_FOUND;

{ register INDX_TYP    CURRENT;

  *P1_INDEX = 0;
  *P2_INDEX = 0;
  *P1_FOUND = 0;
  *P2_FOUND = 0;
SCAN_PER:
  for (CURRENT = 0; CURRENT < NUM_PERS; CURRENT++)
    {
      /* allow identification by name or number. */
      if (STREQ (P1_IDENT, PERSON [CURRENT] . IDENT) ||
          STREQ (P1_IDENT, PERSON [CURRENT] . NAME))
        {
         (*P1_FOUND)++;
         *P1_INDEX = CURRENT;
        }
      if (STREQ (P2_IDENT, PERSON [CURRENT] . IDENT) ||
          STREQ (P2_IDENT, PERSON [CURRENT] . NAME))
        {
         (*P2_FOUND)++;
         *P2_INDEX = CURRENT;
        }
    }  /*  end SCAN_PER loop */
}    /* end of SEEK_PER */
```

```
FIND_REL (TARG_DEX, SRCE_DEX)
  /* Finds shortest path (if any) between two PERSONs and
     determines their REL_SHIP based on immediate relations
     traversed in path.  PERSON array simulates a directed graph,
     and algorithm finds shortest path, based on following
     weights: PARENT-CHILD edge  = 1.0
              SPOUSE-SPOUSE edge = 1.8 */

  INDX_TYP                   TARG_DEX, SRCE_DEX;

{ register INDX_TYP          PERS_DEX;
  INDX_TYP                   THIS_NOD, BEST_DEX, LST_NRBY,
                             NRBY_ND [MAX_PERS];
  register NBR_PTR           THIS_NBR;
  float                      MIN_DIST;

  typedef short int          SRCH_TYP;
#define SEARCHNG             1
#define SUCCESS              2
#define FAILED               3

  SRCH_TYP                   SRCH_ST;

/* begin execution of FIND_REL */

  /* initialize PERSON-array for processing -
     mark all nodes as not seen */
  for (PERS_DEX = 0; PERS_DEX < NUM_PERS; PERS_DEX++)
       PERSON [PERS_DEX] . REACH_ST = NOT_SEEN;
  THIS_NOD = SRCE_DEX;
  /* mark source node as REACHED */
  PERSON [THIS_NOD] . REACH_ST = REACHED;
  PERSON [THIS_NOD] . DIST_SRC = 0.0;
  /* no NEARBY nodes exist yet */
  LST_NRBY = -1;
  SRCH_ST  = (THIS_NOD == TARG_DEX) ? SUCCESS : SEARCHNG;
```

```
  /* Loop keeps processing closest-to-source, unREACHED node
     until target REACHED, or no more connected nodes. */
SEEKTARG:
  while (SRCH_ST == SEARCHNG)
    {  /* Process all nodes adjacent to THIS_NOD */
    for (THIS_NBR = PERSON [THIS_NOD] . NBR_HDR;
         THIS_NBR != NULL;
         THIS_NBR = THIS_NBR -> NEXT_NBR)
      PROC_ADJ (THIS_NOD, THIS_NBR -> NBR_DEX, THIS_NBR -> NBR_EDGE,
                NRBY_ND, &LST_NRBY);

    /* All nodes adjacent to THIS_NOD are set.  Now search for
       shortest-distance unREACHED (but NEARBY) node to process next. */
    if (LST_NRBY == -1)
       SRCH_ST = FAILED;
    else   /* determine next node to process */
       {
       MIN_DIST = 1.0E+18;
       for (PERS_DEX = 0; PERS_DEX <= LST_NRBY; PERS_DEX++)
         if (PERSON [NRBY_ND [PERS_DEX]] . DIST_SRC < MIN_DIST)
           {
            BEST_DEX  = PERS_DEX;
            MIN_DIST  = PERSON [NRBY_ND [PERS_DEX]] . DIST_SRC;
           }
       /* establish new THIS_NOD */
       THIS_NOD = NRBY_ND [BEST_DEX];
       /* change THIS_NOD from being NEARBY to REACHED */
       PERSON [THIS_NOD] . REACH_ST = REACHED;
       /* remove THIS_NOD from NEARBY list */
       NRBY_ND [BEST_DEX] = NRBY_ND [LST_NRBY--];
       if (THIS_NOD == TARG_DEX)
          SRCH_ST = SUCCESS;
       }
    }  /*  end SEEKTARG loop  */

  /* Shortest path between PERSONs now established.  Next task is
     to translate path to English description of REL_SHIP. */
  if (SRCH_ST == FAILED)
     printf (" %ls is not related to %ls\n",
              PERSON [TARG_DEX] . NAME, PERSON [SRCE_DEX] . NAME);
  else   /* success - parse path to find and display REL_SHIP */
    {
     RESOLVE  (SRCE_DEX, TARG_DEX);
     CMPT_GNS (SRCE_DEX, TARG_DEX);
    }
}  /* end FIND_REL */
```

```
/* procedures under FIND_REL */

PROC_ADJ (BASENODE, NXT_NODE, N_B_EDGE, NRBY_ND, LST_NRBY)
  /* NXT_NODE is adjacent to last-REACHED node (== BASENODE).
     If NXT_NODE already REACHED, do nothing.
     If previously seen, check whether path thru BASENODE is
     shorter than current path to NXT_NODE, and if so re-link
     next to base.
     If not previously seen, link next to base node. */

  register INDX_TYP      NXT_NODE;
  INDX_TYP               BASENODE, NRBY_ND[], *LST_NRBY;
  EDG_TYPE               N_B_EDGE;

{ float                  WGHT_EDG, DIST_BAS;

  /* begin execution of PROC_ADJ */
  if (PERSON [NXT_NODE] . REACH_ST != REACHED)
    {
     WGHT_EDG = (N_B_EDGE == SPOUSE) ? 1.8 : 1.0;
     DIST_BAS = WGHT_EDG + PERSON [BASENODE] . DIST_SRC;
     if (PERSON [NXT_NODE] . REACH_ST == NOT_SEEN)
       {
        PERSON [NXT_NODE] . REACH_ST = NEARBY;
        NRBY_ND [++ *LST_NRBY] = NXT_NODE;
        /* link next to base by re-setting its predecessor index to
           point to base, note type of edge, and re-set distance
           as it is through base node. */
        PERSON [NXT_NODE] . DIST_SRC = DIST_BAS;
        PERSON [NXT_NODE] . PATHPRED = BASENODE;
        PERSON [NXT_NODE] . EDG_PRED = N_B_EDGE;
       }
     else   /* REACH_ST = NEARBY */
        if (DIST_BAS < PERSON [NXT_NODE] . DIST_SRC)
          {  /* link next to base by re-setting its predecessor index to
                point to base, note type of edge, and re-set distance
                as it is through base node. */
           PERSON [NXT_NODE] . DIST_SRC = DIST_BAS;
           PERSON [NXT_NODE] . PATHPRED = BASENODE;
           PERSON [NXT_NODE] . EDG_PRED = N_B_EDGE;
          }
    }
}  /* end PROC_ADJ */
```

```
RESOLVE (SRCE_DEX, TARG_DEX)
  /* RESOLVE condenses the shortest path to a
     series of REL_SHIPs for which there are English
     descriptions. */

  INDX_TYP              SRCE_DEX, TARG_DEX;

{ /* these variables are used to generate KEY_PERSs */
  COUNTER               GEN_CNT;

  /* these variables are used to condense the path */
  KEY_REC               KEY_PERS [MAX_PERS];
  REL_TYPE              KEY_REL, LKEY_REL, PRIM_REL, NXT_PRIM;
  register INDX_TYP     KEY_DEX;
  INDX_TYP              LKEY_DEX, PRIM_DEX, THIS_NOD;
  BOOLEAN               SEEKMORE;


  /* begin execution of RESOLVE */
  printf (" Shortest path between identified persons: \n");
  /* Display path and initialize KEY_PERS array from path elements. */
TRAVERSE:
  for (THIS_NOD  = TARG_DEX, KEY_DEX = 0; THIS_NOD != SRCE_DEX;
       THIS_NOD  = PERSON [THIS_NOD] . PATHPRED, KEY_DEX++)
    {
     printf (" %1s is ",  PERSON [THIS_NOD] . NAME);
     KEY_PERS [KEY_DEX] . PERS_DEX = THIS_NOD;
     KEY_PERS [KEY_DEX] . PROXIMTY = FULL;
     KEY_PERS [KEY_DEX] . REL_NEXT = PERSON [THIS_NOD] . EDG_PRED;
     switch (PERSON [THIS_NOD] . EDG_PRED)
       {
        case PARENT: printf ("parent of\n");
                     KEY_PERS [KEY_DEX] . GEN_GAP = 1;
                     break;
        case CHILD : printf ("child of\n");
                     KEY_PERS [KEY_DEX] . GEN_GAP = 1;
                     break;
        case SPOUSE: printf ("spouse of\n");
                     KEY_PERS [KEY_DEX] . GEN_GAP = 0;
                     break;
       }  /* end switch */
    }  /* end TRAVERSE loop */
  printf (" %1s\n", PERSON [THIS_NOD] . NAME);
  KEY_PERS [KEY_DEX]      . PERS_DEX = THIS_NOD;
  KEY_PERS [KEY_DEX]      . REL_NEXT = NULL_REL;
  KEY_PERS [KEY_DEX + 1]  . REL_NEXT = NULL_REL;
```

```
  /* Resolve CHILD-PARENT and CHILD-SPOUSE-PARENT relations
     to SIBLING relations. */
FIND_SIB:
  for (KEY_DEX = 0; KEY_PERS [KEY_DEX] . REL_NEXT != NULL_REL; KEY_DEX++)
    {
     if (KEY_PERS [KEY_DEX] . REL_NEXT == CHILD)
       {
        LKEY_REL = KEY_PERS [KEY_DEX + 1] . REL_NEXT;
        if (LKEY_REL == PARENT)
          {   /* found either full or half SIBLINGs */
           BOOLEAN   FULL_SIB();

           KEY_PERS [KEY_DEX] . PROXIMTY =
              FULL_SIB (KEY_PERS [KEY_DEX]      . PERS_DEX,
                        KEY_PERS [KEY_DEX + 2] . PERS_DEX)
              ? FULL : HALF;
           KEY_PERS [KEY_DEX] . GEN_GAP  = 0;
           KEY_PERS [KEY_DEX] . REL_NEXT = SIBLING;
           CONDENSE (KEY_DEX, 1, KEY_PERS);
          }
        else
          if (LKEY_REL == SPOUSE
              && KEY_PERS [KEY_DEX + 2] . REL_NEXT == PARENT)
            {  /* found step-SIBLINGs */
             KEY_PERS [KEY_DEX] . GEN_GAP  = 0;
             KEY_PERS [KEY_DEX] . PROXIMTY = STEP;
             KEY_PERS [KEY_DEX] . REL_NEXT = SIBLING;
             CONDENSE (KEY_DEX, 2, KEY_PERS);
            }
       }  /* end if REL_NEXT == CHILD */
    }  /*  end FIND_SIB loop */

  /* Resolve CHILD-CHILD-... and PARENT-PARENT-... relations to
     direct descendant or ancestor relations. */
FIND_ANC:
  for (KEY_DEX = 0; KEY_PERS [KEY_DEX] . REL_NEXT != NULL_REL; KEY_DEX++)
    {
     if (KEY_PERS [KEY_DEX] . REL_NEXT == CHILD ||
         KEY_PERS [KEY_DEX] . REL_NEXT == PARENT)
       {
        for (LKEY_DEX = KEY_DEX + 1;
             KEY_PERS [LKEY_DEX] . REL_NEXT == KEY_PERS [KEY_DEX] . REL_NEXT;
             LKEY_DEX++) ;
        GEN_CNT = LKEY_DEX - KEY_DEX;
        if (GEN_CNT > 1)   /* compress generations */
          {
           KEY_PERS [KEY_DEX] . GEN_GAP = GEN_CNT;
           CONDENSE (KEY_DEX, GEN_CNT - 1, KEY_PERS);
          }
       }  /*  end if REL_NEXT == CHILD or PARENT */
    }  /*  end FIND_ANC loop */
```

```
/* Resolve CHILD-SIBLING-PARENT to COUSIN,
           CHILD-SIBLING        to NEPHEW,
           SIBLING-PARENT       to UNCLE. */
FIND_CUZ:
  for (KEY_DEX = 0; KEY_PERS [KEY_DEX] . REL_NEXT != NULL_REL; KEY_DEX++)
    {
     LKEY_REL = KEY_PERS [KEY_DEX + 1] . REL_NEXT;
     if (KEY_PERS [KEY_DEX] . REL_NEXT == CHILD && LKEY_REL == SIBLING)
       {  /* COUSIN or NEPHEW */
        if (KEY_PERS [KEY_DEX + 2] . REL_NEXT == PARENT)
          {  /* found COUSIN */
           COUNTER     GAP1, GAP2;

           GAP1 = KEY_PERS [KEY_DEX]     . GEN_GAP;
           GAP2 = KEY_PERS [KEY_DEX + 2] . GEN_GAP;
           KEY_PERS [KEY_DEX] . PROXIMTY = KEY_PERS [KEY_DEX + 1] . PROXIMTY;
           KEY_PERS [KEY_DEX] . GEN_GAP
                = (GAP1 < GAP2) ? (GAP2 - GAP1) : (GAP1 - GAP2);
           KEY_PERS [KEY_DEX] . CUZ_RANK = (GAP1 < GAP2) ? GAP1 : GAP2;
           KEY_PERS [KEY_DEX] . REL_NEXT = COUSIN;
           CONDENSE (KEY_DEX, 2, KEY_PERS);
          }
        else  /* found NEPHEW */
          {
           KEY_PERS [KEY_DEX] . PROXIMTY = KEY_PERS [KEY_DEX + 1] . PROXIMTY;
           KEY_PERS [KEY_DEX] . REL_NEXT = NEPHEW;
           CONDENSE (KEY_DEX, 1, KEY_PERS);
          }
       }  /*  end COUSIN or NEPHEW */
     else
       if (KEY_PERS [KEY_DEX] . REL_NEXT == SIBLING && LKEY_REL == PARENT)
         {   /* found UNCLE */
          KEY_PERS [KEY_DEX] . GEN_GAP = KEY_PERS [KEY_DEX + 1] . GEN_GAP;
          KEY_PERS [KEY_DEX] . REL_NEXT = UNCLE;
          CONDENSE (KEY_DEX, 1, KEY_PERS);
         }
    }  /*  end FIND_CUZ loop */
```

```
  /* Loop below will pick out valid adjacent strings of elements
     to be displayed.  KEY_DEX points to first element,
     LKEY_DEX to last element, and PRIM_DEX to the
     element which determines the primary English word to be used.
     Associativity of adjacent elements in condensed table
     is based on English usage. */

  printf (" Condensed path:\n");
CONSLIDT:
  for (KEY_DEX = 0; KEY_PERS [KEY_DEX] . REL_NEXT != NULL_REL;
       KEY_DEX = LKEY_DEX + 1)
    {
     KEY_REL  = KEY_PERS [KEY_DEX] . REL_NEXT;
     LKEY_DEX = KEY_DEX;
     PRIM_DEX = KEY_DEX;
     if (KEY_PERS [KEY_DEX + 1] . REL_NEXT != NULL_REL)
       {  /* seek multi-element combination */
        SEEKMORE = TRUE;
        if (KEY_REL == SPOUSE)
          {
           PRIM_DEX = ++LKEY_DEX;
           /* Nothing can follow SPOUSE-SIBLING or SPOUSE-COUSIN */
           SEEKMORE = ! (KEY_PERS [LKEY_DEX] . REL_NEXT & (SIBLING | COUSIN));
          }
        /* PRIM_DEX is now correctly set.  Next if-statement
           determines if a following SPOUSE relation should be
           appended to this combination or left for the next
           combination. */
        if (SEEKMORE && KEY_PERS [PRIM_DEX + 1] . REL_NEXT == SPOUSE)
          {  /* Only a SPOUSE can follow a Primary;
                check primary preceding and following SPOUSE. */
           PRIM_REL = KEY_PERS [PRIM_DEX]     . REL_NEXT;
           NXT_PRIM = KEY_PERS [PRIM_DEX + 2] . REL_NEXT;
           if ((NXT_PRIM & (NEPHEW | COUSIN | NULL_REL))
              || (PRIM_REL == NEPHEW)
              || ((PRIM_REL & (SIBLING | PARENT)) && NXT_PRIM != UNCLE ))
              /* append following SPOUSE with this combination. */
              LKEY_DEX++;
          }
       }  /* end multi-element combination */
     SHOW_REL (KEY_DEX, LKEY_DEX, PRIM_DEX, KEY_PERS);
    }  /* end CONSLIDT loop */
  printf (" %1s\n", PERSON [KEY_PERS [KEY_DEX] . PERS_DEX] . NAME);
}  /* end of RESOLVE */
```

```
BOOLEAN  FULL_SIB (INDEX1, INDEX2)
  /* Determines whether two PERSONs are full siblings, i.e.,
     have the same two parents. */
  register INDX_TYP   INDEX1, INDEX2;

{
  return
    ! STREQ (PERSON [INDEX1] . REL_ID [FATHR_ID], NULL_ID) &&
    ! STREQ (PERSON [INDEX1] . REL_ID [MOTHR_ID], NULL_ID) &&
    STREQ (PERSON [INDEX1] . REL_ID [FATHR_ID],
           PERSON [INDEX2] . REL_ID [FATHR_ID])            &&
    STREQ (PERSON [INDEX1] . REL_ID [MOTHR_ID],
           PERSON [INDEX2] . REL_ID [MOTHR_ID]);
}

CONDENSE (AT_INDEX, GAP_SIZE, KEY_PERS)
  /* CONDENSE condenses superfluous entries from the
     KEY_PERS array, starting at AT_INDEX. */

  register INDX_TYP      AT_INDEX;
  COUNTER                GAP_SIZE;
  KEY_REC                KEY_PERS [];

{ register INDX_TYP      SEND_DEX;

  do
    {
     AT_INDEX++;
     SEND_DEX = AT_INDEX + GAP_SIZE;
     KEY_PERS [AT_INDEX] = KEY_PERS [SEND_DEX];
    }
  while (KEY_PERS [SEND_DEX] . REL_NEXT != NULL_REL);
}
```

```
/* procedures under RESOLVE  */

SHOW_REL (FRST_DEX, LAST_DEX, PRIM_DEX, KEY_PERS)
  /* SHOW_REL takes 1, 2, or 3 adjacent elements in the
     condensed table and generates the English description of
     the relation between the first and last + 1 elements. */

  INDX_TYP              FRST_DEX, LAST_DEX, PRIM_DEX;
  KEY_REC               KEY_PERS [];

{ BOOLEAN               INLAW;
  SIB_TYPE              THIS_PRX;
  GNDR_TYP              THIS_GND;
  short int             SUFFIX;
  register REL_TYPE     FRST_REL, LAST_REL, PRIM_REL;
  COUNTER               THIS_GAP, THIS_CUZ;

  FRST_REL = KEY_PERS [FRST_DEX] . REL_NEXT;
  LAST_REL = KEY_PERS [LAST_DEX] . REL_NEXT;
  PRIM_REL = KEY_PERS [PRIM_DEX] . REL_NEXT;

  /* set THIS_PRX */
  if ((PRIM_REL == PARENT && FRST_REL == SPOUSE) ||
      (PRIM_REL == CHILD  && LAST_REL  == SPOUSE))
     THIS_PRX = STEP;
  else
    if (PRIM_REL & (SIBLING | UNCLE | NEPHEW | COUSIN))
       THIS_PRX = KEY_PERS [PRIM_DEX] . PROXIMTY;
    else
       THIS_PRX = FULL;

  /* set THIS_GAP */
  if (PRIM_REL & (PARENT | CHILD | UNCLE | NEPHEW | COUSIN))
     THIS_GAP = KEY_PERS [PRIM_DEX] . GEN_GAP;
  else
     THIS_GAP = 0;

  /* set INLAW */
  INLAW = FALSE;
  if (FRST_REL == SPOUSE && (PRIM_REL & (SIBLING | CHILD | NEPHEW | COUSIN)))
     INLAW = TRUE;
  else
     if (LAST_REL == SPOUSE &&
         (PRIM_REL & (SIBLING | PARENT | UNCLE | COUSIN)))
        INLAW = TRUE;

  /* set THIS_CUZ */
  if (PRIM_REL == COUSIN)
     THIS_CUZ = KEY_PERS [PRIM_DEX] . CUZ_RANK;
  else
     THIS_CUZ = 0;
```

```
/* parameters are set - now generate display. */

printf (" %ls is ", PERSON [KEY_PERS [FRST_DEX] . PERS_DEX] . NAME);
if (PRIM_REL & (PARENT | CHILD | UNCLE | NEPHEW))
  {  /* display generation-qualifier */
   if (THIS_GAP >= 3)
     {
      printf ("great");
      if (THIS_GAP > 3)
         printf ("*%ld", THIS_GAP - 2);
      printf ("-");
     }
   if (THIS_GAP >= 2)
      printf ("grand-");
  }
else
   if (PRIM_REL == COUSIN && THIS_CUZ > 1)
     {
      printf ("%ld", THIS_CUZ);
      SUFFIX = THIS_CUZ % 10;
      switch (SUFFIX)
        {
         case 1:  printf ("st ");  break;
         case 2:  printf ("nd ");  break;
         case 3:  printf ("rd ");  break;
         default: printf ("th ");  break;
        }
     }

if (THIS_PRX == STEP)
   printf ("step-");
else
   if (THIS_PRX == HALF)
      printf ("half-");
```

```
  THIS_GND = PERSON [KEY_PERS [FRST_DEX] . PERS_DEX] . GENDER;
  switch (PRIM_REL)
    {
     case PARENT : if (THIS_GND == MALE) printf ("father");
                   else                  printf ("mother");
                   break;
     case CHILD  : if (THIS_GND == MALE) printf ("son");
                   else                  printf ("daughter");
                   break;
     case SPOUSE : if (THIS_GND == MALE) printf ("husband");
                   else                  printf ("wife");
                   break;
     case SIBLING: if (THIS_GND == MALE) printf ("brother");
                   else                  printf ("sister");
                   break;
     case UNCLE  : if (THIS_GND == MALE) printf ("uncle");
                   else                  printf ("aunt");
                   break;
     case NEPHEW : if (THIS_GND == MALE) printf ("nephew");
                   else                  printf ("niece");
                   break;
     case COUSIN : printf ("cousin");
                   break;
     default     : printf ("null");
                   break;
    }

  if (INLAW)
     printf ("-in-law");

  if (PRIM_REL == COUSIN && THIS_GAP > 0)
     if (THIS_GAP > 1)
        printf (" %ld times removed", THIS_GAP);
     else
        printf (" once removed");

  printf (" of\n");
}  /* end of SHOW_REL */
```

```
/* procedures under FIND_REL */

CMPT_GNS (INDEX1, INDEX2)
  /* CMPT_GNS assumes that each ancestor contributes
     half of the genetic material to a PERSON.  It finds common
     ancestors between two PERSONs and computes the expected
     value of the PROPORTN of common material. */

  register INDX_TYP   INDEX1, INDEX2;

{ float               COM_PROP;

  /* First zero out all ancestors to allow adding.  This is necessary
     because there might be two paths to an ancestor. */
  ZERO_PRO (INDEX1);
  /* now mark with shared PROPORTN */
  MARK_PRO (PERSON [INDEX1] . IDENT, 1.0, INDEX1);
  COM_PROP = 0.0;
  CHK_COM ( & COM_PROP, PERSON [INDEX1] . IDENT, 1.0, 0.0, INDEX2);
  printf (" Proportion of common genetic material = %1.5e \n",
          COM_PROP);
}  /* end of CMPT_GNS */

ZERO_PRO (ZERO_DEX)
  /* ZERO_PRO recursively seeks out all ancestors and
     zeros them out. */

  register INDX_TYP    ZERO_DEX;

{ register NBR_PTR     THIS_NBR;

  PERSON [ZERO_DEX] . DSC_GENE = 0.0;
  for (THIS_NBR = PERSON [ZERO_DEX] . NBR_HDR;
       THIS_NBR != NULL;
       THIS_NBR = THIS_NBR -> NEXT_NBR)
     {
      if (THIS_NBR -> NBR_EDGE == PARENT)
         ZERO_PRO (THIS_NBR -> NBR_DEX);
     }
}  /* end of ZERO_PRO */
```

```
MARK_PRO (MARKER, PROPORTN, MARK_DEX)
  /* MARK_PRO recursively seeks out all ancestors and
     marks them with the sender's PROPORTN of shared
     genetic material.  This PROPORTN is diluted by one-half
     for each generation. */

  ID_TYPE              MARKER;
  float                PROPORTN;
  INDX_TYP             MARK_DEX;

{ register NBR_PTR     THIS_NBR;

  strcpy (PERSON [MARK_DEX] . DSC_ID, MARKER);
  PERSON [MARK_DEX] . DSC_GENE += PROPORTN;
  for (THIS_NBR = PERSON [MARK_DEX] . NBR_HDR;
       THIS_NBR != NULL;
       THIS_NBR = THIS_NBR -> NEXT_NBR)
     {
      if (THIS_NBR -> NBR_EDGE == PARENT)
         MARK_PRO (MARKER, PROPORTN / 2.0, THIS_NBR -> NBR_DEX);
     }
}  /* end of MARK_PRO */

CHK_COM (COM_PTR, MATCH_ID, PROPORTN, COUNTED, CHK_DEX)
  /* CHK_COM searches all the ancestors of
     CHK_DEX to see if any have been marked, and if so
     adds the appropriate amount to *COM_PTR. */

  float                *COM_PTR, PROPORTN, COUNTED;
  ID_TYPE              MATCH_ID;
  INDX_TYP             CHK_DEX;

{ register NBR_PTR     THIS_NBR;
  register float       CONTRIB;

  if (STREQ (PERSON [CHK_DEX] . DSC_ID, MATCH_ID))
     {  /* Increment *COM_PTR by the contribution of
           this common ancestor, but discount for the contribution
           of less remote ancestors already counted. */
      CONTRIB = PERSON [CHK_DEX] . DSC_GENE * PROPORTN;
      *COM_PTR += CONTRIB - COUNTED;
     }
  else
     CONTRIB = 0.0;
  for (THIS_NBR = PERSON [CHK_DEX] . NBR_HDR;
       THIS_NBR != NULL;
       THIS_NBR = THIS_NBR -> NEXT_NBR)
     {
      if (THIS_NBR -> NBR_EDGE == PARENT)
         CHK_COM (COM_PTR, MATCH_ID, PROPORTN / 2.0,
                  CONTRIB / 4.0, THIS_NBR -> NBR_DEX);
     }
}  /* end of CHK_COM */
```

5.0 COBOL

In keeping with the general convention of the examples, language-supplied keywords and identifiers are written in lower case in the program. To conform strictly to the COBOL-74 standard, however, programs must use only upper-case letters.

```
* ---- Compilation unit number 1 ----

 identification division.
 program-id. RELATE.

 environment division.

 configuration section.
 source-computer. VAX-11.
 object-computer. VAX-11.

 input-output section.
 file-control.
     select PEOPLE assign to "PEOPLE.DAT",
                   file status is PEOPLE-STATUS.

 data division.

 file section.
 fd  PEOPLE
     label records are standard.
 01  PEOPLE-RECORD.
     05  NAME                 pic X(20).
     05  IDENTIFIER           pic 999.
***     "M" for MALE and "F" for FEMALE
     05  GENDER               pic X.
     05  IMMEDIATE-RELATIONS.
         10  RELATIVE-IDENTIFIER  occurs 3 times pic 999.

 working-storage section.

 77  ARG-PERSON1-INDEX            pic 999.
 77  ARG-PERSON2-INDEX            pic 999.

 01  PEOPLE-STATUS.
     05  STATUS-1                 pic X.
         88 END-OF-PEOPLE-FILE            value "1".
     05  STATUS-2                 pic X.

*  Define global objects

 01  TRUTH-VALUES.
     05  IS-TRUE            pic X   value "T".
     05  IS-FALSE           pic X   value "F".

 01  SPECIAL-IDENT-VALUE.
     05  NULL-IDENT         pic 999 value 000.
```

```
*  each PERSON's record in the file identifies at most three
*  others directly related: father, mother, and spouse
 01  GIVEN-IDENTIFIERS.
     05  FATHER-IDENT      pic 9   value 1.
     05  MOTHER-IDENT      pic 9   value 2.
     05  SPOUSE-IDENT      pic 9   value 3.

 01  GENDER-TYPE.
     05  MALE              pic X   value "M".
     05  FEMALE            pic X   value "F".

 01  RELATION-TYPE.
     05  PARENT            pic 9   value 1.
     05  CHILD             pic 9   value 2.
     05  SPOUSE            pic 9   value 3.
     05  SIBLING           pic 9   value 4.
     05  UNCLE             pic 9   value 5.
     05  NEPHEW            pic 9   value 6.
     05  COUSIN            pic 9   value 7.
     05  NULL-RELATION     pic 9   value 8.

*  A node in the graph (= PERSON) has either already been reached,
*  is immediately adjacent to those reached, or farther away.
 01  REACHED-TYPE.
     05  REACHED           pic 9   value 1.
     05  NEARBY            pic 9   value 2.
     05  NOT-SEEN          pic 9   value 3.
```

```
*  the PERSON array is the central repository of information
*  about inter-relationships.
*  All relationships are captured in the directed graph of which
*  each record is a node.
 01  PERSON-TABLE.
     05  NUMBER-OF-PERSONS        usage index.
     05  PERSON occurs 300 times
               indexed by CURRENT, PREVIOUS,
                          FROM-INDEX, TO-INDEX,
                          PERSON1-INDEX, PERSON2-INDEX.
***  static information - filled from PEOPLE file:
        10  NAME                  pic X(20).
        10  IDENTIFIER            pic 999.
        10  GENDER                pic X.
***    IDENTIFIERs of immediate relatives - father, mother, spouse
        10  IMMEDIATE-RELATIONS.
            15  RELATIVE-IDENTIFIER  occurs 3 times indexed by RELATIONSHIP
                                  pic 999.
***  pointers to immediate neighbors in graph
        10  NEIGHBOR-COUNT        pic 99.
        10  NEIGHBOR-RECORD occurs 20 times indexed by NEXT-NEIGHBOR.
            15  NEIGHBOR-INDEX    usage index.
            15  NEIGHBOR-EDGE     pic 9.
***  data used when traversing graph to resolve user request:
        10  DISTANCE-FROM-SOURCE  pic 99999V9.
        10  PATH-PREDECESSOR      usage index.
        10  EDGE-TO-PREDECESSOR   pic 9.
        10  REACHED-STATUS        pic 9.
***  data used to compute common genetic material
        10  DESCENDANT-IDENTIFIER pic 999.
        10  DESCENDANT-GENES      pic 9V99999999.

*  These variables are used to accept and resolve requests for
*  RELATIONSHIP information.
 01  RELATIONSHIP-WORK-ITEMS.
     05  REQUEST-BUFFER        pic X(60).
         88  REQUEST-TO-STOP   value "stop".
     05  PERSON1-IDENT         pic X(20).
     05  PERSON2-IDENT         pic X(20).
     05  PERSON1-FOUND         pic 999.
     05  PERSON2-FOUND         pic 999.
     05  ERROR-MESSAGE         pic X(40).
     05  REQUEST-OK            pic X(40)   value "Request OK".

 01  AUXILIARY-VARIABLES.
     05  RELATION-LOOP-DONE          pic X.
         88  RELATION-LOOP-IS-DONE   value "T".
     05  TEMP-INDEX                  usage index.
     05  THIS-EDGE                   pic 9.
     05  LEADING-SPACES              pic 99.
     05  SEMICOLON-COUNT             pic 99.
     05  CURRENT-IDENT               pic 999.
     05  PREVIOUS-IDENT              pic 999.
     05  TEMP-IDENT                  pic X(20).
```

```
 procedure division.
 MAIN-LINE.
     open input PEOPLE.
     read PEOPLE at end perform NULL.

*   This loop reads in the PEOPLE file and constructs the PERSON
*   array from it (one PERSON = one record = one array entry).
*   As records are read in, links are constructed to represent the
*   PARENT-CHILD or SPOUSE RELATIONSHIP.  The array then implements
*   a directed graph which is used to satisfy subsequent user
*   requests.  The file is assumed to be correct - no validation
*   is performed on it.

     perform READ-IN-PEOPLE thru READ-IN-PEOPLE-EXIT
        varying CURRENT from 1 by 1 until END-OF-PEOPLE-FILE.
     set CURRENT down by 1.
     set NUMBER-OF-PERSONS to CURRENT.
     close PEOPLE.

*   PERSON array is now loaded and edges between immediate relatives
*   (PARENT-CHILD or SPOUSE-SPOUSE) are established.

     perform PROMPT-AND-READ.

*   While-loop accepts requests and finds RELATIONSHIP (if any)
*   between pairs of PERSONs.

     perform READ-AND-PROCESS-REQUEST thru READ-AND-PROCESS-REQUEST-EXIT
        until REQUEST-TO-STOP.
     display " End of relation-finder.".
     stop run.

 READ-IN-PEOPLE.
***  copy direct information from file to array
     move corresponding PEOPLE-RECORD to PERSON (CURRENT).
     move IMMEDIATE-RELATIONS of PEOPLE-RECORD
       to IMMEDIATE-RELATIONS of PERSON (CURRENT).
***  Location of adjacent persons as yet undetermined
     move zero to NEIGHBOR-COUNT of PERSON (CURRENT).
***  Descendants as yet undetermined
     move NULL-IDENT to DESCENDANT-IDENTIFIER of PERSON (CURRENT).
     move IDENTIFIER of PERSON (CURRENT) to CURRENT-IDENT.
***  Compare this PERSON against all previously entered PERSONs
***  to search for RELATIONSHIPs.
     perform COMPARE-TO-PREVIOUS varying PREVIOUS from 1 by 1
                                  until PREVIOUS not < CURRENT.
     read PEOPLE at end perform NULL.
 READ-IN-PEOPLE-EXIT.
     exit.

 NULL.
     exit.
```

```
 COMPARE-TO-PREVIOUS.
     move IDENTIFIER of PERSON (PREVIOUS) to PREVIOUS-IDENT.
***  Search for father, mother, or spouse relationship in
***  either direction between this and PREVIOUS PERSON.
***  Assume at most one RELATIONSHIP exists.
     move IS-FALSE to RELATION-LOOP-DONE.
     perform TRY-ALL-RELATIONSHIPS
        varying RELATIONSHIP from FATHER-IDENT by 1
        until RELATIONSHIP > SPOUSE-IDENT or RELATION-LOOP-IS-DONE.
 TRY-ALL-RELATIONSHIPS.
     if RELATIVE-IDENTIFIER of PERSON (CURRENT, RELATIONSHIP) =
           PREVIOUS-IDENT
        set FROM-INDEX to CURRENT
        set TO-INDEX   to PREVIOUS
        perform LINK-RELATIVES
        move IS-TRUE to RELATION-LOOP-DONE
     else
        if CURRENT-IDENT =
              RELATIVE-IDENTIFIER of PERSON (PREVIOUS, RELATIONSHIP)
           set FROM-INDEX to PREVIOUS
           set TO-INDEX   to CURRENT
           perform LINK-RELATIVES
           move IS-TRUE to RELATION-LOOP-DONE.

 LINK-RELATIVES.
*  establishes cross-indexing between immediately related PERSONs.

     if RELATIONSHIP = SPOUSE-IDENT
        move SPOUSE to THIS-EDGE
        perform LINK-ONE-WAY
        set TEMP-INDEX to FROM-INDEX
        set FROM-INDEX to TO-INDEX
        set TO-INDEX   to TEMP-INDEX
        perform LINK-ONE-WAY
     else
*       RELATIONSHIP is father or mother
        move PARENT to THIS-EDGE
        perform LINK-ONE-WAY
        move CHILD to THIS-EDGE
        set TEMP-INDEX to FROM-INDEX
        set FROM-INDEX to TO-INDEX
        set TO-INDEX   to TEMP-INDEX
        perform LINK-ONE-WAY.

 LINK-ONE-WAY.
***  Establishes the NEIGHBOR-RECORD from one PERSON to another
     add  1            to NEIGHBOR-COUNT of PERSON (FROM-INDEX).
     set NEXT-NEIGHBOR to NEIGHBOR-COUNT of PERSON (FROM-INDEX).
     set NEIGHBOR-INDEX of PERSON (FROM-INDEX, NEXT-NEIGHBOR)
        to TO-INDEX.
     move THIS-EDGE
        to NEIGHBOR-EDGE  of PERSON (FROM-INDEX, NEXT-NEIGHBOR).
```

```
 PROMPT-AND-READ.
*  Issues prompt for user-request, reads in request,
*  blank-fills buffer, and skips to next line of input.

     display " ".
     display " ---------------------------------------------".
     display " Enter two person-identifiers (name or number),".
     display " separated by semicolon. Enter ""stop"" to stop.".
     move spaces to REQUEST-BUFFER.
     accept REQUEST-BUFFER.

 READ-AND-PROCESS-REQUEST.
     perform CHECK-REQUEST.

***  Syntax check of request completed.  Now either display error
***  message or search for the two PERSONs.

     if ERROR-MESSAGE = REQUEST-OK
        perform PROCESS-LEGAL-REQUEST
     else
        display " Incorrect request format: ", ERROR-MESSAGE.
     perform PROMPT-AND-READ.
 READ-AND-PROCESS-REQUEST-EXIT.
     exit.

 CHECK-REQUEST.
*  Performs syntactic check on request in buffer
*  and fills in identifiers of the two requested persons.

     move zero to SEMICOLON-COUNT.
     inspect REQUEST-BUFFER tallying SEMICOLON-COUNT
        for all ";".
     if SEMICOLON-COUNT not = 1
        move "must be exactly one semicolon." to ERROR-MESSAGE
     else
        move zero to LEADING-SPACES
        inspect REQUEST-BUFFER tallying LEADING-SPACES
           for leading spaces
        add 1 to LEADING-SPACES
        unstring REQUEST-BUFFER delimited by ";"
           into PERSON1-IDENT, TEMP-IDENT
           with pointer LEADING-SPACES
        if PERSON1-IDENT = spaces
           move "null field preceding semicolon." to ERROR-MESSAGE
        else
           if TEMP-IDENT = spaces
              move "null field following semicolon." to ERROR-MESSAGE
           else
              move zero to LEADING-SPACES
              inspect TEMP-IDENT tallying LEADING-SPACES
                 for leading spaces
              add 1 to LEADING-SPACES
              unstring TEMP-IDENT into PERSON2-IDENT
                 with pointer LEADING-SPACES
              move REQUEST-OK to ERROR-MESSAGE.
```

```
 PROCESS-LEGAL-REQUEST.
***   search for requested PERSONs.
      move zero to PERSON1-FOUND, PERSON2-FOUND.
      perform SCAN-ALL-PERSONS varying CURRENT from 1 by 1
         until CURRENT > NUMBER-OF-PERSONS.
      if PERSON1-FOUND = 1 and PERSON2-FOUND = 1
***      Exactly one match for each PERSON - proceed to
***      determine RELATIONSHIP, if any.
         if PERSON1-INDEX = PERSON2-INDEX
            if GENDER of PERSON (PERSON1-INDEX) = MALE
               display " ", NAME of PERSON (PERSON1-INDEX),
                    " is identical to himself."
            else
               display " ", NAME of PERSON (PERSON1-INDEX),
                    " is identical to herself."
         else
            set ARG-PERSON1-INDEX to PERSON1-INDEX
            set ARG-PERSON2-INDEX to PERSON2-INDEX
            call "FINDREL" using
                 ARG-PERSON1-INDEX, ARG-PERSON2-INDEX, PERSON-TABLE
      else
***      either not found or more than one found
         perform MISSING-OR-DUPLICATE-PERSONS.

 SCAN-ALL-PERSONS.
      if PERSON1-IDENT = NAME       of PERSON (CURRENT) or
                         IDENTIFIER of PERSON (CURRENT)
         set PERSON1-INDEX to CURRENT
         add 1 to PERSON1-FOUND.
      if PERSON2-IDENT = NAME       of PERSON (CURRENT) or
                         IDENTIFIER of PERSON (CURRENT)
         set PERSON2-INDEX to CURRENT
         add 1 to PERSON2-FOUND.

 MISSING-OR-DUPLICATE-PERSONS.
      if PERSON1-FOUND = zero
         display " First person not found."
      else
         if PERSON1-FOUND > 1
            display " Duplicate names for first person - use",
                    " numeric identifier.".
      if PERSON2-FOUND = zero
         display " Second person not found."
      else
         if PERSON2-FOUND > 1
            display " Duplicate names for second person - use",
                    " numeric identifier.".
```

```
* ---- Compilation unit number 2 ----

 identification division.
 program-id. FINDREL.

*     Finds shortest path (if any) between two PERSONs and
*     determines their RELATIONSHIP based on immediate relations
*     traversed in path.  PERSON array simulates a directed graph,
*     and algorithm finds shortest path, based on following
*     weights: PARENT-CHILD edge  = 1.0
*              SPOUSE-SPOUSE edge = 1.8

 environment division.

 configuration section.
 source-computer. VAX-11.
 object-computer. VAX-11.

 data division.
 working-storage section.

*  Define global objects

 01  TRUTH-VALUES.
     05  IS-TRUE              pic X   value "T".
     05  IS-FALSE             pic X   value "F".

*  each PERSON's record in the file identifies at most three
*  others directly related: father, mother, and spouse
 01  GIVEN-IDENTIFIERS.
     05  FATHER-IDENT         pic 9   value 1.
     05  MOTHER-IDENT         pic 9   value 2.
     05  SPOUSE-IDENT         pic 9   value 3.

 01  GENDER-TYPE.
     05  MALE                 pic X   value "M".
     05  FEMALE               pic X   value "F".

 01  RELATION-TYPE.
     05  PARENT               pic 9   value 1.
     05  CHILD                pic 9   value 2.
     05  SPOUSE               pic 9   value 3.
     05  SIBLING              pic 9   value 4.
     05  UNCLE                pic 9   value 5.
     05  NEPHEW               pic 9   value 6.
     05  COUSIN               pic 9   value 7.
     05  NULL-RELATION        pic 9   value 8.
```

```
*  A node in the graph (= PERSON) has either already been reached,
*  is immediately adjacent to those reached, or farther away.
 01  REACHED-TYPE.
     05  REACHED           pic 9   value 1.
     05  NEARBY            pic 9   value 2.
     05  NOT-SEEN          pic 9   value 3.

 01  SEARCH-TYPE.
     05  SEARCHING      pic 9   value 1.
     05  SUCCEEDED      pic 9   value 2.
     05  FAILED         pic 9   value 3.

 01  SIBLING-TYPE.
     05  STEP           pic 9   value 1.
     05  HALF           pic 9   value 2.
     05  FULL           pic 9   value 3.

 01  KEY-PERSON-TABLE.
     05  KEY-PERSON  occurs 300 times
             indexed by KEY-INDEX, LATER-KEY-INDEX, PRIMARY-INDEX,
                        FIRST-INDEX, LAST-INDEX,
                        RECEIVE-INDEX, SEND-INDEX.
         10  RELATION-TO-NEXT    pic 9.
         10  PERSON-INDEX        usage index.
         10  GENERATION-GAP      pic 999.
         10  PROXIMITY           pic 9.
         10  COUSIN-RANK         pic 999.

 01  AUXILIARY-VARIABLES.
***  these variables are used to find the shortest path
     05  WEIGHT-THIS-EDGE           pic 99V9.
     05  DISTANCE-THRU-BASE-NODE    pic 99999V9.
     05  SEARCH-STATUS              pic 9.
     05  NEARBY-NODE                usage index,  occurs 300 times,
         indexed by THIS-NEARBY-INDEX, BEST-NEARBY-INDEX, LAST-NEARBY-INDEX.
     05  THIS-EDGE                  pic 9.
     05  NEXT-BASE-EDGE             pic 9.
     05  MINIMAL-DISTANCE           pic 9999999V9.
     05  DISPLAY-BUFFER             pic X(70).
     05  DISPLAY-POINTER            pic 99.
     05  NULL-IDENT                 pic 999  value 000.

***  these variables are used to condense the path
     05  KEY-RELATION               pic 9.
     05  LATER-KEY-RELATION         pic 9.
     05  PRIMARY-RELATION           pic 9.
     05  FIRST-RELATION             pic 9.
     05  LAST-RELATION              pic 9.
     05  NEXT-PRIMARY-RELATION      pic 9.
     05  GAP-SIZE                   pic 999.
     05  ANOTHER-ELEMENT-POSSIBLE   pic X.
         88  ANOTHER-ELEMENT-IS-POSSIBLE   value "T".
```

```
***  these variables are used to generate KEY-PERSONs and for DISPLAY
     05  GENERATION-COUNT          pic 999.
     05  TEMP-NUMBER               pic 999.
     05  THIS-COUSIN-RANK          pic 999.
     05  THIS-PROXIMITY            pic 9.
     05  THIS-GENDER               pic X.
     05  THIS-GENERATION-GAP       pic 999.
     05  SUFFIX-INDICATOR          pic 9.
     05  TWO-DIGIT-FIELD           pic Z9.
     05  INLAW                     pic X.
         88  RELATION-IS-INLAW             value "T".
     05  MALE-NAME-VALUES.
         10 filler      pic X(8)  value "father  ".
         10 filler      pic X(8)  value "son     ".
         10 filler      pic X(8)  value "husband ".
         10 filler      pic X(8)  value "brother ".
         10 filler      pic X(8)  value "uncle   ".
         10 filler      pic X(8)  value "nephew  ".
         10 filler      pic X(8)  value "cousin  ".
         10 filler      pic X(8)  value "null    ".
     05  MALE-NAME-TABLE redefines MALE-NAME-VALUES.
         10 PRIMARY-MALE-NAME  pic X(8) occurs 8 times
            indexed by MALE-INDEX.
     05  FEMALE-NAME-VALUES.
         10 filler      pic X(8)  value "mother  ".
         10 filler      pic X(8)  value "daughter".
         10 filler      pic X(8)  value "wife    ".
         10 filler      pic X(8)  value "sister  ".
         10 filler      pic X(8)  value "aunt    ".
         10 filler      pic X(8)  value "niece   ".
         10 filler      pic X(8)  value "cousin  ".
         10 filler      pic X(8)  value "null    ".
     05  FEMALE-NAME-TABLE redefines FEMALE-NAME-VALUES.
         10 PRIMARY-FEMALE-NAME  pic X(8) occurs 8 times
            indexed by FEMALE-INDEX.
```

```
 linkage section.

 77  PARM-TARGET-INDEX          pic 999.
 77  PARM-SOURCE-INDEX          pic 999.

 01  PERSON-TABLE.
     05  NUMBER-OF-PERSONS          usage index.
     05  PERSON occurs 300 times
            indexed by INDEX1, INDEX2, TARGET-INDEX, SOURCE-INDEX,
                       BASE-NODE, THIS-NODE, NEXT-NODE.
***  static information - filled from PEOPLE file:
        10  NAME                    pic X(20).
        10  IDENTIFIER              pic 999.
        10  GENDER                  pic X.
***    IDENTIFIERs of immediate relatives - father, mother, spouse
        10  IMMEDIATE-RELATIONS.
            15  RELATIVE-IDENTIFIER  occurs 3 times indexed by RELATIONSHIP
                                    pic 999.
***  pointers to immediate neighbors in graph
        10  NEIGHBOR-COUNT          pic 99.
        10  NEIGHBOR-RECORD occurs 20 times indexed by THIS-NEIGHBOR.
            15  NEIGHBOR-INDEX      usage index.
            15  NEIGHBOR-EDGE       pic 9.
***  data used when traversing graph to resolve user request:
        10  DISTANCE-FROM-SOURCE    pic 99999V9.
        10  PATH-PREDECESSOR        usage index.
        10  EDGE-TO-PREDECESSOR     pic 9.
        10  REACHED-STATUS          pic 9.
***  data used to compute common genetic material
        10  DESCENDANT-IDENTIFIER pic 999.
        10  DESCENDANT-GENES        pic 9V99999999.

 procedure division using
           PARM-TARGET-INDEX, PARM-SOURCE-INDEX, PERSON-TABLE.
 MAIN-LINE.
     set TARGET-INDEX to PARM-TARGET-INDEX.
     set SOURCE-INDEX to PARM-SOURCE-INDEX.
***  initialize PERSON-array for processing -
***  mark all nodes as not seen
     perform MARK-AS-NOT-SEEN varying THIS-NODE from 1 by 1
        until THIS-NODE > NUMBER-OF-PERSONS.
     set THIS-NODE to SOURCE-INDEX.
***  mark source node as REACHED
     move REACHED to REACHED-STATUS       of PERSON (THIS-NODE).
     move zero    to DISTANCE-FROM-SOURCE of PERSON (THIS-NODE).
***  no nearby nodes exist yet
     set LAST-NEARBY-INDEX to 1.
     set LAST-NEARBY-INDEX down by 1.
     if THIS-NODE = TARGET-INDEX
        move SUCCEEDED to SEARCH-STATUS
     else
        move SEARCHING to SEARCH-STATUS.
```

```
***  Loop keeps processing closest-to-source, unREACHED node
***  until target REACHED, or no more connected nodes.
     perform SEARCH-FOR-TARGET until SEARCH-STATUS not = SEARCHING.

***  Shortest path between PERSONs now established.  Next task is
***  to translate path to English description of RELATIONSHIP.
     if SEARCH-STATUS = FAILED
        display " ", NAME of PERSON (TARGET-INDEX), " is not related to ",
                     NAME of PERSON (SOURCE-INDEX)
     else
***     success - parse path to find and display RELATIONSHIP
        perform RESOLVE-PATH-TO-ENGLISH
        call "COMGENES" using
             PARM-SOURCE-INDEX, PARM-TARGET-INDEX, PERSON-TABLE.
 END-OF-FINDREL.
     exit program.

 MARK-AS-NOT-SEEN.
     move NOT-SEEN to REACHED-STATUS of PERSON (THIS-NODE).

 SEARCH-FOR-TARGET.
***  Process all nodes adjacent to THIS-NODE
     perform PROCESS-ADJACENT-NODE varying THIS-NEIGHBOR from 1 by 1
        until THIS-NEIGHBOR > NEIGHBOR-COUNT of PERSON (THIS-NODE).
***  All nodes adjacent to THIS-NODE are set.  Now search for
***  shortest-distance unREACHED (but NEARBY) node to process next.
     if LAST-NEARBY-INDEX = zero
        move FAILED to SEARCH-STATUS
     else
***     determine next node to process
        move 9999999 to MINIMAL-DISTANCE
        perform FIND-CLOSEST-UNREACHED-NODE varying THIS-NEARBY-INDEX
           from 1 by 1 until THIS-NEARBY-INDEX > LAST-NEARBY-INDEX

***     establish new THIS-NODE
        set THIS-NODE to NEARBY-NODE (BEST-NEARBY-INDEX)
***     change THIS-NODE from being NEARBY to REACHED
        move REACHED to REACHED-STATUS of PERSON (THIS-NODE)
***     remove THIS-NODE from NEARBY list
        set NEARBY-NODE (BEST-NEARBY-INDEX) to NEARBY-NODE (LAST-NEARBY-INDEX)
        set LAST-NEARBY-INDEX down by 1
        if THIS-NODE = TARGET-INDEX
           move SUCCEEDED to SEARCH-STATUS.
```

```
 PROCESS-ADJACENT-NODE.
     set BASE-NODE to THIS-NODE.
     set NEXT-NODE to NEIGHBOR-INDEX of PERSON (BASE-NODE, THIS-NEIGHBOR).
     move NEIGHBOR-EDGE of PERSON (BASE-NODE, THIS-NEIGHBOR)
        to NEXT-BASE-EDGE.
***  NEXT-NODE is adjacent to last-REACHED node (= BASE-NODE).
***  if NEXT-NODE already REACHED, do nothing.
***  If previously seen, check whether path thru BASE-NODE is
***  shorter than current path to NEXT-NODE, and if so re-link
***  next to base.
***  If not previously seen, link next to base node.
     if NEXT-BASE-EDGE = SPOUSE
        move 1.8 to WEIGHT-THIS-EDGE
     else
        move 1.0 to WEIGHT-THIS-EDGE.
     if REACHED-STATUS of PERSON (NEXT-NODE) not = REACHED
        add WEIGHT-THIS-EDGE, DISTANCE-FROM-SOURCE of PERSON (BASE-NODE)
            giving DISTANCE-THRU-BASE-NODE
        if REACHED-STATUS of PERSON (NEXT-NODE) = NOT-SEEN
           move NEARBY to REACHED-STATUS of PERSON (NEXT-NODE)
           set LAST-NEARBY-INDEX up by 1
           set NEARBY-NODE (LAST-NEARBY-INDEX) to NEXT-NODE
           perform LINK-NEXT-NODE-TO-BASE-NODE
        else
***        REACHED-STATUS = NEARBY
           if DISTANCE-THRU-BASE-NODE
                 < DISTANCE-FROM-SOURCE of PERSON (NEXT-NODE)
              perform LINK-NEXT-NODE-TO-BASE-NODE.

 LINK-NEXT-NODE-TO-BASE-NODE.
***  link next to base by re-setting its predecessor index to
***  point to base, note type of edge, and re-set distance
***  as it is through base node.
     move DISTANCE-THRU-BASE-NODE
       to DISTANCE-FROM-SOURCE of PERSON (NEXT-NODE).
     set PATH-PREDECESSOR of PERSON (NEXT-NODE) to BASE-NODE.
     move NEXT-BASE-EDGE to EDGE-TO-PREDECESSOR of PERSON (NEXT-NODE).

 FIND-CLOSEST-UNREACHED-NODE.
     set NEXT-NODE to NEARBY-NODE (THIS-NEARBY-INDEX).
     if DISTANCE-FROM-SOURCE of PERSON (NEXT-NODE) < MINIMAL-DISTANCE
        set BEST-NEARBY-INDEX to THIS-NEARBY-INDEX
        move DISTANCE-FROM-SOURCE of PERSON (NEXT-NODE) to MINIMAL-DISTANCE.
```

```
 RESOLVE-PATH-TO-ENGLISH.
***   RESOLVE-PATH-TO-ENGLISH condenses the shortest path to a
***   series of RELATIONSHIPs for which there are English
***   descriptions.

***   Key persons are the ones in the RELATIONSHIP path which remain
***   after the path is condensed.

      display " Shortest path between identified persons: ".
      set THIS-NODE to TARGET-INDEX.
***   Display path and initialize KEY-PERSON array from path elements.
      perform TRAVERSE-SHORTEST-PATH varying KEY-INDEX from 1 by 1
         until THIS-NODE = SOURCE-INDEX.
      display " ", NAME of PERSON (THIS-NODE).
      set PERSON-INDEX of KEY-PERSON (KEY-INDEX) to THIS-NODE.
      move NULL-RELATION to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX).
      move NULL-RELATION to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX + 1).

***   Resolve CHILD-PARENT and CHILD-SPOUSE-PARENT relations
***   to SIBLING relations.
      perform FIND-SIBLINGS varying KEY-INDEX from 1 by 1
         until RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = NULL-RELATION.

***   Resolve CHILD-CHILD-... and PARENT-PARENT-... relations to
***   direct descendant or ancestor relations.
      perform FIND-ANCESTORS-OR-DESCENDANTS varying KEY-INDEX from 1 by 1
         until RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = NULL-RELATION.

***   Resolve CHILD-SIBLING-PARENT to COUSIN,
***           CHILD-SIBLING        to NEPHEW,
***           SIBLING-PARENT       to UNCLE.
      perform FIND-COUSINS-NEPHEWS-UNCLES varying KEY-INDEX from 1 by 1
         until RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = NULL-RELATION.

***    Loop below will pick out valid adjacent strings of elements
***    to be displayed.  KEY-INDEX points to first element,
***    LATER-KEY-INDEX to last element, and PRIMARY-INDEX to the
***    element which determines the primary English word to be used.
***    Associativity of adjacent elements in condensed table
***    is based on English usage.
       set KEY-INDEX to 1.
       display " Condensed path:".
       perform CONSOLIDATE-ADJACENT-PERSONS
          until RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = NULL-RELATION
       set THIS-NODE to PERSON-INDEX of KEY-PERSON (KEY-INDEX).
       display " ", NAME of PERSON (THIS-NODE).
***    end of RESOLVE-PATH-TO-ENGLISH
```

```
 TRAVERSE-SHORTEST-PATH.
     set PERSON-INDEX of KEY-PERSON (KEY-INDEX) to THIS-NODE.
     move FULL to PROXIMITY of KEY-PERSON (KEY-INDEX).
     move EDGE-TO-PREDECESSOR of PERSON (THIS-NODE)
          to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX).
     if EDGE-TO-PREDECESSOR of PERSON (THIS-NODE) = SPOUSE
         move zero to GENERATION-GAP of KEY-PERSON (KEY-INDEX)
         display " ", NAME of PERSON (THIS-NODE), " is spouse of"
     else
         move 1 to GENERATION-GAP of KEY-PERSON (KEY-INDEX)
         if EDGE-TO-PREDECESSOR of PERSON (THIS-NODE) = PARENT
            display " ", NAME of PERSON (THIS-NODE), " is parent of"
         else
***         edge is child-type
            display " ", NAME of PERSON (THIS-NODE), " is child of".
     set THIS-NODE to PATH-PREDECESSOR of PERSON (THIS-NODE).

 FIND-SIBLINGS.
     if RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = CHILD
        move RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX + 1)
             to LATER-KEY-RELATION
        if LATER-KEY-RELATION = PARENT
***        then found either full or half SIBLINGs
           perform SET-UP-FULL-HALF-SIBLING
        else
           if LATER-KEY-RELATION = SPOUSE and
              RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX + 2) = PARENT
***        then found step-siblings
              move zero    to GENERATION-GAP   of KEY-PERSON (KEY-INDEX)
              move STEP    to PROXIMITY        of KEY-PERSON (KEY-INDEX)
              move SIBLING to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX)
              move 2 to GAP-SIZE
              perform CONDENSE-KEY-PERSONS.

 SET-UP-FULL-HALF-SIBLING.
***   Determines whether two PERSONs are full siblings, i.e.,
***   have the same two parents.
     set INDEX1 to PERSON-INDEX of KEY-PERSON (KEY-INDEX).
     set INDEX2 to PERSON-INDEX of KEY-PERSON (KEY-INDEX + 2).
     if (NULL-IDENT not =
               RELATIVE-IDENTIFIER of PERSON (INDEX1, FATHER-IDENT)
          and RELATIVE-IDENTIFIER of PERSON (INDEX1, MOTHER-IDENT))
          and (RELATIVE-IDENTIFIER of PERSON (INDEX1, FATHER-IDENT) =
                RELATIVE-IDENTIFIER of PERSON (INDEX2, FATHER-IDENT))
          and (RELATIVE-IDENTIFIER of PERSON (INDEX1, MOTHER-IDENT) =
                RELATIVE-IDENTIFIER of PERSON (INDEX2, MOTHER-IDENT))
        move FULL to PROXIMITY of KEY-PERSON (KEY-INDEX)
     else
        move HALF to PROXIMITY of KEY-PERSON (KEY-INDEX).
     move zero    to GENERATION-GAP   of KEY-PERSON (KEY-INDEX).
     move SIBLING to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX).
     move 1 to GAP-SIZE.
     perform CONDENSE-KEY-PERSONS.
```

```
 FIND-ANCESTORS-OR-DESCENDANTS.
     if RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = CHILD or PARENT
        perform NULL varying LATER-KEY-INDEX from KEY-INDEX by 1
           until RELATION-TO-NEXT of KEY-PERSON (LATER-KEY-INDEX) not =
                 RELATION-TO-NEXT of KEY-PERSON       (KEY-INDEX)
        set GENERATION-COUNT to LATER-KEY-INDEX
        set TEMP-NUMBER      to KEY-INDEX
        subtract TEMP-NUMBER from GENERATION-COUNT
        if GENERATION-COUNT > 1
***        compress generations
           move GENERATION-COUNT to GENERATION-GAP of KEY-PERSON (KEY-INDEX)
           subtract 1 from GENERATION-COUNT giving GAP-SIZE
           perform CONDENSE-KEY-PERSONS.

 FIND-COUSINS-NEPHEWS-UNCLES.
     move RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX + 1)
       to LATER-KEY-RELATION
     if RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = CHILD and
        LATER-KEY-RELATION = SIBLING
***  then COUSIN or NEPHEW
        if RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX + 2) = PARENT
           perform FOUND-COUSIN
        else
***        found NEPHEW
           move PROXIMITY of KEY-PERSON (KEY-INDEX + 1) to
                PROXIMITY of KEY-PERSON (KEY-INDEX)
           move NEPHEW to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX)
           move 1 to GAP-SIZE
           perform CONDENSE-KEY-PERSONS
     else
        if RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) = SIBLING and
           LATER-KEY-RELATION = PARENT
***     then found UNCLE
           move GENERATION-GAP of KEY-PERSON (KEY-INDEX + 1) to
                GENERATION-GAP of KEY-PERSON (KEY-INDEX)
           move UNCLE to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX)
           move 1 to GAP-SIZE
           perform CONDENSE-KEY-PERSONS.
 FOUND-COUSIN.
     if GENERATION-GAP of KEY-PERSON (KEY-INDEX)
           < GENERATION-GAP of KEY-PERSON (KEY-INDEX + 2)
        move GENERATION-GAP of KEY-PERSON (KEY-INDEX)
          to COUSIN-RANK of KEY-PERSON (KEY-INDEX)
     else
        move GENERATION-GAP of KEY-PERSON (KEY-INDEX + 2)
          to COUSIN-RANK of KEY-PERSON (KEY-INDEX).
***  subtract moves in absolute value since GENERATION-GAP is unsigned
     subtract GENERATION-GAP of KEY-PERSON (KEY-INDEX + 2)
        from  GENERATION-GAP of KEY-PERSON (KEY-INDEX).
     move PROXIMITY of KEY-PERSON (KEY-INDEX + 1)
       to PROXIMITY of KEY-PERSON (KEY-INDEX).
     move COUSIN to RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX).
     move 2 to GAP-SIZE.
     perform CONDENSE-KEY-PERSONS.
 NULL.
     exit.
```

```
 CONDENSE-KEY-PERSONS.
***     CONDENSE-KEY-PERSONS condenses superfluous entries from the
***     KEY-PERSON array, starting at KEY-INDEX.
        set RECEIVE-INDEX to KEY-INDEX.
        set RECEIVE-INDEX up by 1.
        set SEND-INDEX to RECEIVE-INDEX.
        set SEND-INDEX up by GAP-SIZE.
        perform SLIDE-IT-DOWN varying RECEIVE-INDEX from RECEIVE-INDEX by 1
           until RELATION-TO-NEXT of KEY-PERSON (RECEIVE-INDEX - 1)
                 = NULL-RELATION.
 SLIDE-IT-DOWN.
        move KEY-PERSON (SEND-INDEX) to KEY-PERSON (RECEIVE-INDEX).
        set SEND-INDEX up by 1.

 CONSOLIDATE-ADJACENT-PERSONS.
        move RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX) to KEY-RELATION.
        set LATER-KEY-INDEX, PRIMARY-INDEX to KEY-INDEX.
        if RELATION-TO-NEXT of KEY-PERSON (KEY-INDEX + 1) not = NULL-RELATION
           perform SEEK-MULTI-ELEMENT-COMBINATION.
        set FIRST-INDEX to KEY-INDEX.
        set LAST-INDEX to LATER-KEY-INDEX.
        perform DISPLAY-RELATION.
        set KEY-INDEX to LATER-KEY-INDEX.
        set KEY-INDEX up by 1.

 SEEK-MULTI-ELEMENT-COMBINATION.
        move IS-TRUE to ANOTHER-ELEMENT-POSSIBLE.
        if KEY-RELATION = SPOUSE
           set LATER-KEY-INDEX up by 1
           set PRIMARY-INDEX up by 1
           if RELATION-TO-NEXT of KEY-PERSON (LATER-KEY-INDEX)
                  = SIBLING or COUSIN
***        then nothing can follow spouse-sibling or spouse-cousin
              move IS-FALSE to ANOTHER-ELEMENT-POSSIBLE.
***     PRIMARY-INDEX is now correctly set.  Next if-statement
***     determines if a following SPOUSE relation should be
***     appended to this combination or left for the next
***     combination.
        if RELATION-TO-NEXT of KEY-PERSON (PRIMARY-INDEX + 1) = SPOUSE
              and ANOTHER-ELEMENT-IS-POSSIBLE
***        Only a SPOUSE can follow a Primary
***        check primary preceding and following SPOUSE.
           move RELATION-TO-NEXT of KEY-PERSON (PRIMARY-INDEX)
             to PRIMARY-RELATION
           move RELATION-TO-NEXT of KEY-PERSON (PRIMARY-INDEX + 2)
             to NEXT-PRIMARY-RELATION
           if (NEXT-PRIMARY-RELATION = NEPHEW or COUSIN or NULL-RELATION)
              or (PRIMARY-RELATION = NEPHEW)
              or ( (PRIMARY-RELATION = SIBLING or PARENT)
                    and NEXT-PRIMARY-RELATION not = UNCLE )
***        then append following SPOUSE with this combination.
              set LATER-KEY-INDEX up by 1.
```

```
 DISPLAY-RELATION.
***  DISPLAY-RELATION takes 1, 2, or 3 adjacent elements in the
***  condensed table and generates the English description of
***  the relation between the first and last + 1 elements.

     move RELATION-TO-NEXT of KEY-PERSON (FIRST-INDEX)
          to FIRST-RELATION.
     move RELATION-TO-NEXT of KEY-PERSON (LAST-INDEX)
          to LAST-RELATION.
     move RELATION-TO-NEXT of KEY-PERSON (PRIMARY-INDEX)
          to PRIMARY-RELATION.
***  set THIS-PROXIMITY
     if (PRIMARY-RELATION = PARENT and FIRST-RELATION = SPOUSE) or
        (PRIMARY-RELATION = CHILD  and LAST-RELATION  = SPOUSE)
        move STEP to THIS-PROXIMITY
     else
        if PRIMARY-RELATION = SIBLING or UNCLE or NEPHEW or COUSIN
           move PROXIMITY of KEY-PERSON (PRIMARY-INDEX) to THIS-PROXIMITY
        else
           move FULL to THIS-PROXIMITY.
***  set THIS-GENERATION-GAP
     if PRIMARY-RELATION = PARENT or CHILD or UNCLE or NEPHEW or COUSIN
        move GENERATION-GAP of KEY-PERSON (PRIMARY-INDEX)
                  to THIS-GENERATION-GAP
     else
        move zero to THIS-GENERATION-GAP.
***  set INLAW
     if (FIRST-RELATION = SPOUSE) and
        (PRIMARY-RELATION = SIBLING or CHILD or NEPHEW or COUSIN)
        move IS-TRUE to INLAW
     else
        if (LAST-RELATION = SPOUSE) and
           (PRIMARY-RELATION = SIBLING or PARENT or UNCLE or COUSIN)
           move IS-TRUE to INLAW
        else
           move IS-FALSE to INLAW.
***  set THIS-COUSIN-RANK
     if PRIMARY-RELATION = COUSIN
        move COUSIN-RANK of KEY-PERSON (PRIMARY-INDEX) to THIS-COUSIN-RANK
     else
        move zero to THIS-COUSIN-RANK.
```

```
***  parameters are set - now generate display.

     set THIS-NODE to PERSON-INDEX of KEY-PERSON (FIRST-INDEX).
     move spaces to DISPLAY-BUFFER.
     move 1 to DISPLAY-POINTER.
     string " ", NAME of PERSON (THIS-NODE), " is "
        delimited by size
        into DISPLAY-BUFFER with pointer DISPLAY-POINTER.
     if PRIMARY-RELATION = PARENT or CHILD or UNCLE or NEPHEW
        perform GENERATE-GENERATION-QUALIFIER
     else
        if (PRIMARY-RELATION = COUSIN) and (THIS-COUSIN-RANK > 1)
           move THIS-COUSIN-RANK to TWO-DIGIT-FIELD
           string TWO-DIGIT-FIELD delimited by size into DISPLAY-BUFFER
                  with pointer DISPLAY-POINTER
           divide THIS-COUSIN-RANK by 10 giving TEMP-NUMBER
                  remainder SUFFIX-INDICATOR
           if SUFFIX-INDICATOR = 1
              string "st " delimited by size
                 into DISPLAY-BUFFER with pointer DISPLAY-POINTER
           else if SUFFIX-INDICATOR = 2
              string "nd " delimited by size
                 into DISPLAY-BUFFER with pointer DISPLAY-POINTER
           else if SUFFIX-INDICATOR = 3
              string "rd " delimited by size
                 into DISPLAY-BUFFER with pointer DISPLAY-POINTER
           else
              string "th " delimited by size
                 into DISPLAY-BUFFER with pointer DISPLAY-POINTER.

     if THIS-PROXIMITY = STEP
        string "step-" delimited by size
           into DISPLAY-BUFFER with pointer DISPLAY-POINTER
     else
        if THIS-PROXIMITY = HALF
           string "half-" delimited by size
              into DISPLAY-BUFFER with pointer DISPLAY-POINTER.

     set THIS-NODE to PERSON-INDEX of KEY-PERSON (FIRST-INDEX).
     move GENDER of PERSON (THIS-NODE) to THIS-GENDER.
     set MALE-INDEX, FEMALE-INDEX to PRIMARY-RELATION.
     if THIS-GENDER = MALE
        string PRIMARY-MALE-NAME (MALE-INDEX) delimited by space
           into DISPLAY-BUFFER with pointer DISPLAY-POINTER
     else
        string PRIMARY-FEMALE-NAME (FEMALE-INDEX) delimited by space
           into DISPLAY-BUFFER with pointer DISPLAY-POINTER.

     if RELATION-IS-INLAW
        string "-in-law" delimited by size
           into DISPLAY-BUFFER with pointer DISPLAY-POINTER.
```

```
    if (PRIMARY-RELATION = COUSIN) and (THIS-GENERATION-GAP > 0)
       if THIS-GENERATION-GAP > 1
          move THIS-GENERATION-GAP to TWO-DIGIT-FIELD
          string " ", TWO-DIGIT-FIELD, " times removed"
             delimited by size
             into DISPLAY-BUFFER with pointer DISPLAY-POINTER
       else
          string " once removed" delimited by size
             into DISPLAY-BUFFER with pointer DISPLAY-POINTER.

    string " of" delimited by size
       into DISPLAY-BUFFER with pointer DISPLAY-POINTER.
    display DISPLAY-BUFFER.

GENERATE-GENERATION-QUALIFIER.
    if THIS-GENERATION-GAP not < 3
       string "great" delimited by size
          into DISPLAY-BUFFER with pointer DISPLAY-POINTER
       if THIS-GENERATION-GAP > 3
          subtract 2 from THIS-GENERATION-GAP giving TWO-DIGIT-FIELD
          string "*", TWO-DIGIT-FIELD, "-" delimited by size
             into DISPLAY-BUFFER with pointer DISPLAY-POINTER
       else
          string "-" delimited by size
             into DISPLAY-BUFFER with pointer DISPLAY-POINTER.
    if THIS-GENERATION-GAP not < 2
       string "grand-" delimited by size
          into DISPLAY-BUFFER with pointer DISPLAY-POINTER.
```

```
* ---- Compilation unit number 3 ----

 identification division.
 program-id. COMGENES.

*     COMGENES assumes that each ancestor contributes
*     half of the genetic material to a PERSON.  It finds common
*     ancestors between two PERSONs and computes the expected
*     value of the PROPORTION of common material.

 environment division.

 configuration section.
 source-computer. VAX-11.
 object-computer. VAX-11.

 data division.
 working-storage section.

 01  RELATION-TYPE.
     05  PARENT              pic 9   value 1.
     05  CHILD               pic 9   value 2.
     05  SPOUSE              pic 9   value 3.
     05  SIBLING             pic 9   value 4.
     05  UNCLE               pic 9   value 5.
     05  NEPHEW              pic 9   value 6.
     05  COUSIN              pic 9   value 7.
     05  NULL-RELATION       pic 9   value 8.

 01  AUXILIARY-VARIABLES.
     05  COMMON-PROPORTION          pic 9V9999999999.
     05  MATCH-IDENTIFIER           pic 999.
     05  TEN-DIGIT-FIELD            pic 9.999999999.

 01  STACKED-VARIABLES.
***  used to simulate recursion
     05  STACK-ENTRY   occurs 50 times indexed by STACK-INDEX.
         10  PROPORTION             pic 9V9999999999.
         10  THIS-CONTRIBUTION      pic 9V9999999999.
         10  ALREADY-COUNTED        pic 9V9999999999.
         10  PERSON-INDEX           usage index.
         10  NEXT-NEIGHBOR          pic 999.
```

```
linkage section.

77  PARM-INDEX1           pic 999.
77  PARM-INDEX2           pic 999.

01  PERSON-TABLE.
    05  NUMBER-OF-PERSONS        usage index.
    05  PERSON occurs 300 times indexed by
           INDEX1, INDEX2, THIS-NODE.
***  static information - filled from PEOPLE file:
       10  NAME                  pic X(20).
       10  IDENTIFIER            pic 999.
       10  GENDER                pic X.
***    IDENTIFIERs of immediate relatives - father, mother, spouse
       10  IMMEDIATE-RELATIONS.
           15  RELATIVE-IDENTIFIER  occurs 3 times indexed by RELATIONSHIP
                                 pic 999.
***  pointers to immediate neighbors in graph
       10  NEIGHBOR-COUNT        pic 99.
       10  NEIGHBOR-RECORD occurs 20 times indexed by THIS-NEIGHBOR.
           15  NEIGHBOR-INDEX    usage index.
           15  NEIGHBOR-EDGE     pic 9.
***  data used when traversing graph to resolve user request:
       10  DISTANCE-FROM-SOURCE  pic 99999V9.
       10  PATH-PREDECESSOR      usage index.
       10  EDGE-TO-PREDECESSOR   pic 9.
       10  REACHED-STATUS        pic 9.
***  data used to compute common genetic material
       10  DESCENDANT-IDENTIFIER pic 999.
       10  DESCENDANT-GENES      pic 9V99999999.
```

```
 procedure division using
            PARM-INDEX1, PARM-INDEX2, PERSON-TABLE.
 MAIN-LINE.
     set INDEX1 to PARM-INDEX1.
     set INDEX2 to PARM-INDEX2.
***  First zero out all ancestors to allow adding.  This is necessary
***  because there might be two paths to an ancestor.
     set STACK-INDEX to 1.
     set PERSON-INDEX (STACK-INDEX) to INDEX1.
     move zero to NEXT-NEIGHBOR (STACK-INDEX).
     perform ZERO-PROPORTION until STACK-INDEX < 1.

***  now mark with shared PROPORTION
     move IDENTIFIER of PERSON (INDEX1) to MATCH-IDENTIFIER.
     set STACK-INDEX to 1.
     set PERSON-INDEX (STACK-INDEX) to INDEX1.
     move zero to NEXT-NEIGHBOR (STACK-INDEX).
     move 1.0  to PROPORTION    (STACK-INDEX).
     perform MARK-PROPORTION until STACK-INDEX < 1.
***  traverse ancestor tree for INDEX2, summing overlap
***  with marked tree of INDEX1
     move zero to COMMON-PROPORTION
     set STACK-INDEX to 1.
     set PERSON-INDEX (STACK-INDEX) to INDEX2.
     move IDENTIFIER of PERSON (INDEX1) to MATCH-IDENTIFIER.
     move zero to NEXT-NEIGHBOR   (STACK-INDEX).
     move 1.0  to PROPORTION      (STACK-INDEX).
     move zero to ALREADY-COUNTED (STACK-INDEX).
     perform CHECK-COMMON-PROPORTION until STACK-INDEX < 1.
     move COMMON-PROPORTION to TEN-DIGIT-FIELD.
     display " Proportion of common genetic material = ", TEN-DIGIT-FIELD.
 END-OF-COMGENES.
     exit program.

 ZERO-PROPORTION.
***  ZERO-PROPORTION recursively seeks out all ancestors and
***  zeros them out.
     set THIS-NODE to PERSON-INDEX (STACK-INDEX).
     if NEXT-NEIGHBOR (STACK-INDEX) = zero
        move zero to DESCENDANT-GENES of PERSON (THIS-NODE)
        move 1    to NEXT-NEIGHBOR (STACK-INDEX).
     perform NULL
        varying THIS-NEIGHBOR from NEXT-NEIGHBOR (STACK-INDEX) by 1
        until THIS-NEIGHBOR > NEIGHBOR-COUNT (THIS-NODE)
           or NEIGHBOR-EDGE (THIS-NODE, THIS-NEIGHBOR) = PARENT.
     if THIS-NEIGHBOR > NEIGHBOR-COUNT (THIS-NODE)
***  then no more ancestors
        set STACK-INDEX down by 1
     else
***     set up for next ancestor
        set NEXT-NEIGHBOR (STACK-INDEX) to THIS-NEIGHBOR
        add 1 to NEXT-NEIGHBOR (STACK-INDEX)
        set STACK-INDEX up by 1
        set PERSON-INDEX (STACK-INDEX)
           to NEIGHBOR-INDEX (THIS-NODE, THIS-NEIGHBOR)
        move zero to NEXT-NEIGHBOR (STACK-INDEX).
```

```
 MARK-PROPORTION.
***  MARK-PROPORTION recursively seeks out all ancestors and
***  marks them with the sender's PROPORTION of shared
***  genetic material.  This PROPORTION is diluted by one-half
***  for each generation.

     set THIS-NODE to PERSON-INDEX (STACK-INDEX).
     if NEXT-NEIGHBOR (STACK-INDEX) = zero
        move MATCH-IDENTIFIER
             to DESCENDANT-IDENTIFIER of PERSON (THIS-NODE)
        add PROPORTION (STACK-INDEX)
             to DESCENDANT-GENES      of PERSON (THIS-NODE)
        move 1 to NEXT-NEIGHBOR (STACK-INDEX).
     perform NULL
        varying THIS-NEIGHBOR from NEXT-NEIGHBOR (STACK-INDEX) by 1
        until THIS-NEIGHBOR > NEIGHBOR-COUNT (THIS-NODE)
           or NEIGHBOR-EDGE (THIS-NODE, THIS-NEIGHBOR) = PARENT.
     if THIS-NEIGHBOR > NEIGHBOR-COUNT (THIS-NODE)
***  then no more ancestors
        set STACK-INDEX down by 1
     else
***     set up for next ancestor
        set NEXT-NEIGHBOR (STACK-INDEX) to THIS-NEIGHBOR
        add 1 to NEXT-NEIGHBOR (STACK-INDEX)
        set STACK-INDEX up by 1
        set PERSON-INDEX (STACK-INDEX)
           to NEIGHBOR-INDEX (THIS-NODE, THIS-NEIGHBOR)
        move zero to NEXT-NEIGHBOR (STACK-INDEX)
        divide PROPORTION (STACK-INDEX - 1) by 2 giving
               PROPORTION (STACK-INDEX).
```

```
 CHECK-COMMON-PROPORTION.
***   CHECK-COMMON-PROPORTION searches all the ancestors of
***   CHECK-INDEX to see if any have been marked, and if so
***   adds the appropriate amount to COMMON-PROPORTION.

      set THIS-NODE to PERSON-INDEX (STACK-INDEX).
      if NEXT-NEIGHBOR (STACK-INDEX) = zero
         move 1 to NEXT-NEIGHBOR (STACK-INDEX)
         if DESCENDANT-IDENTIFIER of PERSON (THIS-NODE) = MATCH-IDENTIFIER
***         Increment COMMON-PROPORTION by the contribution of
***         this common ancestor, but discount for the contribution
***         of less remote ancestors already counted.
            multiply DESCENDANT-GENES of PERSON (THIS-NODE)
               by PROPORTION (STACK-INDEX)
               giving THIS-CONTRIBUTION (STACK-INDEX)
            compute COMMON-PROPORTION = COMMON-PROPORTION
                  + THIS-CONTRIBUTION (STACK-INDEX)
                  - ALREADY-COUNTED   (STACK-INDEX)
         else
            move zero to THIS-CONTRIBUTION (STACK-INDEX).
      perform NULL
         varying THIS-NEIGHBOR from NEXT-NEIGHBOR (STACK-INDEX) by 1
         until THIS-NEIGHBOR > NEIGHBOR-COUNT (THIS-NODE)
            or NEIGHBOR-EDGE (THIS-NODE, THIS-NEIGHBOR) = PARENT.
      if THIS-NEIGHBOR > NEIGHBOR-COUNT (THIS-NODE)
***   then no more ancestors
         set STACK-INDEX down by 1
      else
***      set up for next ancestor
         set NEXT-NEIGHBOR (STACK-INDEX) to THIS-NEIGHBOR
         add 1 to NEXT-NEIGHBOR (STACK-INDEX)
         set STACK-INDEX up by 1
         set PERSON-INDEX (STACK-INDEX)
            to NEIGHBOR-INDEX (THIS-NODE, THIS-NEIGHBOR)
         move zero to NEXT-NEIGHBOR (STACK-INDEX)
         divide PROPORTION (STACK-INDEX - 1) by 2 giving
                PROPORTION (STACK-INDEX)
         divide THIS-CONTRIBUTION (STACK-INDEX - 1) by 4 giving
                ALREADY-COUNTED (STACK-INDEX).

 NULL.
     exit.
```

6.0 FORTRAN

In keeping with the general convention of the examples, language-supplied keywords and identifiers are written in lower case in the program. To conform strictly to the FORTRAN standard, however, programs must use only upper-case letters.

```
      program RELATE

c   Establish global constants

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

c   Each PERSON's record in the file identifies at most three
c   others directly related: father, mother, and spouse

      integer    FATHID, MOTHID, SPOUID
      parameter (FATHID = 1, MOTHID = 2, SPOUID = 3)

      character  REQOK*10, REQSTP*4
      parameter (REQOK = 'Request OK', REQSTP = 'stop')

      character  MALE*1,     FEMALE*1
      parameter (MALE = 'M', FEMALE = 'F')

      integer    PARENT, CHILD, SPOUSE, SIBLNG,
     1           UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1           UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)

c   These common blocks hold the PERSON array, which is global to
c   the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID
```

```
c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)        NAME    (MAXPRS)
      character*(IDLEN)         IDENT   (MAXPRS)
      character*1               GENDER  (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)         RELID   (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                   NBRCNT  (MAXPRS)
      integer                   NBRDEX  (MAXPRS, MAXNBR)
      integer                   NBREDG  (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                      DSTSRC  (MAXPRS)
      integer                   PATHPR  (MAXPRS)
      integer                   EDGPRD  (MAXPRS)
      integer                   RCHST   (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)         DSCID   (MAXPRS)
      real                      DSCGEN  (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                   NUMPER

c  *** end of declarations for common data ***

c  These variables are used when establishing the PERSON array
c  from the PEOPLE file.
      integer               CURRNT, PRVDEX
      character*(IDLEN)     PREVID, CURRID
      integer               RELSHP

c  These variables are used to accept and resolve requests for
c  RELSHP information.
      integer               BUFDEX, SEMLOC
      character*(BUFLEN)    REQBUF
      character*(NAMLEN)    P1IDNT, P2IDNT
      integer               P1FND, P2FND
      character*(MSGLEN)    ERRMSG
      integer               P1DEX, P2DEX
      character*7           PRNOUN
```

```
c  *** execution of main sequence begins here ***

      open (unit=10, file='PEOPLE.DAT', status='old', form='formatted')

c     This loop reads in the PEOPLE file and constructs the PERSON
c     array from it (one PERSON = one record = one array entry).
c     As records are read in, links are constructed to represent the
c     PARENT-CHILD or SPOUSE relationship. The array then implements
c     a directed graph which is used to satisfy subsequent user
c     requests.  The file is assumed to be correct - no validation
c     is performed on it.

      do 110 CURRNT=1, MAXPRS
c        copy direct information from file to array
         read (unit=10, fmt='(a20, a3, a1, 3a3)', end=111)
     1         NAME(CURRNT), IDENT(CURRNT), GENDER(CURRNT),
     2         ((RELID(CURRNT,ITEMP), ITEMP=FATHID, SPOUID))
c        Location of adjacent persons as yet undetermined
         NBRCNT (CURRNT) = 0
c        Descendants as yet undetermined
         DSCID  (CURRNT) = NULLID
c        Compare this PERSON against all previously entered PERSONs
c        to search for relationships.
         CURRID = IDENT (CURRNT)
         do 120 PRVDEX = 1, CURRNT-1
            PREVID = IDENT (PRVDEX)
c           Search for father, mother, or spouse relationship in
c           either direction between this and previous PERSON.
c           Assume at most one relationship exists.
            do 130 RELSHP = FATHID, SPOUID
               if (PREVID .eq. RELID (CURRNT, RELSHP)) then
                  call LNKREL (CURRNT, RELSHP, PRVDEX)
                  goto 131
               else if (CURRID .eq. RELID (PRVDEX, RELSHP)) then
                  call LNKREL (PRVDEX, RELSHP, CURRNT)
                  goto 131
               end if
130         continue
131         continue
120      continue
110   continue
111   continue
      NUMPER = CURRNT - 1
      close (unit=10, status='keep')

c     PERSON array is now loaded and edges between immediate relatives
c     (PARENT-CHILD or SPOUSE-SPOUSE) are established.
```

```
c     Loop accepts requests and finds relationship (if any)
c     between pairs of PERSONs.

200   continue
         call PROMPT (REQBUF)
         if (REQBUF .eq. REQSTP) goto 201
         call CHKRQS (REQBUF, ERRMSG, P1IDNT, P2IDNT)

c        Syntax check of request completed.  Now either display error
c        message or search for the two PERSONs.

         if (ERRMSG .eq. REQOK) then
c           Request syntactically correct - search for requested PERSONs.
            call SEEKPR (P1IDNT, P2IDNT, P1DEX, P2DEX,
     1                   P1FND, P2FND)
            if (P1FND .eq. 1 .and. P2FND .eq. 1) then
c              Exactly one match for each PERSON - proceed to
c              determine relationship, if any.
               if (P1DEX .eq. P2DEX) then
                  if (GENDER (P1DEX) .eq. MALE) then
                     PRNOUN = 'himself'
                  else
                     PRNOUN = 'herself'
                  end if
                  write (unit=*, fmt=9002) NAME (P1DEX), PRNOUN
9002              format (a22, ' is identical to ', a7, '.')
               else
                  call FINDRL (P1DEX, P2DEX)
               end if
            else
c              either not found or more than one found
               if (P1FND .eq. 0) then
                  write (unit=*, fmt='(''  First person not found.'')')
               else if (P1FND .gt. 1) then
                  write (unit=*,
     1                   fmt='(''  Duplicate names for first person'',
     2                         '' - use numeric identifier.'')')
               end if
               if (P2FND .eq. 0) then
                  write (unit=*, fmt='(''  Second person not found.'')')
               else if (P2FND .gt. 1) then
                  write (unit=*,
     1                   fmt='(''  Duplicate names for second person'',
     2                         '' - use numeric identifier.'')')
               end if
            end if
c           end processing of syntactically legal request
         else
            write  (unit=*, fmt=9004) ERRMSG
9004        format ('  Incorrect request format: ', a40)
         end if
      goto 200
201   continue
      write (unit=*, fmt='(''  End of relation-finder.'')')
c  End of main line of RELATE
      end
```

```
c  procedures under RELATE

      subroutine LNKREL (FRMDEX, RELSHP, TODEX)
c     establishes cross-indexing between immediately related PERSONs.
      integer    FRMDEX, TODEX, RELSHP

c  Each PERSON's record in the file identifies at most three
c  others directly related: father, mother, and spouse

      integer    FATHID, MOTHID, SPOUID
      parameter (FATHID = 1, MOTHID = 2, SPOUID = 3)

      integer    PARENT, CHILD, SPOUSE, SIBLNG,
     1           UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1           UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)

      if (RELSHP .eq. SPOUID) then
         call LNKONE (FRMDEX, SPOUSE, TODEX)
         call LNKONE (TODEX,  SPOUSE, FRMDEX)
      else
c        RELSHP is father or mother
         call LNKONE (FRMDEX, PARENT, TODEX)
         call LNKONE (TODEX,  CHILD,  FRMDEX)
      end if
      end
```

```
      subroutine LNKONE (FRMDEX, THSEDG, TODEX)
c     Establishes the NBR pointers from one PERSON to another
      integer    FRMDEX, TODEX, THSEDG

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID

c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)      NAME    (MAXPRS)
      character*(IDLEN)       IDENT   (MAXPRS)
      character*1             GENDER  (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)       RELID   (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                 NBRCNT  (MAXPRS)
      integer                 NBRDEX  (MAXPRS, MAXNBR)
      integer                 NBREDG  (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                    DSTSRC  (MAXPRS)
      integer                 PATHPR  (MAXPRS)
      integer                 EDGPRD  (MAXPRS)
      integer                 RCHST   (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)       DSCID   (MAXPRS)
      real                    DSCGEN  (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                 NUMPER

c  *** end of declarations for common data ***

      ITEMP = NBRCNT (FRMDEX) + 1
      NBRCNT (FRMDEX)        = ITEMP
      NBRDEX (FRMDEX, ITEMP) = TODEX
      NBREDG (FRMDEX, ITEMP) = THSEDG
      end
```

```
      subroutine PROMPT (REQBUF)
c     Issues prompt for user-request, reads in request,
c     blank-fills buffer, and skips to next line of input.

      character*(*)   REQBUF

      write  (unit=*, fmt=9001)
9001  format (/,'  ----------------------------------------------'
     1         /,'  Enter two person-identifiers (name or number),'
     2         /,'  separated by semicolon. Enter "stop" to stop.')

c *** NOTE THAT THIS IS NOT A STANDARD WAY TO READ A LINE FROM
c *** THE TERMINAL (see section 12.9.5.2.1).  THE STANDARD
c *** PROVIDES NO SUCH CAPABILITY.

      read (unit=*, fmt='(a60)') REQBUF
      end

      subroutine CHKRQS (REQBUF, REQST, P1IDNT, P2IDNT)
c     Performs syntactic check on request in buffer.

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      character  REQOK*10, REQSTP*4
      parameter (REQOK = 'Request OK', REQSTP = 'stop')

      character             REQBUF*(BUFLEN), REQST*(MSGLEN)
      character*(NAMLEN)    P1IDNT, P2IDNT, LTRIM
      integer               SEMLOC

      SEMLOC = INDEX (REQBUF,';')
      P2IDNT = REQBUF (SEMLOC+1 : BUFLEN)

c     set REQST, based on results of scan of REQBUF, and
c     fill in P1IDNT and P2IDNT.
```

```
      if (SEMLOC .eq. 0 .or. INDEX (P2IDNT, ';') .ne. 0) then
          REQST = 'must be exactly one semicolon.'
      else
         if (SEMLOC .eq. 1) then
            P1IDNT = ' '
         else
            P1IDNT = REQBUF (1 : SEMLOC-1)
         end if
         if (P1IDNT .eq. ' ') then
            REQST = 'null field preceding semicolon.'
         else if (P2IDNT .eq. ' ') then
            REQST = 'null field following semicolon.'
         else
            REQST  = REQOK
            P1IDNT = LTRIM (P1IDNT)
            P2IDNT = LTRIM (P2IDNT)
         end if
      end if
      end

      character*(*) function LTRIM (STRING)
c     LTRIM deletes leading spaces and returns the resulting value.

      character*(*) STRING

      do 100 ITEMP = 1, len(STRING)
         if (STRING (ITEMP : ITEMP) .ne. ' ') goto 101
100   continue
101   continue
      LTRIM = STRING (ITEMP : len(STRING))
      end

      subroutine SEEKPR  (P1IDNT, P2IDNT, P1DEX, P2DEX,
     1                     P1FND, P2FND)
c     SEEKPR scans through the PERSON array, looking for the two
c     requested PERSONs.  Match may be by NAME or unique IDENT-number.

      integer     MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1            MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1            MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      character*(NAMLEN)   P1IDNT, P2IDNT
      integer              P1DEX, P2DEX, P1FND, P2FND

      integer              CURRNT
```

```
c   These common blocks hold the PERSON array, which is global to
c   the entire program.
       common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                  EDGPRD, RCHST, DSCGEN, NUMPER

       common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID

c   The following data items constitute the PERSON array, which
c   is the central repository of information about inter-relationships.

c   static information - filled from PEOPLE file
       character*(NAMLEN)         NAME    (MAXPRS)
       character*(IDLEN)          IDENT   (MAXPRS)
       character*1                GENDER  (MAXPRS)
c   IDENTs of immediate relatives - father, mother, spouse
       character*(IDLEN)          RELID   (MAXPRS, MAXGVN)
c   pointers to immediate neighbors in graph
       integer                    NBRCNT  (MAXPRS)
       integer                    NBRDEX  (MAXPRS, MAXNBR)
       integer                    NBREDG  (MAXPRS, MAXNBR)
c   data used when traversing graph to resolve user request:
       real                       DSTSRC  (MAXPRS)
       integer                    PATHPR  (MAXPRS)
       integer                    EDGPRD  (MAXPRS)
       integer                    RCHST   (MAXPRS)
c   data used to compute common genetic material
       character*(IDLEN)          DSCID   (MAXPRS)
       real                       DSCGEN  (MAXPRS)

c   NUMPER keeps track of the actual number of persons
       integer                    NUMPER

c   *** end of declarations for common data ***

       P1DEX = 0
       P2DEX = 0
       P1FND = 0
       P2FND = 0
       do 100 CURRNT = 1, NUMPER
c         allow identification by name or number.
          if (P1IDNT .eq. IDENT (CURRNT) .or.
     1        P1IDNT .eq. NAME  (CURRNT)) then
             P1FND = P1FND + 1
             P1DEX = CURRNT
          end if
          if (P2IDNT .eq. IDENT (CURRNT) .or.
     1        P2IDNT .eq. NAME  (CURRNT)) then
             P2FND = P2FND + 1
             P2DEX = CURRNT
          end if
100    continue
       end
```

```
      subroutine FINDRL (TRGDEX, SRCDEX)
c     Finds shortest path (if any) between two PERSONs and
c     determines their relationship based on immediate relations
c     traversed in path.  PERSON array simulates a directed graph,
c     and algorithm finds shortest path, based on following
c     weights: PARENT-CHILD edge  = 1.0
c              SPOUSE-SPOUSE edge = 1.8

      integer    TRGDEX, SRCDEX

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

c  A node in the graph (= PERSON) has either already been reached,
c  is immediately adjacent to those reached, or farther away.

      integer    REACHD, NEARBY, NOSEEN
      parameter (REACHD = 1, NEARBY = 2, NOSEEN = 3)

c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID

c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)        NAME    (MAXPRS)
      character*(IDLEN)         IDENT   (MAXPRS)
      character*1               GENDER  (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)         RELID   (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                   NBRCNT  (MAXPRS)
      integer                   NBRDEX  (MAXPRS, MAXNBR)
      integer                   NBREDG  (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                      DSTSRC  (MAXPRS)
      integer                   PATHPR  (MAXPRS)
      integer                   EDGPRD  (MAXPRS)
      integer                   RCHST   (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)         DSCID   (MAXPRS)
      real                      DSCGEN  (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                   NUMPER
c  *** end of declarations for common data ***
```

```
      integer             PERDEX, THSNOD, ADJNOD,
     1                    BSTDEX, LASTNR, NEARND (MAXPRS)
      integer             THSEDG, THSNBR
      integer             RELSHP
      real                MINDIS

      integer             SRCHNG, SUCCES, FAILED
      parameter          (SRCHNG = 1, SUCCES = 2, FAILED = 3)

      integer             SRCHST

c  begin execution of FINDRL

c     initialize PERSON-array for processing -
c     mark all nodes as not seen
      do 100 PERDEX = 1, NUMPER
         RCHST (PERDEX) = NOSEEN
100   continue
      THSNOD = SRCDEX
c     mark source node as reached
      RCHST  (THSNOD) = REACHD
      DSTSRC (THSNOD) = 0.0
c     no NEARBY nodes exist yet
      LASTNR = 0
      if (THSNOD .eq. TRGDEX) then
         SRCHST = SUCCES
      else
         SRCHST = SRCHNG
      end if
```

```
c     Loop keeps processing closest-to-source, unreached node
c     until target reached, or no more connected nodes.
200   continue
         if (SRCHST .ne. SRCHNG) goto 201
c        Process all nodes adjacent to THSNOD
         do 210 THSNBR = 1, NBRCNT (THSNOD)
            call PROCAD (THSNOD, NBRDEX  (THSNOD, THSNBR),
     1                   NBREDG (THSNOD, THSNBR), NEARND, LASTNR)
210      continue

c        All nodes adjacent to THSNOD are set.  Now search for
c        shortest-distance unreached (but NEARBY) node to process next.
         if (LASTNR .eq. 0) then
            SRCHST = FAILED
         else
c           determine next node to process
            MINDIS = 1.0E+18
            do 220 PERDEX = 1, LASTNR
               if (DSTSRC (NEARND (PERDEX)) .lt. MINDIS) then
                  BSTDEX = PERDEX
                  MINDIS = DSTSRC (NEARND (PERDEX))
               end if
220         continue
c           establish new THSNOD
            THSNOD = NEARND (BSTDEX)
c           change THSNOD from being NEARBY to reached
            RCHST (THSNOD) = REACHD
c           remove THSNOD from NEARBY list
            NEARND (BSTDEX) = NEARND (LASTNR)
            LASTNR = LASTNR - 1
            if (THSNOD .eq. TRGDEX) SRCHST = SUCCES
         end if
      goto 200
201   continue

c     Shortest path between PERSONs now established.  Next task is
c     to translate path to English description of relationship.
      if (SRCHST .eq. FAILED) then
         write (unit=*, fmt=9001) NAME (TRGDEX), NAME (SRCDEX)
9001     format (a22, ' is not related to ', a20)
      else
c        success - parse path to find and display relationship
         call RESOLV (SRCDEX, TRGDEX)
c        compute proportion of common genetic material
         call CMPTGN (SRCDEX, TRGDEX)
      end if
      end
```

```
c   procedures under FINDRL

      subroutine PROCAD (BASNOD, NXTNOD, NBEDGE, NEARND, LASTNR)
c     NXTNOD is adjacent to last-reached node (= BASNOD).
c     If NXTNOD already reached, do nothing.
c     If previously seen, check whether path thru BASNOD is
c     shorter than current path to NXTNOD, and if so re-link
c     next to base.
c     If not previously seen, link next to base node.

      integer    NXTNOD, BASNOD, NEARND(*), LASTNR
      integer    NBEDGE

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

c   A node in the graph (= PERSON) has either already been reached,
c   is immediately adjacent to those reached, or farther away.

      integer    REACHD, NEARBY, NOSEEN
      parameter (REACHD = 1, NEARBY = 2, NOSEEN = 3)

c   These common blocks hold the PERSON array, which is global to
c   the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID

c   The following data items constitute the PERSON array, which
c   is the central repository of information about inter-relationships.

c   static information - filled from PEOPLE file
      character*(NAMLEN)       NAME    (MAXPRS)
      character*(IDLEN)        IDENT   (MAXPRS)
      character*1              GENDER  (MAXPRS)
c   IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)        RELID   (MAXPRS, MAXGVN)
c   pointers to immediate neighbors in graph
      integer                  NBRCNT  (MAXPRS)
      integer                  NBRDEX  (MAXPRS, MAXNBR)
      integer                  NBREDG  (MAXPRS, MAXNBR)
c   data used when traversing graph to resolve user request:
      real                     DSTSRC  (MAXPRS)
      integer                  PATHPR  (MAXPRS)
      integer                  EDGPRD  (MAXPRS)
      integer                  RCHST   (MAXPRS)
c   data used to compute common genetic material
      character*(IDLEN)        DSCID   (MAXPRS)
      real                     DSCGEN  (MAXPRS)
```

```
c  NUMPER keeps track of the actual number of persons
      integer                    NUMPER

c  *** end of declarations for common data ***

      real        WGHTEG, DSTBAS

c     begin execution of PROCAD
      if (RCHST (NXTNOD) .ne. REACHD) then
         if (NBEDGE .eq. SPOUSE) then
            WGHTEG = 1.8
         else
            WGHTEG = 1.0
         end if
         DSTBAS = WGHTEG + DSTSRC (BASNOD)
         if (RCHST (NXTNOD) .eq. NOSEEN) then
c           change status of THSNOD from not-seen to NEARBY
            RCHST (NXTNOD) = NEARBY
            LASTNR = LASTNR + 1
            NEARND (LASTNR) = NXTNOD
c           link next to base by re-setting its predecessor index to
c           point to base, note type of edge, and re-set distance
c           as it is through base node.
            DSTSRC (NXTNOD) = DSTBAS
            PATHPR (NXTNOD) = BASNOD
            EDGPRD (NXTNOD) = NBEDGE
         else
c           RCHST is NEARBY
            if (DSTBAS .lt. DSTSRC (NXTNOD)) then
c              link next to base by re-setting its predecessor index to
c              point to base, note type of edge, and re-set distance
c              as it is through base node.
               DSTSRC (NXTNOD) = DSTBAS
               PATHPR (NXTNOD) = BASNOD
               EDGPRD (NXTNOD) = NBEDGE
            end if
         end if
      end if
      end
```

```
      subroutine RESOLV (SRCDEX, TRGDEX)
c     RESOLV condenses the shortest path to a series of
c     relationships for which there are English descriptions.

      integer    SRCDEX, TRGDEX

c  Establish global constants

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      character  MALE*1,      FEMALE*1
      parameter (MALE = 'M', FEMALE = 'F')

      integer    PARENT, CHILD, SPOUSE, SIBLNG,
     1           UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1           UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)

c  sibling proximity can have three values

      integer    STEP, HALF, FULL
      parameter (STEP = 1, HALF = 2, FULL = 3)

c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID
```

```
c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)        NAME    (MAXPRS)
      character*(IDLEN)         IDENT   (MAXPRS)
      character*1               GENDER  (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)         RELID   (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                   NBRCNT  (MAXPRS)
      integer                   NBRDEX  (MAXPRS, MAXNBR)
      integer                   NBREDG  (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                      DSTSRC  (MAXPRS)
      integer                   PATHPR  (MAXPRS)
      integer                   EDGPRD  (MAXPRS)
      integer                   RCHST   (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)         DSCID   (MAXPRS)
      real                      DSCGEN  (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                   NUMPER

c  *** end of declarations for common data ***

c     these variables are used to generate key-person data
      integer             GENCNT, THSCUZ
      integer             THSPRX

c     these variables are used to condense the path

      common /KEYPER/ RELNXT, PERDEX, GENGAP, PRXMTY, CUZRNK

c     Key persons are the ones in the relationship path which remain
c     after the path is condensed.

      integer             RELNXT (MAXPRS)
      integer             PERDEX (MAXPRS)
      integer             GENGAP (MAXPRS)
      integer             PRXMTY (MAXPRS)
      integer             CUZRNK (MAXPRS)

      integer             KEYREL, LATREL, PRIREL, NXTPRI
      integer             KEYDEX, LATDEX, PRIDEX, THSNOD
      integer             GAP1, GAP2

      logical             SEEKMR, FULSIB
```

```
c     begin execution of RESOLV
      write (unit=*,
     1       fmt='('' Shortest path between identified persons: '')')
c     Display path and initialize key person arrays from path elements.
      THSNOD  = TRGDEX
      do 100 KEYDEX = 1, MAXPRS
         if (THSNOD .eq. SRCDEX) goto 101
         PERDEX (KEYDEX) = THSNOD
         PRXMTY (KEYDEX) = FULL
         RELNXT (KEYDEX) = EDGPRD (THSNOD)
         if (EDGPRD (THSNOD) .eq. SPOUSE) then
            write (unit=*, fmt='(a22, '' is spouse of'')') NAME (THSNOD)
            GENGAP (KEYDEX) = 0
         else
            GENGAP (KEYDEX) = 1
            if (EDGPRD (THSNOD) .eq. PARENT) then
               write (unit=*, fmt='(a22, '' is parent of'')')
     1                 NAME (THSNOD)
            else
               write (unit=*, fmt='(a22, '' is child of'')')
     1                 NAME (THSNOD)
            end if
         end if
         THSNOD = PATHPR (THSNOD)
100   continue
101   continue
      write (unit=*, fmt='(a22)') NAME (THSNOD)
      PERDEX (KEYDEX)     = THSNOD
      RELNXT (KEYDEX)     = NULLRL
      RELNXT (KEYDEX + 1) = NULLRL
```

```
c     resolve CHILD-PARENT and CHILD-SPOUSE-PARENT relations
c     to SIBLNG relations.
      do 200 KEYDEX = 1, MAXPRS
         if (RELNXT (KEYDEX) .eq. NULLRL) goto 201
         if (RELNXT (KEYDEX) .eq. CHILD) then
            LATREL = RELNXT (KEYDEX + 1)
            if (LATREL .eq. PARENT) then
c              found either full or half SIBLNGs
               if (FULSIB (PERDEX (KEYDEX), PERDEX (KEYDEX + 2))) then
                  PRXMTY (KEYDEX) = FULL
               else
                  PRXMTY (KEYDEX) = HALF
               end if
               GENGAP (KEYDEX) = 0
               RELNXT (KEYDEX) = SIBLNG
               call CONDNS (KEYDEX, 1)
            else if (LATREL .eq. SPOUSE .and.
     1               RELNXT (KEYDEX + 2) .eq. PARENT) then
c              found step-SIBLNGs
               GENGAP (KEYDEX) = 0
               PRXMTY (KEYDEX) = STEP
               RELNXT (KEYDEX) = SIBLNG
               call CONDNS (KEYDEX, 2)
            end if
         end if
200   continue
201   continue

c     resolve CHILD-CHILD-... and PARENT-PARENT-... relations to
c     direct descendant or ancestor relations.
      do 300 KEYDEX = 1, MAXPRS
         if (RELNXT (KEYDEX) .eq. NULLRL) goto 301
         if (RELNXT (KEYDEX) .eq. CHILD .or.
     1        RELNXT (KEYDEX) .eq. PARENT) then
            do 310 LATDEX = KEYDEX + 1, MAXPRS
               if (RELNXT (LATDEX) .ne. RELNXT (KEYDEX)) goto 311
310         continue
311         continue
            GENCNT = LATDEX - KEYDEX
            if (GENCNT .gt. 1) then
c              compress generations
               GENGAP (KEYDEX) = GENCNT
               call CONDNS (KEYDEX, GENCNT - 1)
            end if
         end if
300   continue
301   continue
```

```
c     resolve CHILD-SIBLNG-PARENT to COUSIN,
c             CHILD-SIBLNG        to NEPHEW,
c             SIBLNG-PARENT       to UNCLE.
      do 400 KEYDEX = 1, MAXPRS
         if (RELNXT (KEYDEX) .eq. NULLRL) goto 401
         LATREL = RELNXT (KEYDEX + 1)
         if (RELNXT (KEYDEX) .eq. CHILD .and. LATREL .eq. SIBLNG) then
c           found COUSIN or NEPHEW
            PRXMTY (KEYDEX) = PRXMTY (KEYDEX + 1)
            if (RELNXT (KEYDEX + 2) .eq. PARENT) then
c              found COUSIN
               GAP1 = GENGAP (KEYDEX)
               GAP2 = GENGAP (KEYDEX + 2)
               GENGAP (KEYDEX) = abs (GAP1 - GAP2)
               CUZRNK (KEYDEX) = min (GAP1, GAP2)
               RELNXT (KEYDEX) = COUSIN
               call CONDNS (KEYDEX, 2)
            else
c              found NEPHEW
               RELNXT (KEYDEX) = NEPHEW
               call CONDNS (KEYDEX, 1)
            end if
         else
            if (RELNXT (KEYDEX) .eq. SIBLNG .and.
     1          LATREL .eq. PARENT) then
c              found UNCLE
               GENGAP (KEYDEX) = GENGAP (KEYDEX + 1)
               RELNXT (KEYDEX) = UNCLE
               call CONDNS (KEYDEX, 1)
            end if
         end if
400   continue
401   continue
```

```
c     Loop below will pick out valid adjacent strings of elements
c     to be displayed.  KEYDEX points to first element,
c     LATDEX to last element, and PRIDEX to the
c     element which determines the primary English word to be used.
c     Associativity of adjacent elements in condensed table
c     is based on English usage.

      KEYDEX = 1
      write (unit=*, fmt='(''  Condensed path:'')')
500   continue
         if (RELNXT (KEYDEX) .eq. NULLRL) goto 501
         KEYREL = RELNXT (KEYDEX)
         LATDEX = KEYDEX
         PRIDEX = KEYDEX
         if (RELNXT (KEYDEX + 1) .ne. NULLRL) then
c           seek multi-element combination
            SEEKMR = .true.
            if (KEYREL .eq. SPOUSE) then
               LATDEX = LATDEX + 1
               PRIDEX = LATDEX
c              Nothing can follow SPOUSE-SIBLNG or SPOUSE-COUSIN
               SEEKMR = .not. (RELNXT (LATDEX) .eq. SIBLNG .or.
     1                         RELNXT (LATDEX) .eq. COUSIN)
            end if

c           PRIDEX is now correctly set.  Next if-statement
c           determines if a following SPOUSE relation should be
c           appended to this combination or left for the next
c           combination.
            if (SEEKMR .and. RELNXT (PRIDEX + 1) .eq. SPOUSE) then
c              Only a SPOUSE can follow a Primary.
c              Check primary preceding and following SPOUSE.
               PRIREL = RELNXT (PRIDEX)
               NXTPRI = RELNXT (PRIDEX + 2)
               if ((NXTPRI .eq. NEPHEW .or.
     1              NXTPRI .eq. COUSIN .or.
     2              NXTPRI .eq. NULLRL)
     3            .or. (PRIREL .eq. NEPHEW)
     4            .or. ((PRIREL .eq. SIBLNG .or. PRIREL .eq. PARENT)
     5                  .and. NXTPRI .ne. UNCLE )) then
c                 append following SPOUSE with this combination.
                  LATDEX = LATDEX + 1
               end if
            end if
         end if
c        end multi-element combination
         call SHOWRE (KEYDEX, LATDEX, PRIDEX)
         KEYDEX = LATDEX + 1
      goto 500
501   continue
      write (unit=*, fmt='(a22)') NAME (PERDEX (KEYDEX))
      end
c     end of RESOLV
```

```
      logical function FULSIB (INDEX1, INDEX2)
c     Determines whether two PERSONs are full siblings, i.e.,
c     have the same two parents.

      integer    INDEX1, INDEX2

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      integer    FATHID, MOTHID, SPOUID
      parameter (FATHID = 1, MOTHID = 2, SPOUID = 3)

c   These common blocks hold the PERSON array, which is global to
c   the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID

c   The following data items constitute the PERSON array, which
c   is the central repository of information about inter-relationships.

c   static information - filled from PEOPLE file
      character*(NAMLEN)       NAME    (MAXPRS)
      character*(IDLEN)        IDENT   (MAXPRS)
      character*1              GENDER  (MAXPRS)
c   IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)        RELID   (MAXPRS, MAXGVN)
c   pointers to immediate neighbors in graph
      integer                  NBRCNT  (MAXPRS)
      integer                  NBRDEX  (MAXPRS, MAXNBR)
      integer                  NBREDG  (MAXPRS, MAXNBR)
c   data used when traversing graph to resolve user request:
      real                     DSTSRC  (MAXPRS)
      integer                  PATHPR  (MAXPRS)
      integer                  EDGPRD  (MAXPRS)
      integer                  RCHST   (MAXPRS)
c   data used to compute common genetic material
      character*(IDLEN)        DSCID   (MAXPRS)
      real                     DSCGEN  (MAXPRS)
c   NUMPER keeps track of the actual number of persons
      integer                  NUMPER

c   *** end of declarations for common data ***

      FULSIB =
     1   RELID (INDEX1, FATHID) .ne. NULLID                    .and.
     2   RELID (INDEX1, MOTHID) .ne. NULLID                    .and.
     3   RELID (INDEX1, FATHID) .eq. RELID (INDEX2, FATHID) .and.
     4   RELID (INDEX1, MOTHID) .eq. RELID (INDEX2, MOTHID)
      end
```

```
      subroutine CONDNS (ATDEX, GAPSIZ)
c     CONDNS condenses superfluous entries from the
c     key person arrays, starting at ATDEX.

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      integer    PARENT, CHILD, SPOUSE, SIBLNG,
     1           UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1           UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)

      common /KEYPER/ RELNXT, PERDEX, GENGAP, PRXMTY, CUZRNK

c     Key persons are the ones in the relationship path which remain
c     after the path is condensed.

      integer           RELNXT (MAXPRS)
      integer           PERDEX (MAXPRS)
      integer           GENGAP (MAXPRS)
      integer           PRXMTY (MAXPRS)
      integer           CUZRNK (MAXPRS)

      integer           ATDEX, GAPSIZ, SENDEX, RCVDEX

      RCVDEX = ATDEX
100   continue
         RCVDEX = RCVDEX + 1
         SENDEX = RCVDEX + GAPSIZ
         RELNXT (RCVDEX) = RELNXT (SENDEX)
         PERDEX (RCVDEX) = PERDEX (SENDEX)
         GENGAP (RCVDEX) = GENGAP (SENDEX)
         PRXMTY (RCVDEX) = PRXMTY (SENDEX)
         CUZRNK (RCVDEX) = CUZRNK (SENDEX)
         if (RELNXT (SENDEX) .ne. NULLRL) goto 100
      end
```

```
c  procedures under RESOLV

      subroutine SHOWRE (FSTDEX, LSTDEX, PRIDEX)
c     SHOWRE takes 1, 2, or 3 adjacent elements in the
c     condensed table and generates the English description of
c     the relation between the first and last + 1 elements.

c  Establish global constants

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      character  MALE*1,     FEMALE*1
      parameter (MALE = 'M', FEMALE = 'F')

      integer    PARENT, CHILD, SPOUSE, SIBLNG,
     1           UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1           UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)

c  sibling proximity can have three values

      integer    STEP, HALF, FULL
      parameter (STEP = 1, HALF = 2, FULL = 3)

c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID
```

```
c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)        NAME     (MAXPRS)
      character*(IDLEN)         IDENT    (MAXPRS)
      character*1               GENDER   (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)         RELID    (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                   NBRCNT   (MAXPRS)
      integer                   NBRDEX   (MAXPRS, MAXNBR)
      integer                   NBREDG   (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                      DSTSRC   (MAXPRS)
      integer                   PATHPR   (MAXPRS)
      integer                   EDGPRD   (MAXPRS)
      integer                   RCHST    (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)         DSCID    (MAXPRS)
      real                      DSCGEN   (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                   NUMPER

      common /KEYPER/ RELNXT, PERDEX, GENGAP, PRXMTY, CUZRNK

c     Key persons are the ones in the relationship path which remain
c     after the path is condensed.

      integer             RELNXT (MAXPRS)
      integer             PERDEX (MAXPRS)
      integer             GENGAP (MAXPRS)
      integer             PRXMTY (MAXPRS)
      integer             CUZRNK (MAXPRS)

c  *** end of declarations for common data ***

      logical             INLAW
      integer             THSPRX, THSGAP, THSCUZ
      character           TWODIG*2
      integer             SUFPTR
      character           SUFCHR*12
      integer             FSTDEX, LSTDEX, PRIDEX
      integer             FSTREL, LSTREL, PRIREL
      character*75        OUTBUF
      integer             OUTPTR
```

```
c  begin execution of SHOWRE

      FSTREL = RELNXT (FSTDEX)
      LSTREL = RELNXT (LSTDEX)
      PRIREL = RELNXT (PRIDEX)

c     set THSPRX
      if ((PRIREL .eq. PARENT .and. FSTREL .eq. SPOUSE) .or.
     1    (PRIREL .eq. CHILD  .and. LSTREL .eq. SPOUSE)) then
         THSPRX = STEP
      else
         if (PRIREL .eq. SIBLNG .or. PRIREL .eq. UNCLE .or.
     1        PRIREL .eq. NEPHEW .or. PRIREL .eq. COUSIN) then
            THSPRX = PRXMTY (PRIDEX)
         else
            THSPRX = FULL
         end if
      end if

c     set THSGAP
      if (PRIREL .eq. PARENT .or. PRIREL .eq. CHILD  .or.
     1    PRIREL .eq. UNCLE  .or. PRIREL .eq. NEPHEW .or.
     2    PRIREL .eq. COUSIN) then
         THSGAP = GENGAP (PRIDEX)
      else
         THSGAP = 0
      end if

c     set INLAW
      if (FSTREL .eq. SPOUSE .and.
     1       (PRIREL .eq. SIBLNG .or. PRIREL .eq. CHILD .or.
     2        PRIREL .eq. NEPHEW .or. PRIREL .eq. COUSIN)) then
         INLAW = .true.
      else
         if (LSTREL .eq. SPOUSE .and.
     1          (PRIREL .eq. SIBLNG .or. PRIREL .eq. PARENT .or.
     2           PRIREL .eq. UNCLE  .or. PRIREL .eq. COUSIN)) then
            INLAW = .true.
         else
            INLAW = .false.
         end if
      end if

c     set THSCUZ
      if (PRIREL .eq. COUSIN) then
         THSCUZ = CUZRNK (PRIDEX)
      else
         THSCUZ = 0
      end if
```

```
c     parameters are set - now generate display.

      OUTBUF = NAME (PERDEX (FSTDEX)) // ' is '
      OUTPTR = NAMLEN + 5
      if (PRIREL .eq. PARENT .or. PRIREL .eq. CHILD .or.
     1    PRIREL .eq. UNCLE .or.  PRIREL .eq. NEPHEW) then
c        display generation-qualifier
         if (THSGAP .ge. 3) then
            call APPEND (OUTBUF, OUTPTR, 'great')
            if (THSGAP .gt. 3) then
               write (unit=TWODIG, fmt='(i2)') THSGAP - 2
               call APPEND (OUTBUF, OUTPTR, '*' // TWODIG)
            end if
            call APPEND (OUTBUF, OUTPTR, '-')
         end if
         if (THSGAP .ge. 2) then
            call APPEND (OUTBUF, OUTPTR, 'grand-')
         end if
      else
         if (PRIREL .eq. COUSIN .and. THSCUZ .gt. 1) then
c           display cousin-degree
            write (unit=TWODIG, fmt='(i2)') THSCUZ
            call APPEND (OUTBUF, OUTPTR, TWODIG)
            SUFPTR = mod (THSCUZ, 10)
            if (SUFPTR .gt. 3) SUFPTR = 0
            SUFPTR = 3 * SUFPTR + 1
            SUFCHR = 'th st nd rd '
            call APPEND (OUTBUF, OUTPTR, SUFCHR (SUFPTR : SUFPTR + 2))
         end if
      end if

      if (THSPRX .eq. STEP) then
         call APPEND (OUTBUF, OUTPTR, 'step-')
      else
         if (THSPRX .eq. HALF) then
            call APPEND (OUTBUF, OUTPTR, 'half-')
         end if
      end if
```

```
      if (GENDER (PERDEX (FSTDEX)) .eq. MALE) then
         goto (201,202,203,204,205,206,297,298), PRIREL
201      continue
            call APPEND (OUTBUF, OUTPTR, ´father´)
            goto 300
202      continue
            call APPEND (OUTBUF, OUTPTR, ´son´)
            goto 300
203      continue
            call APPEND (OUTBUF, OUTPTR, ´husband´)
            goto 300
204      continue
            call APPEND (OUTBUF, OUTPTR, ´brother´)
            goto 300
205      continue
            call APPEND (OUTBUF, OUTPTR, ´uncle´)
            goto 300
206      continue
            call APPEND (OUTBUF, OUTPTR, ´nephew´)
            goto 300
      else
c        gender is FEMALE
         goto (251,252,253,254,255,256,297,298), PRIREL
251      continue
            call APPEND (OUTBUF, OUTPTR, ´mother´)
            goto 300
252      continue
            call APPEND (OUTBUF, OUTPTR, ´daughter´)
            goto 300
253      continue
            call APPEND (OUTBUF, OUTPTR, ´wife´)
            goto 300
254      continue
            call APPEND (OUTBUF, OUTPTR, ´sister´)
            goto 300
255      continue
            call APPEND (OUTBUF, OUTPTR, ´aunt´)
            goto 300
256      continue
            call APPEND (OUTBUF, OUTPTR, ´niece´)
            goto 300
      end if
297   continue
         call APPEND (OUTBUF, OUTPTR, ´cousin´)
         goto 300
298   continue
         call APPEND (OUTBUF, OUTPTR, ´null´)
         goto 300
300   continue
```

```
      if (INLAW) call APPEND (OUTBUF, OUTPTR, '-in-law')

      if (PRIREL .eq. COUSIN .and. THSGAP .gt. 0) then
         if (THSGAP .gt. 1) then
            write (unit=TWODIG, fmt='(i2)') THSGAP
            call APPEND (OUTBUF, OUTPTR, ' '//TWODIG//' times removed')
         else
            call APPEND (OUTBUF, OUTPTR, ' once removed')
         end if
      end if

      call APPEND (OUTBUF, OUTPTR, ' of')
      write (unit=*, fmt='(a77)') OUTBUF
      end

      subroutine APPEND (STRING, PTR, ADDEND)
c     APPEND appends the contents of ADDEND to STRING in the position
c     indicated by PTR, and increments PTR

      character      STRING*(*), ADDEND*(*)
      integer        PTR, ADDLEN

      ADDLEN = len (ADDEND)
      STRING (PTR : PTR + ADDLEN - 1) = ADDEND
      PTR = PTR + ADDLEN
      end

c  procedures under FINDRL

      subroutine CMPTGN (INDEX1, INDEX2)
c     CMPTGN assumes that each ancestor contributes
c     half of the genetic material to a PERSON.  It finds common
c     ancestors between two PERSONs and computes the expected
c     value of the proportion of common material.

      integer    INDEX1, INDEX2

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID
```

```
c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)        NAME    (MAXPRS)
      character*(IDLEN)         IDENT   (MAXPRS)
      character*1               GENDER  (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)         RELID   (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                   NBRCNT  (MAXPRS)
      integer                   NBRDEX  (MAXPRS, MAXNBR)
      integer                   NBREDG  (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                      DSTSRC  (MAXPRS)
      integer                   PATHPR  (MAXPRS)
      integer                   EDGPRD  (MAXPRS)
      integer                   RCHST   (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)         DSCID   (MAXPRS)
      real                      DSCGEN  (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                   NUMPER

c  STACK is common to the routines which calculate genetic overlap.
c  It is used to implement recursive traversal of the ancestor trees.

      integer     STKSIZ
      parameter (STKSIZ = 50)

      common /STACK/ PROPTN, CONTRB, COUNTD, PERDEX, NXTNBR,
     1               STKPTR

      real        PROPTN  (STKSIZ)
      real        CONTRB  (STKSIZ)
      real        COUNTD  (STKSIZ)
      integer     PERDEX  (STKSIZ)
      integer     NXTNBR  (STKSIZ)
      integer     STKPTR

c  *** end of declarations for common data ***

      real        COMPRP
```

```
c     First zero out all ancestors to allow adding.  This is necessary
c     because there might be two paths to an ancestor.
      STKPTR = 1
      PERDEX (STKPTR) = INDEX1
      NXTNBR (STKPTR) = 0
100   continue
         call ZERPRO
         if (STKPTR .ge. 1) goto 100
101   continue
c     now mark with shared PROPTN
      STKPTR = 1
      PERDEX (STKPTR) = INDEX1
      NXTNBR (STKPTR) = 0
      PROPTN (STKPTR) = 1.0
200   continue
         call MRKPRO (IDENT (INDEX1))
         if (STKPTR .ge. 1) goto 200
201   continue
c     traverse ancestor tree for INDEX2. summing overlap with
c     marked tree of INDEX1
      COMPRP = 0.0
      STKPTR = 1
      PERDEX (STKPTR) = INDEX2
      NXTNBR (STKPTR) = 0
      PROPTN (STKPTR) = 1.0
      COUNTD (STKPTR) = 0.0
300   continue
         call CHKCOM (COMPRP, IDENT (INDEX1))
         if (STKPTR .ge. 1) goto 300
301   continue
      write (unit=*, fmt=9001) COMPRP
9001  format('  Proportion of common genetic material = ', 1p, e12.5e2)
      end

      subroutine ZERPRO
c     ZERPRO recursively seeks out all ancestors and
c     zeros them out.

      integer     MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1            MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1            MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      integer     PARENT, CHILD, SPOUSE, SIBLNG,
     1            UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1            UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)
```

```
c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID

c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)       NAME    (MAXPRS)
      character*(IDLEN)        IDENT   (MAXPRS)
      character*1              GENDER  (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)        RELID   (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                  NBRCNT  (MAXPRS)
      integer                  NBRDEX  (MAXPRS, MAXNBR)
      integer                  NBREDG  (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                     DSTSRC  (MAXPRS)
      integer                  PATHPR  (MAXPRS)
      integer                  EDGPRD  (MAXPRS)
      integer                  RCHST   (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)        DSCID   (MAXPRS)
      real                     DSCGEN  (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                  NUMPER

c  STACK is common to the routines which calculate genetic overlap.
c  It is used to implement recursive traversal of the ancestor trees.

      integer    STKSIZ
      parameter (STKSIZ = 50)

      common /STACK/ PROPTN, CONTRB, COUNTD, PERDEX, NXTNBR,
     1               STKPTR

      real       PROPTN  (STKSIZ)
      real       CONTRB  (STKSIZ)
      real       COUNTD  (STKSIZ)
      integer    PERDEX  (STKSIZ)
      integer    NXTNBR  (STKSIZ)
      integer    STKPTR

c  *** end of declarations for common data ***
```

```
      integer      ZERDEX, THSNBR

      ZERDEX = PERDEX (STKPTR)
      if (NXTNBR (STKPTR) .eq. 0) then
         DSCGEN (ZERDEX) = 0.0
         NXTNBR (STKPTR) = 1
      end if
      do 100 THSNBR = NXTNBR (STKPTR), NBRCNT (ZERDEX)
         if (NBREDG (ZERDEX, THSNBR) .eq. PARENT) goto 101
100   continue
101   continue
      if (THSNBR .gt. NBRCNT (ZERDEX)) then
c        no more ancestors from this person
         STKPTR = STKPTR - 1
      else
c        set up for next ancestor
         NXTNBR (STKPTR) = THSNBR + 1
         STKPTR = STKPTR + 1
         PERDEX (STKPTR) = NBRDEX (ZERDEX, THSNBR)
         NXTNBR (STKPTR) = 0
      end if
      end

      subroutine MRKPRO (MARKER)
c     MRKPRO recursively seeks out all ancestors and
c     marks them with the sender's proportion of shared
c     genetic material.  This proportion is diluted by one-half
c     for each generation.

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      integer    PARENT, CHILD, SPOUSE, SIBLNG,
     1           UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1           UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)

c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID
```

```
c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)        NAME    (MAXPRS)
      character*(IDLEN)         IDENT   (MAXPRS)
      character*1               GENDER  (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)         RELID   (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                   NBRCNT  (MAXPRS)
      integer                   NBRDEX  (MAXPRS, MAXNBR)
      integer                   NBREDG  (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                      DSTSRC  (MAXPRS)
      integer                   PATHPR  (MAXPRS)
      integer                   EDGPRD  (MAXPRS)
      integer                   RCHST   (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)         DSCID   (MAXPRS)
      real                      DSCGEN  (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                   NUMPER

c  STACK is common to the routines which calculate genetic overlap.
c  It is used to implement recursive traversal of the ancestor trees.

      integer    STKSIZ
      parameter (STKSIZ = 50)

      common /STACK/ PROPTN, CONTRB, COUNTD, PERDEX, NXTNBR,
     1               STKPTR

      real       PROPTN  (STKSIZ)
      real       CONTRB  (STKSIZ)
      real       COUNTD  (STKSIZ)
      integer    PERDEX  (STKSIZ)
      integer    NXTNBR  (STKSIZ)
      integer    STKPTR

c  *** end of declarations for common data ***

      character*(IDLEN)     MARKER
      integer               MRKDEX, THSNBR
```

```
      MRKDEX = PERDEX (STKPTR)
      if (NXTNBR (STKPTR) .eq. 0) then
         DSCID  (MRKDEX) = MARKER
         DSCGEN (MRKDEX) = DSCGEN (MRKDEX) + PROPTN (STKPTR)
         NXTNBR (STKPTR) = 1
      end if
      do 100 THSNBR = NXTNBR (STKPTR), NBRCNT (MRKDEX)
         if (NBREDG (MRKDEX, THSNBR) .eq. PARENT) goto 101
100   continue
101   continue
      if (THSNBR .gt. NBRCNT (MRKDEX)) then
c        no more ancestors from this person
         STKPTR = STKPTR - 1
      else
c        set up for next ancestor
         NXTNBR (STKPTR) = THSNBR + 1
         STKPTR = STKPTR + 1
         PERDEX (STKPTR) = NBRDEX (MRKDEX, THSNBR)
         NXTNBR (STKPTR) = 0
         PROPTN (STKPTR) = PROPTN (STKPTR - 1) / 2.0
      end if
      end

      subroutine CHKCOM (COMPRP, MTCHID)
c     CHKCOM searches all the ancestors of CHKDEX to see if any have
c     been marked, and if so adds the appropriate amount to COMPRP.

      integer    MAXPRS, NAMLEN, IDLEN, BUFLEN,
     1           MSGLEN, MAXNBR, MAXGVN
      parameter (MAXPRS = 300, NAMLEN = 20, IDLEN = 3, BUFLEN = 60,
     1           MSGLEN = 40, MAXNBR = 20, MAXGVN = 3)

      character  NULLID*(IDLEN)
      parameter (NULLID = '000')

      integer    PARENT, CHILD, SPOUSE, SIBLNG,
     1           UNCLE, NEPHEW, COUSIN, NULLRL
      parameter (PARENT = 1, CHILD = 2, SPOUSE = 3, SIBLNG = 4,
     1           UNCLE = 5, NEPHEW = 6, COUSIN = 7, NULLRL = 8)

c  These common blocks hold the PERSON array, which is global to
c  the entire program.
      common /PERNUM/  NBRCNT, NBRDEX, NBREDG, DSTSRC, PATHPR,
     1                 EDGPRD, RCHST, DSCGEN, NUMPER

      common /PERCHR/  NAME, IDENT, GENDER, RELID, DSCID
```

```
c  The following data items constitute the PERSON array, which
c  is the central repository of information about inter-relationships.

c  static information - filled from PEOPLE file
      character*(NAMLEN)        NAME     (MAXPRS)
      character*(IDLEN)         IDENT    (MAXPRS)
      character*1               GENDER   (MAXPRS)
c  IDENTs of immediate relatives - father, mother, spouse
      character*(IDLEN)         RELID    (MAXPRS, MAXGVN)
c  pointers to immediate neighbors in graph
      integer                   NBRCNT   (MAXPRS)
      integer                   NBRDEX   (MAXPRS, MAXNBR)
      integer                   NBREDG   (MAXPRS, MAXNBR)
c  data used when traversing graph to resolve user request:
      real                      DSTSRC   (MAXPRS)
      integer                   PATHPR   (MAXPRS)
      integer                   EDGPRD   (MAXPRS)
      integer                   RCHST    (MAXPRS)
c  data used to compute common genetic material
      character*(IDLEN)         DSCID    (MAXPRS)
      real                      DSCGEN   (MAXPRS)

c  NUMPER keeps track of the actual number of persons
      integer                   NUMPER

c  STACK is common to the routines which calculate genetic overlap.
c  It is used to implement recursive traversal of the ancestor trees.

      integer    STKSIZ
      parameter (STKSIZ = 50)

      common /STACK/ PROPTN, CONTRB, COUNTD, PERDEX, NXTNBR,
     1               STKPTR

      real       PROPTN  (STKSIZ)
      real       CONTRB  (STKSIZ)
      real       COUNTD  (STKSIZ)
      integer    PERDEX  (STKSIZ)
      integer    NXTNBR  (STKSIZ)
      integer    STKPTR

c  *** end of declarations for common data ***

      real                COMPRP
      character*(IDLEN)   MTCHID
      integer             CHKDEX
```

```
      CHKDEX = PERDEX (STKPTR)
      if (NXTNBR (STKPTR) .eq. 0) then
         NXTNBR (STKPTR) = 1
         if (DSCID (CHKDEX) .eq. MTCHID) then
c           Increment COMPRP by the contribution of this
c           common ancestor, but discount for the contribution
c           of less remote ancestors already counted.
            CONTRB (STKPTR) = DSCGEN (CHKDEX) * PROPTN (STKPTR)
            COMPRP = COMPRP + CONTRB (STKPTR) - COUNTD (STKPTR)
         else
            CONTRB (STKPTR) = 0.0
         end if
      end if
      do 100 THSNBR = NXTNBR (STKPTR), NBRCNT (CHKDEX)
         if (NBREDG (CHKDEX, THSNBR) .eq. PARENT) goto 101
100   continue
101   continue
      if (THSNBR .gt. NBRCNT (CHKDEX)) then
c        no more ancestors from this person
         STKPTR = STKPTR - 1
      else
c        set up for next ancestor
         NXTNBR (STKPTR) = THSNBR + 1
         STKPTR = STKPTR + 1
         PERDEX (STKPTR) = NBRDEX (CHKDEX, THSNBR)
         NXTNBR (STKPTR) = 0
         PROPTN (STKPTR) = PROPTN (STKPTR - 1) / 2.0
         COUNTD (STKPTR) = CONTRB (STKPTR - 1) / 4.0
      end if
      end
```

7.0 PASCAL

User-defined identifiers are written in mixed upper and lower case, rather than all upper-case, because Pascal provides no separator character, such as "-" or "_" for identifiers. Therefore, upper-case letters are used for readability, e.g., EdgeToPredecessor is used in Pascal where EDGE_TO_PREDECESSOR is used in most of the other languages.

```
program Relate (input, output, People);

const
  MaxPersons        = 300;
  NameLength        = 20;
  { every Person has a unique 3-digit Identifier }
  IdentifierLength  = 3;
  BufferLength      = 60;
  RequestOk         =
    'Request OK
  RequestToStop     =
    'stop

type
  IdentifierRange   = 1..IdentifierLength;
  BufferRange       = 1..BufferLength;
  NameRange         = 1..NameLength;
  DigitType         = '0'..'9';
  NameType          = packed array [NameRange] of char;
  BufferType        = packed array [BufferRange] of char;
  MessageType       = packed array [1..40] of char;
  IdentifierType    = array [IdentifierRange] of DigitType;
  { each Person's record in the file identifies at most three
    others directly related: father, mother, and spouse }
  GivenIdentifiers  = (FatherIdent, MotherIdent, SpouseIdent);
  RelativeArray     = array [GivenIdentifiers] of IdentifierType;
  Counter           = 0..maxint;

  { this is the format of records in the file to be read in }
  FilePersonRecord = record
    Name               : NameType;
    Identifier         : IdentifierType;
    { 'M' for Male and 'F' for Female }
    Gender             : char;
    RelativeIdentifier : RelativeArray
    end;
```

```
  IndexType          = 0..MaxPersons;
  GenderType         = (Male, Female);
  RelationType       = (Parent, Child, Spouse, Sibling, Uncle,
                        Nephew, Cousin, NullRelation);
  { directed edges in the graph are of a given type }
  EdgeType           = Parent..Spouse;
  { A node in the graph (= Person) has either already been reached,
    is immediately adjacent to those reached, or farther away. }
  ReachedType        = (Reached, Nearby, NotSeen);
  { each Person has a linked list of adjacent nodes, called neighbors }
  NeighborPointer    = ^NeighborRecord;

  NeighborRecord = record
    NeighborIndex     : IndexType;
    NeighborEdge      : EdgeType;
    NextNeighbor      : NeighborPointer
    end;

  { All Relationships are captured in the directed graph of which
    each record is a node. }
  PersonRecord = record
  { static information - filled from People file: }
    Name                  : NameType;
    Identifier            : IdentifierType;
    Gender                : GenderType;
    { Identifiers of immediate relatives - father, mother, spouse }
    RelativeIdentifier    : RelativeArray;
    { head of linked list of adjacent nodes }
    NeighborListHeader    : NeighborPointer;
  { data used when traversing graph to resolve user request: }
    DistanceFromSource    : real;
    PathPredecessor       : IndexType;
    EdgeToPredecessor     : EdgeType;
    ReachedStatus         : ReachedType;
  { data used to compute common genetic material }
    DescendantIdentifier : IdentifierType;
    DescendantGenes       : real
    end;

var
  { The Person array is the central repository of information
    about inter-relationships. }
  Person             : array [IndexType] of PersonRecord;

  { These variables are used when establishing the Person array
    from the People file. }
  People             : file of FilePersonRecord;
  Current, Previous, NumberOfPersons
                     : IndexType;
  IdentifierIndex    : IdentifierRange;
  PreviousIdent, CurrentIdent, NullIdent
                     : IdentifierType;
  Relationship       : GivenIdentifiers;
  RelationLoopDone : boolean;
```

```
  { These variables are used to accept and resolve requests for
    Relationship information. }
  BufferIndex, SemicolonLocation
                     : BufferRange;
  RequestBuffer      : BufferType;
  Person1Ident, Person2Ident
                     : NameType;
  Person1Found, Person2Found
                     : Counter;
  ErrorMessage       : MessageType;
  Person1Index, Person2Index
                     : IndexType;

function IdentsEqual (Identa, Identb: IdentifierType) : boolean;
  { Determines whether two numeric Person-Identifiers are equal.
    A function is necessary because the '=' operator does not
    work for arrays of anything but char. }
var
  Index  : 1..IdentifierLength;
begin
  IdentsEqual := true;
  for Index := 1 to IdentifierLength do
    if Identa [Index] <> Identb [Index] then
       IdentsEqual := false
end;  { IdentsEqual }
```

```
procedure LinkRelatives (FromIndex    : IndexType;
                         Relationship : GivenIdentifiers;
                         ToIndex      : IndexType);
  { establishes cross-indexing between immediately related Persons. }

  procedure LinkOneWay (FromIndex     : IndexType;
                        ThisEdge      : EdgeType;
                        ToIndex       : IndexType);
    { Establishes the NeighborRecord from one Person to another }
  var
    NewNeighbor : NeighborPointer;
  begin
    new (NewNeighbor);
    with NewNeighbor^ do
      begin
      NeighborIndex := ToIndex;
      NeighborEdge  := ThisEdge;
      NextNeighbor  := Person [FromIndex] . NeighborListHeader
      end;
    Person [FromIndex] . NeighborListHeader := NewNeighbor
  end;

begin   { execution of LinkRelatives }
  if Relationship = SpouseIdent then
     begin
     LinkOneWay (FromIndex, Spouse, ToIndex);
     LinkOneWay (Toindex, Spouse, FromIndex)
     end
  else   { Relationship is Mother or Father }
     begin
     LinkOneWay (FromIndex, Parent, Toindex);
     LinkOneWay (ToIndex, Child, FromIndex)
     end
end;  { LinkRelatives }

procedure PromptAndRead;
  { Issues prompt for user-request, reads in request,
    blank-fills buffer, and skips to next line of input. }
var
  BufferIndex : BufferRange;
begin
  writeln (´ ´);
  writeln (´ ---------------------------------------------´);
  writeln (´ Enter two person-identifiers (name or number),´);
  writeln (´ separated by semicolon. Enter "stop" to stop.´);
  for BufferIndex := 1 to BufferLength do
    if eoln(input) then
       RequestBuffer [BufferIndex] := ´ ´
    else
       read (input, RequestBuffer [BufferIndex] );
  readln(input)
end;   { PromptAndRead }
```

```
procedure CheckRequest (var RequestStatus     : MessageType;
                        var SemicolonLocation : BufferRange);
  { Performs syntactic check on request in buffer. }
var
  BufferIndex       : BufferRange;
  SemicolonCount    : Counter;
  Person1FieldExists, Person2FieldExists
                    : boolean;
begin
  RequestStatus      := RequestOk;
  Person1FieldExists := false;
  Person2FieldExists := false;
  SemicolonCount := 0;
  for BufferIndex := 1 to BufferLength do
    if RequestBuffer [BufferIndex] <> ' ' then
       if RequestBuffer [BufferIndex] = ';' then
          begin
          SemicolonLocation := BufferIndex;
          SemicolonCount    := SemicolonCount + 1
          end
       else   { Check for non-blanks before/after semicolon. }
          if SemicolonCount < 1 then
             Person1FieldExists := true
          else
             Person2FieldExists := true;
  { set RequestStatus, based on results of scan of RequestBuffer. }
  if SemicolonCount <> 1 then
     RequestStatus := 'must be exactly one semicolon.
  else
     if not Person1FieldExists then
        RequestStatus := 'null field preceding semicolon.
     else
        if not Person2FieldExists then
           RequestStatus := 'null field following semicolon.
end;   { CheckRequest }

procedure BufferToPerson (var PersonId : NameType;
           StartLocation, StopLocation : BufferRange);
  { fills in the PersonId from the designated portion
    of the RequestBuffer. }
var
  BufferIndex : 1..61;  { cannot say "BufferLength + 1" }
  PersonIndex : NameRange;
begin
  BufferIndex := StartLocation;
  while RequestBuffer [BufferIndex] = ' ' do
    BufferIndex := BufferIndex + 1;
  for PersonIndex := 1 to NameLength do
    if BufferIndex > StopLocation then
       PersonId [PersonIndex] := ' '
    else
       begin
       PersonId [PersonIndex] := RequestBuffer [BufferIndex];
       BufferIndex := BufferIndex + 1
       end
end;   { BufferToPerson }
```

```
procedure SearchForRequestedPersons (Person1Ident, Person2Ident : NameType;
          var Person1Index, Person2Index : IndexType;
          var Person1Found, Person2Found : Counter);
  { SearchForRequestedPersons scans through the Person array,
    looking for the two requested persons.  Match may be by name
    or unique identifier-number. }
var
  Current            : IndexType;
  ThisIdent          : NameType;
  IdentifierIndex    : IdentifierRange;
begin
  Person1Found := 0;
  Person2Found := 0;
  ThisIdent    := '                    ';
  for Current  := 1 to NumberOfPersons do
    with Person [Current] do
      begin
      { ThisIdent contains Current Person's numeric Identifier
        left-justified, padded with blanks. }
      for IdentifierIndex := 1 to IdentifierLength do
        ThisIdent [IdentifierIndex] := Identifier [IdentifierIndex];
      { allow identification by name or number. }
      if (Person1Ident = ThisIdent) or (Person1Ident = Name) then
         begin
         Person1Found := Person1Found + 1;
         Person1Index := Current
         end;
      if (Person2Ident = ThisIdent) or (Person2Ident = Name) then
         begin
         Person2Found := Person2Found + 1;
         Person2Index := Current
         end
      end   { with Person [Current] }
end;   { SearchForRequestedPersons }

procedure FindRelationship (TargetIndex, SourceIndex : IndexType);
  { Finds shortest path (if any) between two Persons and
    determines their Relationship based on immediate relations
    traversed in path.  Person array simulates a directed graph,
    and algorithm finds shortest path, based on following
    weights: Parent-Child edge  = 1.0
             Spouse-Spouse edge = 1.8  }
var
  SearchStatus          : (Searching, Succeeded, Failed);
  PersonIndex, ThisNode, AdjacentNode, BestNearbyIndex, LastNearbyIndex
                        : IndexType;
  NearbyNode            : array [IndexType] of IndexType;
  ThisEdge              : EdgeType;
  ThisNeighbor          : NeighborPointer;
  Relationship          : GivenIdentifiers;
  MinimalDistance       : real;
```

```
procedure ProcessAdjacentNode (BaseNode, NextNode : IndexType;
                               NextBaseEdge       : EdgeType);
  { NextNode is adjacent to last-reached node (= BaseNode).
    if NextNode already Reached, do nothing.
    If previously seen, check whether path thru base node is
    shorter than current path to NextNode, and if so re-link
    next to base.
    If not previously seen, link next to base node.  }
var
  WeightThisEdge, DistanceThruBaseNode
                  : real;

  procedure LinkNextNodeToBaseNode;
    { link next to base by re-setting its predecessor Index to
      point to base, note type of edge, and re-set distance
      as it is through base node. }
  begin   { execution of LinkNextNodeToBaseNode }
    with Person [NextNode] do
      begin
      DistanceFromSource := DistanceThruBaseNode;
      PathPredecessor    := BaseNode;
      EdgeToPredecessor  := NextBaseEdge
      end
  end;    { LinkNextNodeToBaseNode }

begin  { execution of ProcessAdjacentNode }
  with Person [NextNode] do
    if ReachedStatus <> Reached then
      begin
      if NextBaseEdge = Spouse then
         WeightThisEdge := 1.8
      else
         WeightThisEdge := 1.0;
      DistanceThruBaseNode := WeightThisEdge +
          Person [BaseNode] . DistanceFromSource;
      if ReachedStatus = NotSeen then
         begin
         ReachedStatus   := Nearby;
         LastNearbyIndex := LastNearbyIndex + 1;
         NearbyNode [LastNearbyIndex] := NextNode;
         LinkNextNodeToBaseNode
         end
      else   { ReachedStatus = Nearby }
         if DistanceThruBaseNode < DistanceFromSource then
            LinkNextNodeToBaseNode;
      end   { if ReachedStatus <> Reached }
end;    { ProcessAdjacentNode }
```

```
procedure ResolvePathToEnglish;
  { ResolvePathToEnglish condenses the shortest path to a
    series of Relationships for which there are English
    descriptions. }
type
  { Key Persons are the ones in the Relationship path which remain
    after the path is condensed. }
  SiblingType     = (Step, Half, Full);
  KeyPersonRecord = record
    PersonIndex   : IndexType;
    GenerationGap : Counter;
    Proximity     : SiblingType;
    case RelationToNext    : RelationType of
      Parent, Child, Spouse, Sibling, Uncle, Nephew, NullRelation
                        : ();
      Cousin            : (CousinRank : Counter)
    end;
var
  { these variables are used to condense the path }
  KeyPerson              : array [IndexType] of KeyPersonRecord;
  KeyRelation, LaterKeyRelation, PrimaryRelation, NextPrimaryRelation
                         : RelationType;
  GenerationCount        : Counter;
  KeyIndex, LaterKeyIndex, PrimaryIndex
                         : IndexType;
  AnotherElementPossible : boolean;

  function FullSibling (Index1, Index2 : IndexType) : boolean;
    { Determines whether two Persons are full siblings, i.e.,
      have the same two Parents. }
  var
    IdentIndex : 1..IdentifierLength;
  begin
    with Person [Index1] do
      FullSibling :=
        (not IdentsEqual (RelativeIdentifier [FatherIdent], NullIdent)) and
        (not IdentsEqual (RelativeIdentifier [MotherIdent], NullIdent)) and
        (IdentsEqual (RelativeIdentifier [FatherIdent],
            Person [Index2] . RelativeIdentifier [FatherIdent] )) and
        (IdentsEqual (RelativeIdentifier [MotherIdent],
            Person [Index2] . RelativeIdentifier [MotherIdent] ))
  end;   { FullSibling }

  procedure CondenseKeyPersons (AtIndex : IndexType; GapSize : Counter);
    { CondenseKeyPersons condenses superfluous entries from the
      KeyPerson array, starting at AtIndex. }
  var
    ReceiveIndex, SendIndex : IndexType;
  begin
    ReceiveIndex := AtIndex;
    repeat
      ReceiveIndex := ReceiveIndex + 1;
      SendIndex    := ReceiveIndex + GapSize;
      KeyPerson [ReceiveIndex] := KeyPerson [SendIndex];
    until KeyPerson [SendIndex] . RelationToNext = NullRelation
  end;   { CondenseKeyPersons }
```

```
procedure DisplayRelation (FirstIndex, LastIndex, PrimaryIndex
                           : IndexType);
  { DisplayRelation takes 1, 2, or 3 adjacent elements in the
    condensed table and generates the English description of
    the relation between the first and last + 1 elements. }
var
  Inlaw             : boolean;
  ThisProximity     : SiblingType;
  ThisGender        : GenderType;
  SuffixIndicator   : 0..9;
  FirstRelation, LastRelation, PrimaryRelation
                    : RelationType;
  ThisGenerationGap, ThisCousinRank
                    : Counter;
begin   { execution of DisplayRelation }
  FirstRelation    := KeyPerson [FirstIndex]   . RelationToNext;
  LastRelation     := KeyPerson [LastIndex]    . RelationToNext;
  PrimaryRelation  := KeyPerson [PrimaryIndex] . RelationToNext;
  { set ThisProximity }
  if ((PrimaryRelation = Parent) and (FirstRelation = Spouse)) or
     ((PrimaryRelation = Child)  and (LastRelation  = Spouse))
  then
     ThisProximity := Step
  else
     if PrimaryRelation in
        [Sibling, Uncle, Nephew, Cousin]
     then
        ThisProximity := KeyPerson [PrimaryIndex] . Proximity
     else
        ThisProximity := Full;
  { set ThisGenerationGap }
  if PrimaryRelation in [Parent, Child, Uncle, Nephew, Cousin]
  then
     ThisGenerationGap := KeyPerson [PrimaryIndex] . GenerationGap
  else
     ThisGenerationGap := 0;
  { set Inlaw }
  Inlaw := false;
  if (FirstRelation = Spouse) and
     (PrimaryRelation in [Sibling, Child, Nephew, Cousin] )
  then
     Inlaw := true;
  if (LastRelation = Spouse) and
     (PrimaryRelation in [Sibling, Parent, Uncle, Cousin] )
  then
     Inlaw := true;
  { set ThisCousinRank }
  if PrimaryRelation = Cousin then
     ThisCousinRank := KeyPerson [PrimaryIndex] . CousinRank
  else
     ThisCousinRank := 0;
```

```
{ parameters are set - now generate display. }

write (´ ´, Person [KeyPerson [FirstIndex] . PersonIndex] . Name,
      ´ is ´);
if PrimaryRelation in [Parent, Child, Uncle, Nephew] then
   begin   { write generation-qualifier }
   if ThisGenerationGap >= 3 then
      begin
      write (´great´);
      if ThisGenerationGap > 3 then
         write (´*´, ThisGenerationGap - 2 : 1);
      write (´-´)
      end;
   if ThisGenerationGap >= 2 then
      write (´grand-´)
   end
else
   if (PrimaryRelation = Cousin) and (ThisCousinRank > 1) then
      begin
      write (ThisCousinRank : 1);
      SuffixIndicator := ThisCousinRank mod 10;
      case SuffixIndicator of
        1 : write (´st ´);
        2 : write (´nd ´);
        3 : write (´rd ´);
        0, 4, 5, 6, 7, 8, 9
          : write (´th ´)
        end
      end;

if ThisProximity = Step then
   write (´step-´)
else
   if ThisProximity = Half then
      write (´half-´);

ThisGender := Person [KeyPerson [FirstIndex] . PersonIndex] . Gender;
case PrimaryRelation of
  Parent       : if ThisGender = Male then write (´father´)
                 else                      write (´mother´);
  Child        : if ThisGender = Male then write (´son´)
                 else                      write (´daughter´);
  Spouse       : if ThisGender = Male then write (´husband´)
                 else                      write (´wife´);
  Sibling      : if ThisGender = Male then write (´brother´)
                 else                      write (´sister´);
  Uncle        : if ThisGender = Male then write (´uncle´)
                 else                      write (´aunt´);
  Nephew       : if ThisGender = Male then write (´nephew´)
                 else                      write (´niece´);
  Cousin       : write (´cousin´);
  NullRelation : write (´null´)
  end;   { case }
```

```
    if Inlaw then
       write ('-in-law');

    if (PrimaryRelation = Cousin) and (ThisGenerationGap > 0) then
       if ThisGenerationGap > 1 then
          write (' ', ThisGenerationGap : 1, ' times removed')
       else
          write (' once removed');

    writeln (' of')
  end;   { DisplayRelation }

begin   { execution of ResolvePathToEnglish }
   writeln (' Shortest path between identified persons: ');
   ThisNode  := TargetIndex;
   KeyIndex  := 1;
   { Display path and initialize KeyPerson array from path elements. }
   while ThisNode <> SourceIndex do
     with Person [ThisNode] do
       begin
       write (' ', Name, ' is ');
       case EdgeToPredecessor of
         Parent : writeln ('parent of');
         Child  : writeln ('child of');
         Spouse : writeln ('spouse of')
       end;
       KeyPerson [KeyIndex] . PersonIndex    := ThisNode;
       KeyPerson [KeyIndex] . RelationToNext := EdgeToPredecessor;
       if EdgeToPredecessor = Spouse then
          KeyPerson [KeyIndex] . GenerationGap := 0
       else   { Parent or Child }
          KeyPerson [KeyIndex] . GenerationGap := 1;
       KeyIndex := KeyIndex + 1;
       ThisNode := PathPredecessor
       end;
   writeln(' ', Person [ThisNode] . Name);
   KeyPerson [KeyIndex]     . PersonIndex    := ThisNode;
   KeyPerson [KeyIndex]     . RelationToNext := NullRelation;
   KeyPerson [KeyIndex + 1] . RelationToNext := NullRelation;
```

```
{ Resolve Child-Parent and Child-Spouse-Parent relations
  to Sibling relations. }
KeyIndex := 1;
while KeyPerson [KeyIndex] . RelationToNext <> NullRelation do
  with KeyPerson [KeyIndex] do
    begin
    if RelationToNext = Child then
       begin
       LaterKeyRelation := KeyPerson [KeyIndex + 1] . RelationToNext;
       if LaterKeyRelation = Parent then
          { found either full or half siblings }
          begin
          RelationToNext := Sibling;
          if FullSibling (PersonIndex,
             KeyPerson [KeyIndex + 2] . PersonIndex)
          then
             Proximity := Full
          else
             Proximity := Half;
          CondenseKeyPersons (KeyIndex, 1)
          end   { processing of full/half siblings }
       else
          if (LaterKeyRelation = Spouse) and
             (KeyPerson [KeyIndex + 2] . RelationToNext = Parent)
          then { found step-siblings }
             begin
             RelationToNext := Sibling;
             Proximity      := Step;
             CondenseKeyPersons (KeyIndex, 2)
             end   { processing of step-siblings }
       end;   { if RelationToNext = Child }
    KeyIndex := KeyIndex + 1
    end;   { with KeyPerson [KeyIndex] }
{ Resolve Child-Child-... and Parent-Parent-... relations to
  direct descendant or ancestor relations. }
KeyIndex := 1;
while KeyPerson [KeyIndex] . RelationToNext <> NullRelation do
  with KeyPerson [KeyIndex] do
    begin
    if (RelationToNext = Child) or (RelationToNext = Parent) then
       begin
       LaterKeyIndex := KeyIndex + 1;
       while KeyPerson [LaterKeyIndex] . RelationToNext =
             RelationToNext do
         LaterKeyIndex := LaterKeyIndex + 1;
       GenerationCount := LaterKeyIndex - KeyIndex;
       if GenerationCount > 1 then
          begin  { compress generations }
          GenerationGap := GenerationCount;
          CondenseKeyPersons (KeyIndex, GenerationCount - 1)
          end
       end;   { if RelationToNext = Child or Parent }
    KeyIndex := KeyIndex + 1
    end;   { with KeyPerson [KeyIndex] }
```

```
{ Resolve Child-Sibling-Parent to Cousin,
          Child-Sibling        to Nephew,
          Sibling-Parent       to Uncle. }
KeyIndex := 1;
while KeyPerson [KeyIndex] . RelationToNext <> NullRelation do
  with KeyPerson [KeyIndex] do
    begin
    LaterKeyRelation := KeyPerson [KeyIndex + 1] . RelationToNext;
    if (RelationToNext = Child) and
       (LaterKeyRelation = Sibling)
    then   { Cousin or Nephew }
       if KeyPerson [KeyIndex + 2] . RelationToNext = Parent then
          { found Cousin }
          begin
          RelationToNext := Cousin;
          Proximity      := KeyPerson [KeyIndex + 1] . Proximity;
          if GenerationGap < KeyPerson [KeyIndex + 2] . GenerationGap
          then
             CousinRank := GenerationGap
          else
             CousinRank := KeyPerson [KeyIndex + 2] . GenerationGap;
          GenerationGap := abs (GenerationGap -
             KeyPerson [KeyIndex + 2] . GenerationGap);
          CondenseKeyPersons (KeyIndex, 2)
          end
       else  { found Nephew }
          begin
          RelationToNext := Nephew;
          Proximity      := KeyPerson [KeyIndex + 1] . Proximity;
          CondenseKeyPersons (KeyIndex, 1)
          end
    else   { not Cousin or Nephew }
       if (RelationToNext = Sibling) and (LaterKeyRelation = Parent)
       then   { found Uncle }
          begin
          RelationToNext := Uncle;
          GenerationGap  := KeyPerson [KeyIndex + 1] . GenerationGap;
          CondenseKeyPersons (KeyIndex, 1)
          end;
    KeyIndex := KeyIndex + 1
    end;   { with KeyPerson [KeyIndex] }
```

```
    { Loop below will pick out valid adjacent strings of elements
      to be displayed.  KeyIndex points to first element,
      LaterKeyIndex to last element, and PrimaryIndex to the
      element which determines the primary English word to be used.
      Associativity of adjacent elements in condensed table
      is based on English usage. }
    KeyIndex := 1;
    writeln (' Condensed path:');
    while KeyPerson [KeyIndex] . RelationToNext <> NullRelation do
      begin
      KeyRelation   := KeyPerson [KeyIndex] . RelationToNext;
      LaterKeyIndex := KeyIndex;
      PrimaryIndex  := KeyIndex;
      if KeyPerson [KeyIndex + 1] . RelationToNext <> NullRelation then
         begin   { seek multi-element combination }
         AnotherElementPossible := true;
         if KeyRelation = Spouse then
            begin
            LaterKeyIndex := LaterKeyIndex + 1;
            PrimaryIndex  := LaterKeyIndex;
            if (KeyPerson [LaterKeyIndex] . RelationToNext = Sibling) or
               (KeyPerson [LaterKeyIndex] . RelationToNext = Cousin)
            then   { Nothing can follow Spouse-Sibling or Spouse-Cousin }
               AnotherElementPossible := false
            end;
         { PrimaryIndex is now correctly set.  Next if-statement
           determines if a following Spouse relation should be
           appended to this combination or left for the next
           combination. }
         if AnotherElementPossible and
            (KeyPerson [PrimaryIndex + 1] . RelationToNext = Spouse)
            { Only a Spouse can follow a Primary }
         then
            begin  { check primary preceding and following Spouse. }
            PrimaryRelation     :=
               KeyPerson [PrimaryIndex] . RelationToNext;
            NextPrimaryRelation :=
               KeyPerson [PrimaryIndex + 2] . RelationToNext;
            if (NextPrimaryRelation in [Nephew, Cousin, NullRelation] )
               or (PrimaryRelation = Nephew)
               or ( ( PrimaryRelation in [Sibling, Parent] )
                    and (NextPrimaryRelation <> Uncle ) )
            then  { append following Spouse with this combination. }
               LaterKeyIndex := LaterKeyIndex + 1
            end  { check primary preceding and following Spouse }
         end;  { multi-element combination }
      DisplayRelation (KeyIndex, LaterKeyIndex, PrimaryIndex);
      KeyIndex := LaterKeyIndex + 1
      end;   { while }
    writeln (' ', Person [KeyPerson [KeyIndex] . PersonIndex] . Name)
 end;   { ResolvePathToEnglish }
```

```
procedure ComputeCommonGenes (Index1, Index2 : IndexType);
  { ComputeCommonGenes assumes that each ancestor contributes
    half of the genetic material to a Person.  It finds common
    ancestors between two Persons and computes the expected
    value of the Proportion of common material. }
var
  CommonProportion : real;

  procedure ZeroProportion (ZeroIndex : IndexType);
    { ZeroProportion recursively seeks out all ancestors and
      zeros them out. }
  var
    ThisNeighbor : NeighborPointer;
  begin
    with Person [ZeroIndex] do
      begin
      DescendantGenes := 0.0;
      ThisNeighbor    := NeighborListHeader
      end;
    while ThisNeighbor <> nil do
      with ThisNeighbor^ do
        begin
        if NeighborEdge = Parent then
           ZeroProportion (NeighborIndex);
        ThisNeighbor := NextNeighbor
        end   { with }
  end;   { ZeroProportion }

  procedure MarkProportion (Marker : IdentifierType;
            Proportion : real; MarkedIndex : IndexType);
    { MarkProportion recursively seeks out all ancestors and
      marks them with the sender's Proportion of shared
      genetic material.  This Proportion is diluted by one-half
      for each generation. }
  var
    ThisNeighbor : NeighborPointer;
  begin
    with Person [MarkedIndex] do
      begin
      DescendantIdentifier := Marker;
      DescendantGenes      := DescendantGenes + Proportion;
      ThisNeighbor         := NeighborListHeader
      end;
    while ThisNeighbor <> nil do
      with ThisNeighbor^ do
        begin
        if NeighborEdge = Parent then
           MarkProportion (Marker, Proportion / 2.0,
                           NeighborIndex );
        ThisNeighbor := NextNeighbor
        end
  end;   { MarkProportion }
```

```
    procedure CheckCommonProportion
              (var CommonProportion : real;
                   MatchIdentifier  : IdentifierType;
                   Proportion       : real;
                   AlreadyCounted   : real;
                   CheckIndex       : IndexType);
      { CheckCommonProportion searches all the ancestors of
        CheckIndex to see if any have been marked, and if so
        adds the appropriate amount to CommonProportion. }
    var
      ThisNeighbor     : NeighborPointer;
      ThisContribution : real;
    begin
      with Person [CheckIndex] do
        begin
        if IdentsEqual (DescendantIdentifier, MatchIdentifier) then
           begin
           { Increment CommonProportion by the contribution of
             this common ancestor, but discount for the contribution
             of less remote ancestors already counted. }
           ThisContribution := DescendantGenes * Proportion;
           CommonProportion := CommonProportion +
                   ThisContribution - AlreadyCounted
           end
        else
           ThisContribution := 0.0;
        ThisNeighbor := NeighborListHeader
        end;   { with Person [CheckIndex] }
      while ThisNeighbor <> nil do
        with ThisNeighbor^ do
          begin
          if NeighborEdge = Parent then
             CheckCommonProportion (CommonProportion,
                   MatchIdentifier, Proportion / 2.0,
                   ThisContribution / 4.0,
                   NeighborIndex );
          ThisNeighbor := NextNeighbor
          end
    end;   { CheckCommonProportion }

  begin   { ComputeCommonGenes }
    { First zero out all ancestors to allow adding.  This is necessary
      because there might be two paths to an ancestor. }
    ZeroProportion (Index1);
    { now mark with shared Proportion }
    MarkProportion ( Person [Index1] . Identifier, 1.0, Index1);
    CommonProportion := 0.0;
    CheckCommonProportion (CommonProportion,
       Person [Index1] . Identifier, 1.0, 0.0, Index2);
    writeln (' Proportion of common genetic material = ',
               CommonProportion : 12)
  end;   { ComputeCommonGenes }
```

```
begin   { execution of FindRelationship }
  {  initialize Person-array for processing -
     mark all nodes as not seen }
  for PersonIndex := 1 to NumberOfPersons do
    Person [PersonIndex] . ReachedStatus := NotSeen;
  { mark source node as Reached }
  ThisNode := SourceIndex;
  with Person [ThisNode] do
    begin
    ReachedStatus      := Reached;
    DistanceFromSource := 0.0
    end;
  { no Nearby nodes exist yet }
  LastNearbyIndex := 0;
  if ThisNode = TargetIndex then
     SearchStatus := Succeeded
  else
     SearchStatus := Searching;
  { Loop keeps processing closest-to-source, unreached node
    until target Reached, or no more connected nodes. }
  while SearchStatus = Searching do
    begin
    { Process all nodes adjacent to ThisNode }
    ThisNeighbor := Person [ThisNode] . NeighborListHeader;
    while ThisNeighbor <> nil do
      with ThisNeighbor^ do
        begin
        ProcessAdjacentNode (ThisNode, NeighborIndex, NeighborEdge);
        ThisNeighbor := NextNeighbor
        end;

    { All nodes adjacent to ThisNode are set.  Now search for
      shortest-distance unreached (but Nearby) node to process next. }
    if LastNearbyIndex = 0 then
       SearchStatus := Failed
    else
       begin
       MinimalDistance := 1.0e+18;
       for PersonIndex := 1 to LastNearbyIndex do
         with Person [NearbyNode [PersonIndex]] do
           if DistanceFromSource < MinimalDistance then
              begin
              BestNearbyIndex := PersonIndex;
              MinimalDistance := DistanceFromSource
              end;
       { Establish new ThisNode }
       ThisNode := NearbyNode [BestNearbyIndex];
       { change ThisNode from being Nearby to Reached }
       Person [ThisNode] . ReachedStatus := Reached;
       { remove ThisNode from Nearby list }
       NearbyNode [BestNearbyIndex] := NearbyNode [LastNearbyIndex];
       LastNearbyIndex := LastNearbyIndex - 1;
       if ThisNode = TargetIndex then
          SearchStatus := Succeeded
       end   { determination of next node to process }
    end;   { while SearchStatus = Searching }
```

```
  { Shortest path between Persons now established.  Next task is
    to translate path to English description of Relationship. }

  if SearchStatus = Failed then
     writeln (' ', Person [TargetIndex] . Name, ' is not related to ',
                   Person [SourceIndex] . Name)
  else   { success - parse path to find and display Relationship }
     begin
     ResolvePathToEnglish;
     ComputeCommonGenes (SourceIndex, TargetIndex)
     end

end;   { FindRelationship }

{ *** execution of main sequence begins here *** }

begin
  for IdentifierIndex := 1 to IdentifierLength do
    NullIdent [IdentifierIndex] := '0';
  reset (People);
  { Current location in array being filled }
  Current := 0;
  { This loop reads in the People file and constructs the Person
    array from it (one Person = one record = one array entry).
    As records are read in, links are constructed to represent the
    Parent-Child or Spouse relationship.  The array then implements
    a directed graph which is used to satisfy subsequent user
    requests.  The file is assumed to be correct - no validation
    is performed on it.  }
  while not eof(People) do
    begin
    Current := Current+1;
    with Person [Current] do
      begin
      { copy direct information from file to array }
      Name          := People^ . Name;
      Identifier    := People^ . Identifier;
      if People^ . Gender = 'M' then
         Gender := Male
      else
         Gender := Female;
      RelativeIdentifier    := People^ . RelativeIdentifier;
      { Location of adjacent persons as yet undetermined }
      NeighborListHeader    := nil;
      { Descendants as yet undetermined. }
      DescendantIdentifier := NullIdent;
      CurrentIdent         := Identifier;
```

```
    { Compare this Person against all previously entered Persons
      to search for Relationships. }
    for Previous := 1 to (Current-1) do
      begin
      PreviousIdent      := Person [Previous] . Identifier;
      RelationLoopDone   := false;
      Relationship       := FatherIdent;
      { Search for father, mother, or spouse Relationship in
        either direction between this and previous Person.
        Assume at most one Relationship exists. }
      repeat
        if IdentsEqual (RelativeIdentifier [Relationship],
                        PreviousIdent) then
           begin
           LinkRelatives (Current, Relationship, Previous);
           RelationLoopDone := true
           end
        else
          if IdentsEqual (CurrentIdent,
             Person [Previous] . RelativeIdentifier [Relationship])
          then
             begin
             LinkRelatives (Previous, Relationship, Current);
             RelationLoopDone := true
             end;
        if Relationship < SpouseIdent then
           Relationship := succ(Relationship)
        else
           RelationLoopDone := true;
      until RelationLoopDone
      end;   { for Previous }
    get(People)
    end   { with Person [Current] }
  end;  { while not eof(People) }
NumberOfPersons := Current;

{ Person array is now loaded and edges between immediate relatives
  (Parent-Child or Spouse-Spouse) are established.

  While-loop accepts requests and finds Relationship (if any)
  between pairs of Persons.  }
```

```
  reset(input);
  PromptAndRead;
  while RequestBuffer <> RequestToStop do
    { The following code retrieves and validates a user request
      for the Relationship between two identified Persons. }
    begin
    CheckRequest (ErrorMessage, SemicolonLocation);

    { Syntax check of request completed.  Now either display error
      message or search for the two Persons. }

    if ErrorMessage = RequestOk then
       begin   { Request syntactically correct -
                 search for requested Persons. }
       BufferToPerson (Person1Ident, 1, SemicolonLocation - 1);
       BufferToPerson (Person2Ident, SemicolonLocation + 1, BufferLength);
       SearchForRequestedPersons (Person1Ident, Person2Ident,
                                  Person1Index, Person2Index,
                                  Person1Found, Person2Found);
       if (Person1Found = 1) and (Person2Found = 1) then
          { Exactly one match for each Person - proceed to
            determine Relationship, if any. }
          if Person1Index = Person2Index then
             begin
             write (' ', Person [Person1Index] . Name,
                    ' is identical to ');
             if Person [Person1Index] . Gender = Male then
                writeln('himself.')
             else
                writeln('herself.')
             end
          else
             FindRelationship (Person1Index, Person2Index)
       else   { either not found or more than one found }
          begin
          if Person1Found = 0 then
             writeln (' First person not found.')
          else
             if Person1Found > 1 then
                writeln (' Duplicate names for first person - use',
                         ' numeric identifier.');
          if Person2Found = 0 then
             writeln (' Second person not found.')
          else
             if Person2Found > 1 then
                writeln (' Duplicate names for second person - use',
                         ' numeric identifier.')
          end
       end   { processing of syntactically legal request }
    else
       writeln (' Incorrect request format: ', ErrorMessage);
    PromptAndRead
    end;   { while RequestBuffer }
  writeln (' End of relation-finder.');

end.
```

8.0 PL/I

In keeping with the general convention of the examples, language-supplied keywords and identifiers are written in lower case in the program. To conform strictly to the PL/I standard, however, programs must use only upper-case letters. In the following program, the logical "Not" operator is represented by the graphic character "~".

```
RELATE: procedure options (main);

/* Begin declaration of global data */

  declare
    /* Used to index relative array, pointing to immediate relatives */
  ( FATHER_IDENT       initial (1),
    MOTHER_IDENT       initial (2),
    SPOUSE_IDENT       initial (3),
    /* Used as mnemonics to represent basic English-word relationships. */
    PARENT             initial (1),
    CHILD              initial (2),
    SPOUSE             initial (3),
    SIBLING            initial (4),
    UNCLE              initial (5),
    NEPHEW             initial (6),
    COUSIN             initial (7),
    NULL_RELATION      initial (8),
    /* Used as mnemonics to represent status of nodes during search
       for shortest path thru graph. */
    REACHED            initial (1),
    NEARBY             initial (2),
    NOT_SEEN           initial (3) )
  fixed binary (4,0),

  /* Used as mnemonics to represent truth-values */
  ( TRUE               initial ('1'b),
    FALSE              initial ('0'b))
  bit (1),

  /* Used to control user requests. */
  ( REQUEST_OK         character (10) initial ('Request OK'),
    REQUEST_TO_STOP    character  (4) initial ('stop')),

  /* Used as mnemonics to represent GENDER */
  ( MALE               initial ('M'),
    FEMALE             initial ('F'))
  character (1);
```

```
declare
  /* the PERSON array is the central repository of information
     about inter-relationships. */
  /* All relationships are captured in the directed graph of which
     each record is a node. */
    01 PERSON dimension (1:300),
      /* static information - filled from PEOPLE file: */
      05  NAME                    character (20),
      05  IDENTIFIER              picture '999',
      05  GENDER                  character (1),
        /* IDENTIFIERs of immediate relatives - father, mother, spouse */
      05  RELATIVE_IDENTIFIER     (1:3)
                                  picture '999',
        /* head of linked list of adjacent nodes */
      05  NEIGHBOR_LIST_HEADER    pointer,
      /* data used when traversing graph to resolve user request: */
      05  DISTANCE_FROM_SOURCE    float decimal (6),
      05  PATH_PREDECESSOR        fixed binary (10,0),
      05  EDGE_TO_PREDECESSOR     fixed binary (4,0),
      05  REACHED_STATUS          fixed binary (4,0),
      /* data used to compute common genetic material */
      05  DESCENDANT_IDENTIFIER   picture '999',
      05  DESCENDANT_GENES        float decimal (6);

declare
  /* each PERSON has a linked list of adjacent nodes, called neighbors */
  01 NEIGHBOR_RECORD based (NEW_NEIGHBOR),
     05 NEIGHBOR_INDEX    fixed binary (10,0),
     05 NEIGHBOR_EDGE     fixed binary (4,0),
     05 NEXT_NEIGHBOR     pointer;

/* End declaration of global data. */

declare
  /* This is the format of records in the file to be read in. */
  01 PEOPLE_RECORD,
     05 NAME                    character (20),
     05 IDENTIFIER              picture '999',
        /* 'M' for MALE and 'F' for FEMALE */
     05 GENDER                  character (1),
     05 RELATIVE_IDENTIFIER (1:3) picture '999';

declare
  /* These variables are used when establishing the PERSON array
     from the PEOPLE file. */
  PEOPLE                 file record sequential input,
  (CURRENT, PREVIOUS, NUMBER_OF_PERSONS)
                         fixed binary (10,0),
  (PREVIOUS_IDENT, CURRENT_IDENT)
                         picture '999',
  NULL_IDENT             picture '999' static initial (000),
  RELATIONSHIP           fixed binary (4,0),
  RELATION_LOOP_DONE     bit (1),
  END_OF_PEOPLE          bit (1);
```

```
declare
  /* These variables are used to accept and resolve requests for
     RELATIONSHIP information. */
  sysin file record input environment (AREAD),
  (BUFFER_INDEX, SEMICOLON_LOCATION)
                    fixed binary (10,0),
  REQUEST_BUFFER    character (60) varying,
  (PERSON1_IDENT, PERSON2_IDENT)
                    character (20),
  (PERSON1_FOUND, PERSON2_FOUND)
                    fixed binary (10,0),
  ERROR_MESSAGE     character (40),
  (PERSON1_INDEX, PERSON2_INDEX)
                    fixed binary (10,0);

/* This on-block captures exceptions from the following code */
on endfile (PEOPLE)
   begin;
   END_OF_PEOPLE = TRUE;
   end;
```

```
/* *** begin execution of main sequence RELATE *** */

  open file (PEOPLE) title ('PEOPLE.DAT');
  END_OF_PEOPLE = FALSE;
  /* This loop reads in the PEOPLE file and constructs the PERSON
     array from it (one PERSON = one record = one array entry).
     As records are read in, links are constructed to represent the
     PARENT-CHILD or SPOUSE RELATIONSHIP.  The array then implements
     a directed graph which is used to satisfy subsequent user
     requests.  The file is assumed to be correct - no validation
     is performed on it.  */
  read file (PEOPLE) into (PEOPLE_RECORD);
READ_IN_PEOPLE:
  do CURRENT = 1 to 300 while (~ END_OF_PEOPLE);
    /* copy direct information from file to array */
    PERSON (CURRENT) = PEOPLE_RECORD, by name;
    /* Location of adjacent persons as yet undetermined. */
    PERSON (CURRENT) . NEIGHBOR_LIST_HEADER = null();
    /* Descendants as yet undetermined */
    PERSON (CURRENT) . DESCENDANT_IDENTIFIER = NULL_IDENT;
    CURRENT_IDENT = PERSON (CURRENT) . IDENTIFIER;
    /* Compare this PERSON against all previously entered PERSONs
      to search for RELATIONSHIPs. */
COMPARE_TO_PREVIOUS:
    do PREVIOUS = 1 to (CURRENT-1);
      PREVIOUS_IDENT      = PERSON (PREVIOUS) . IDENTIFIER;
      RELATION_LOOP_DONE  = FALSE;
      /* Search for father, mother, or spouse relationship in
         either direction between this and PREVIOUS PERSON.
         Assume at most one RELATIONSHIP exists. */
TRY_ALL_RELATIONSHIPS:
      do RELATIONSHIP = FATHER_IDENT to SPOUSE_IDENT
           while (~ RELATION_LOOP_DONE);
        if PERSON (CURRENT) . RELATIVE_IDENTIFIER (RELATIONSHIP) =
             PREVIOUS_IDENT then
           do;
           call LINK_RELATIVES (CURRENT, RELATIONSHIP, PREVIOUS);
           RELATION_LOOP_DONE = TRUE;
           end;
        else
          if CURRENT_IDENT =
             PERSON (PREVIOUS) . RELATIVE_IDENTIFIER (RELATIONSHIP)
          then
             do;
             call LINK_RELATIVES (PREVIOUS, RELATIONSHIP, CURRENT);
             RELATION_LOOP_DONE = TRUE;
             end;
      end TRY_ALL_RELATIONSHIPS;
    end COMPARE_TO_PREVIOUS;
    read file (PEOPLE) into (PEOPLE_RECORD);
  end READ_IN_PEOPLE;
  NUMBER_OF_PERSONS = CURRENT - 1;
  close file (PEOPLE);

  /* PERSON array is now loaded and edges between immediate relatives
    (PARENT-CHILD or SPOUSE-SPOUSE) are established.
```

```
   While-loop accepts requests and finds RELATIONSHIP (if any)
   between pairs of PERSONs.  */

  call PROMPT_AND_READ();
READ_AND_PROCESS_REQUEST:
  do while (REQUEST_BUFFER ~= REQUEST_TO_STOP);
    /* The following code retrieves and validates a user request
      for the RELATIONSHIP between two identified PERSONs. */
    call CHECK_REQUEST (ERROR_MESSAGE, SEMICOLON_LOCATION);

    /* Syntax check of request completed.  Now either display error
      message or search for the two PERSONs. */

    if ERROR_MESSAGE = REQUEST_OK then
       do;   /* Request syntactically correct -
                search for requested PERSONs. */
       call BUFFER_TO_PERSON (PERSON1_IDENT, 1, SEMICOLON_LOCATION - 1);
       call BUFFER_TO_PERSON (PERSON2_IDENT, SEMICOLON_LOCATION + 1,
                              length (REQUEST_BUFFER));
       call SEARCH_FOR_REQUESTED_PERSONS (PERSON1_IDENT, PERSON2_IDENT,
                                          PERSON1_INDEX, PERSON2_INDEX,
                                          PERSON1_FOUND, PERSON2_FOUND);
       if (PERSON1_FOUND = 1) & (PERSON2_FOUND = 1) then
          /* Exactly one match for each PERSON - proceed to
            determine RELATIONSHIP, if any. */
          if PERSON1_INDEX = PERSON2_INDEX then
             if PERSON (PERSON1_INDEX) . GENDER = MALE then
                put skip list (' ' || PERSON (PERSON1_INDEX) . NAME ||
                  ' is identical to himself.');
             else
                put skip list (' ' || PERSON (PERSON1_INDEX) . NAME ||
                  ' is identical to herself.');
          else
             call FIND_RELATIONSHIP (PERSON1_INDEX, PERSON2_INDEX);
       else   /* either not found or more than one found */
          do;
          if PERSON1_FOUND = 0 then
             put skip list (' First person not found.');
          else
             if PERSON1_FOUND > 1 then
                put skip list (' Duplicate names for first person - use' ||
                         ' numeric identifier.');
          if PERSON2_FOUND = 0 then
             put skip list (' Second person not found.');
          else
             if PERSON2_FOUND > 1 then
                put skip list (' Duplicate names for second person - use' ||
                         ' numeric identifier.');
          end;
       end;   /* processing of syntactically legal request */
    else
       put skip list (' Incorrect request format: ' || ERROR_MESSAGE);
    call PROMPT_AND_READ();
  end READ_AND_PROCESS_REQUEST;
  put skip list (' End of relation-finder.');
/* End execution of main sequence RELATE
```

```
        procedures under RELATE begin here */

LINK_RELATIVES: procedure (FROM_INDEX, RELATIONSHIP, TO_INDEX);

declare
  FROM_INDEX       fixed binary (10,0),
  RELATIONSHIP     fixed binary (4,0),
  TO_INDEX         fixed binary (10,0);

/* begin execution of LINK_RELATIVES */

  if RELATIONSHIP = SPOUSE_IDENT then
     do;
     call LINK_ONE_WAY (FROM_INDEX, SPOUSE, TO_INDEX);
     call LINK_ONE_WAY (TO_INDEX, SPOUSE, FROM_INDEX);
     end;
  else  /* RELATIONSHIP is mother or father */
     do;
     call LINK_ONE_WAY (FROM_INDEX, PARENT, TO_INDEX);
     call LINK_ONE_WAY (TO_INDEX, CHILD, FROM_INDEX);
     end;

  LINK_ONE_WAY: procedure (FROM_INDEX, THIS_EDGE, TO_INDEX);

    declare
      FROM_INDEX  fixed binary (10,0),
      THIS_EDGE   fixed binary (4,0),
      TO_INDEX    fixed binary (10,0);

    declare
      NEW_NEIGHBOR  pointer;

  /* begin execution of LINK_ONE_WAY */
     allocate NEIGHBOR_RECORD set (NEW_NEIGHBOR);
     NEW_NEIGHBOR -> NEIGHBOR_INDEX = TO_INDEX;
     NEW_NEIGHBOR -> NEIGHBOR_EDGE  = THIS_EDGE;
     NEW_NEIGHBOR -> NEXT_NEIGHBOR  =
            PERSON (FROM_INDEX) . NEIGHBOR_LIST_HEADER;
     PERSON (FROM_INDEX) . NEIGHBOR_LIST_HEADER = NEW_NEIGHBOR;
   end LINK_ONE_WAY;

end LINK_RELATIVES;

PROMPT_AND_READ: procedure;
  /* Issues prompt for user-request, reads in request,
     blank-fills buffer, and skips to next line of input. */

declare  BUFFER_INDEX      fixed binary (10,0),
         SEMICOLON_COUNT   fixed binary (4,0);
```

```
/* begin execution of PROMPT_AND_READ */
  put skip (2) list (' ----------------------------------------');
  put skip list (' Enter two person-identifiers (name or number),');
  put skip list (' separated by semicolon. Enter "stop" to stop.');
  put skip list (' ');

/*  The use of sysin for record-oriented, rather than stream-oriented,
    input may not be considered to be standard usage.  It is done here
    because stream input cannot recognize line boundaries, so as to
    read an entire line from the terminal.  */
  read file (sysin) into (REQUEST_BUFFER);
end PROMPT_AND_READ;

CHECK_REQUEST: procedure (REQUEST_STATUS, SEMICOLON_LOCATION);
  /* Performs syntactic check on request in buffer. */

declare
  REQUEST_STATUS     character (40),
  SEMICOLON_LOCATION fixed binary (10,0);

/* begin execution of CHECK_REQUEST */
  SEMICOLON_LOCATION = index (REQUEST_BUFFER, ';');
  if SEMICOLON_LOCATION = 0 |
     index (substr (REQUEST_BUFFER, SEMICOLON_LOCATION + 1), ';') > 0
  then
     REQUEST_STATUS = 'must be exactly one semicolon.';
  else
     if before (REQUEST_BUFFER, ';') = ' ' then
        REQUEST_STATUS = 'null field preceding semicolon.';
     else
        if after (REQUEST_BUFFER, ';') = ' ' then
           REQUEST_STATUS = 'null field following semicolon.';
        else
           REQUEST_STATUS = REQUEST_OK;
end CHECK_REQUEST;

BUFFER_TO_PERSON: procedure (PERSON_ID, START_LOCATION, STOP_LOCATION);
  /* fills in the PERSON_ID from the designated portion
     of the REQUEST_BUFFER. */

  declare
    PERSON_ID    character (20),
    (START_LOCATION, STOP_LOCATION)
                 fixed binary (10,0);
  declare
    FIRST_NON_BLANK fixed binary (10,0);

/* begin execution of BUFFER_TO_PERSON */
  do FIRST_NON_BLANK = START_LOCATION to STOP_LOCATION
     while (substr (REQUEST_BUFFER, FIRST_NON_BLANK, 1) = ' ');
  end;
  PERSON_ID = substr (REQUEST_BUFFER, FIRST_NON_BLANK,
                      STOP_LOCATION - FIRST_NON_BLANK + 1);
end BUFFER_TO_PERSON;
```

```
SEARCH_FOR_REQUESTED_PERSONS: procedure (PERSON1_IDENT, PERSON2_IDENT,
                                         PERSON1_INDEX, PERSON2_INDEX,
                                         PERSON1_FOUND, PERSON2_FOUND);
  /* SEARCH_FOR_REQUESTED_PERSONS scans through the PERSON array,
     looking for the two requested PERSONs.  Match may be by NAME
     or unique IDENTIFIER-number. */
  declare
    (PERSON1_IDENT, PERSON2_IDENT) character (20),
    (PERSON1_INDEX, PERSON2_INDEX) fixed binary (10,0),
    (PERSON1_FOUND, PERSON2_FOUND) fixed binary (10,0);
  declare
    THIS_IDENT        character (20),
    CURRENT           fixed binary (10,0);
/* begin execution of SEARCH_FOR_REQUESTED_PERSONS */
  PERSON1_FOUND = 0;
  PERSON2_FOUND = 0;
SCAN_ALL_PERSONS:
  do CURRENT  = 1 to NUMBER_OF_PERSONS;
    /* THIS_IDENT contains CURRENT PERSON's numeric IDENTIFIER
       left-justified, padded with blanks.  */
    THIS_IDENT = PERSON (CURRENT) . IDENTIFIER;
    /* allow identification by name or number. */
    if (PERSON1_IDENT = THIS_IDENT) |
       (PERSON1_IDENT = PERSON (CURRENT) . NAME)
    then
       do;
       PERSON1_FOUND = PERSON1_FOUND + 1;
       PERSON1_INDEX = CURRENT;
       end;
    if (PERSON2_IDENT = THIS_IDENT) |
       (PERSON2_IDENT = PERSON (CURRENT) . NAME)
    then
       do;
       PERSON2_FOUND = PERSON2_FOUND + 1;
       PERSON2_INDEX = CURRENT;
       end;
  end SCAN_ALL_PERSONS;
end SEARCH_FOR_REQUESTED_PERSONS;

/* End of utility procedures under RELATE.
```

```
   FIND_RELATIONSHIP does major work of program: determines
   relationship between any two people in PERSON array. */

FIND_RELATIONSHIP: procedure (TARGET_INDEX, SOURCE_INDEX);
  /* Finds shortest path (if any) between two PERSONs and
     determines their RELATIONSHIP based on immediate relations
     traversed in path.  PERSON array simulates a directed graph,
     and algorithm finds shortest path, based on following
     weights: PARENT-CHILD edge  = 1.0
              SPOUSE-SPOUSE edge = 1.8  */
  declare
    (TARGET_INDEX, SOURCE_INDEX) fixed binary (10,0);
  declare
    SEARCH_STATUS            character (1),
      /* values for SEARCH_STATUS */
      (SEARCHING                initial ('?'),
       SUCCEEDED                initial ('!'),
       FAILED                   initial ('X')) character (1),
    (PERSON_INDEX, THIS_NODE, ADJACENT_NODE, BEST_NEARBY_INDEX,
     LAST_NEARBY_INDEX)      fixed binary (10,0),
    NEARBY_NODE              dimension (1:300) fixed binary (10,0),
    THIS_EDGE                fixed binary (4,0),
    THIS_NEIGHBOR            pointer,
    RELATIONSHIP             fixed binary (4,0),
    MINIMAL_DISTANCE         float decimal (6);

/*  begin execution of FIND_RELATIONSHIP */
  /* initialize PERSON-array for processing -
     mark all nodes as not seen */
  PERSON . REACHED_STATUS = NOT_SEEN;
  /* mark source node as REACHED */
  THIS_NODE = SOURCE_INDEX;
  PERSON (THIS_NODE) . REACHED_STATUS       = REACHED;
  PERSON (THIS_NODE) . DISTANCE_FROM_SOURCE = 0.0;
  /* no NEARBY nodes exist yet */
  LAST_NEARBY_INDEX = 0;
  if THIS_NODE = TARGET_INDEX then
     SEARCH_STATUS = SUCCEEDED;
  else
     SEARCH_STATUS = SEARCHING;
```

```
  /* Loop keeps processing closest-to-source, unREACHED node
    until target REACHED, or no more connected nodes. */
SEARCH_FOR_TARGET:
  do while (SEARCH_STATUS = SEARCHING);
    /* Process all nodes adjacent to THIS_NODE */
    THIS_NEIGHBOR = PERSON (THIS_NODE) . NEIGHBOR_LIST_HEADER;
    do while (THIS_NEIGHBOR ~= null());
      call PROCESS_ADJACENT_NODE (THIS_NODE,
                                  THIS_NEIGHBOR -> NEIGHBOR_INDEX,
                                  THIS_NEIGHBOR -> NEIGHBOR_EDGE);
      THIS_NEIGHBOR = THIS_NEIGHBOR -> NEXT_NEIGHBOR;
    end;

    /* All nodes adjacent to THIS_NODE are set.  Now search for
      shortest-distance unREACHED (but NEARBY) node to process next. */
    if LAST_NEARBY_INDEX = 0 then
       SEARCH_STATUS = FAILED;
    else
       do;
       MINIMAL_DISTANCE = 1.0e+18;
       do PERSON_INDEX = 1 to LAST_NEARBY_INDEX;
         if PERSON (NEARBY_NODE (PERSON_INDEX)) . DISTANCE_FROM_SOURCE
               < MINIMAL_DISTANCE then
            do;
            BEST_NEARBY_INDEX = PERSON_INDEX;
            MINIMAL_DISTANCE  =
                PERSON (NEARBY_NODE (PERSON_INDEX)) . DISTANCE_FROM_SOURCE;
            end;
       end;  /* PERSON_INDEX loop */
       /* establish new THIS_NODE */
       THIS_NODE = NEARBY_NODE (BEST_NEARBY_INDEX);
       /* change THIS_NODE from being NEARBY to REACHED */
       PERSON (THIS_NODE) . REACHED_STATUS = REACHED;
       /* remove THIS_NODE from NEARBY list */
       NEARBY_NODE (BEST_NEARBY_INDEX) = NEARBY_NODE (LAST_NEARBY_INDEX);
       LAST_NEARBY_INDEX = LAST_NEARBY_INDEX - 1;
       if THIS_NODE = TARGET_INDEX then
          SEARCH_STATUS = SUCCEEDED;
       end;   /* determination of next node to process */
    end SEARCH_FOR_TARGET;

  /* Shortest path between PERSONs now established.  Next task is
    to translate path to English description of RELATIONSHIP. */

  if SEARCH_STATUS = FAILED then
     put skip list (' ', PERSON (TARGET_INDEX) . NAME, ' is not related to
                    PERSON (SOURCE_INDEX) . NAME);
  else   /* success - parse path to find and display RELATIONSHIP */
     do;
     call RESOLVE_PATH_TO_ENGLISH;
     call COMPUTE_COMMON_GENES (SOURCE_INDEX, TARGET_INDEX);
     end;

  /* End execution of FIND_RELATIONSHIP.
```

```
   Utility procedures begin here. */

  PROCESS_ADJACENT_NODE: procedure (BASE_NODE, NEXT_NODE, NEXT_BASE_EDGE);
    /* NEXT_NODE is adjacent to last-REACHED node (= BASE_NODE).
       if NEXT_NODE already REACHED, do nothing.
       If previously seen, check whether path thru BASE_NODE is
       shorter than current path to NEXT_NODE, and if so re-link
       next to base.
       If not previously seen, link next to base node.  */
    declare
      (BASE_NODE, NEXT_NODE) fixed binary (10,0),
       NEXT_BASE_EDGE        fixed binary (4,0);
    declare
      (WEIGHT_THIS_EDGE, DISTANCE_THRU_BASE_NODE)
                             float decimal (6);

  /* begin execution of PROCESS_ADJACENT_NODE */
    if PERSON (NEXT_NODE) . REACHED_STATUS ~= REACHED then
       do;
       if NEXT_BASE_EDGE = SPOUSE then
          WEIGHT_THIS_EDGE = 1.8;
       else
          WEIGHT_THIS_EDGE = 1.0;
       DISTANCE_THRU_BASE_NODE = WEIGHT_THIS_EDGE +
           PERSON (BASE_NODE) . DISTANCE_FROM_SOURCE;
       if PERSON (NEXT_NODE) . REACHED_STATUS = NOT_SEEN then
          do;
          PERSON (NEXT_NODE) . REACHED_STATUS = NEARBY;
          LAST_NEARBY_INDEX = LAST_NEARBY_INDEX + 1;
          NEARBY_NODE (LAST_NEARBY_INDEX) = NEXT_NODE;
          call LINK_NEXT_NODE_TO_BASE_NODE;
          end;
       else   /* REACHED_STATUS = NEARBY */
          if DISTANCE_THRU_BASE_NODE <
                PERSON (NEXT_NODE) . DISTANCE_FROM_SOURCE then
             call LINK_NEXT_NODE_TO_BASE_NODE;
       end;   /* if REACHED_STATUS not = REACHED */

    LINK_NEXT_NODE_TO_BASE_NODE: procedure;
     /* link next to base by re-setting its predecessor index to
        point to base, note type of edge, and re-set distance
        as it is through base node. */
    /* begin execution of LINK_NEXT_NODE_TO_BASE_NODE */
      PERSON (NEXT_NODE) . DISTANCE_FROM_SOURCE = DISTANCE_THRU_BASE_NODE;
      PERSON (NEXT_NODE) . PATH_PREDECESSOR     = BASE_NODE;
      PERSON (NEXT_NODE) . EDGE_TO_PREDECESSOR  = NEXT_BASE_EDGE;
    end LINK_NEXT_NODE_TO_BASE_NODE;

  end PROCESS_ADJACENT_NODE;

/* End utility procedures under FIND_RELATIONSHIP.
```

```
   Begin two major procedures: RESOLVE_PATH_TO_ENGLISH and
   COMPUTE_COMMON_GENES */

RESOLVE_PATH_TO_ENGLISH: procedure;
/* RESOLVE_PATH_TO_ENGLISH condenses the shortest path to a
   series of RELATIONSHIPs for which there are English
   descriptions. */
  /* Key persons are the ones in the RELATIONSHIP path which remain
    after the path is condensed. */
  declare
    /* values for sibling proximity */
    (STEP   initial ('S'),
     HALF   initial ('H'),
     FULL   initial ('F')) character (1);
  declare
    01 KEY_PERSON dimension (1:300),
       05  PERSON_INDEX        fixed binary (10,0),
       05  GENERATION_GAP      fixed binary (10,0),
       05  PROXIMITY           character (1),
       05  RELATION_TO_NEXT    fixed binary (4,0),
       05  COUSIN_RANK         fixed binary (10,0);

  declare
    /* these variables are used to condense the path */
    (KEY_RELATION, LATER_KEY_RELATION, PRIMARY_RELATION,
     NEXT_PRIMARY_RELATION)     fixed binary (4,0),
    GENERATION_COUNT            fixed binary (10,0),
    (KEY_INDEX, LATER_KEY_INDEX, PRIMARY_INDEX)
                                fixed binary (10,0),
    ANOTHER_ELEMENT_POSSIBLE    bit (1);

/* begin execution of RESOLVE_PATH_TO_ENGLISH */
   put skip list (' Shortest path between identified persons: ');
   THIS_NODE  = TARGET_INDEX;
   /* Display path and initialize KEY_PERSON array from path elements. */
TRAVERSE_SHORTEST_PATH:
   do KEY_INDEX = 1 to 300 while (THIS_NODE ~= SOURCE_INDEX);
     begin;
       declare
         EDGE_TYPE dimension (1:3) character (9) static
              initial ('parent of', 'child of', 'spouse of');
       put skip list ('  ' || PERSON (THIS_NODE) . NAME || ' is ' ||
          EDGE_TYPE (PERSON (THIS_NODE) . EDGE_TO_PREDECESSOR));
     end;
     KEY_PERSON (KEY_INDEX) . PERSON_INDEX     = THIS_NODE;
     KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT =
        PERSON (THIS_NODE) . EDGE_TO_PREDECESSOR;
     if PERSON (THIS_NODE) . EDGE_TO_PREDECESSOR = SPOUSE then
        KEY_PERSON (KEY_INDEX) . GENERATION_GAP = 0;
     else
        KEY_PERSON (KEY_INDEX) . GENERATION_GAP = 1;
     THIS_NODE = PERSON (THIS_NODE) . PATH_PREDECESSOR;
   end TRAVERSE_SHORTEST_PATH;
   put skip list('  ' || PERSON (THIS_NODE) . NAME);
```

```
   KEY_PERSON (KEY_INDEX)     . PERSON_INDEX     = THIS_NODE;
   KEY_PERSON (KEY_INDEX)     . RELATION_TO_NEXT = NULL_RELATION;
   KEY_PERSON (KEY_INDEX + 1) . RELATION_TO_NEXT = NULL_RELATION;
   /* Resolve CHILD-PARENT and CHILD-SPOUSE-PARENT relations
     to SIBLING relations. */
FIND_SIBLINGS:
   do KEY_INDEX = 1 to 300
      while (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT ~= NULL_RELATION);
     if KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = CHILD then
        do;
        LATER_KEY_RELATION = KEY_PERSON (KEY_INDEX + 1) . RELATION_TO_NEXT;
        if LATER_KEY_RELATION = PARENT then
           /* found either full or half SIBLINGs */
           do;
           KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = SIBLING;
           if FULL_SIBLING (KEY_PERSON (KEY_INDEX)     . PERSON_INDEX,
                            KEY_PERSON (KEY_INDEX + 2) . PERSON_INDEX)
           then
              KEY_PERSON (KEY_INDEX) . PROXIMITY = FULL;
           else
              KEY_PERSON (KEY_INDEX) . PROXIMITY = HALF;
           call CONDENSE_KEY_PERSONS (KEY_INDEX, 1);
           end;   /* processing of full/half SIBLINGs */
        else
           if (LATER_KEY_RELATION = SPOUSE) &
              (KEY_PERSON (KEY_INDEX + 2) . RELATION_TO_NEXT = PARENT)
           then  /* found step-SIBLINGs */
              do;
              KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = SIBLING;
              KEY_PERSON (KEY_INDEX) . PROXIMITY        = STEP;
              call CONDENSE_KEY_PERSONS (KEY_INDEX, 2);
              end;   /* processing of step-SIBLINGs */
        end;   /* if RELATION_TO_NEXT = CHILD */
   end FIND_SIBLINGS;
   /* Resolve CHILD-CHILD-... and PARENT-PARENT-... relations to
     direct descendant or ancestor relations. */
FIND_ANCESTORS_OR_DESCENDANTS:
   do KEY_INDEX = 1 to 300
      while (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT ~= NULL_RELATION);
     if (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = CHILD) |
        (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = PARENT)
     then
        do;
        do LATER_KEY_INDEX = KEY_INDEX + 1 to 300
           while (KEY_PERSON (LATER_KEY_INDEX) . RELATION_TO_NEXT =
                  KEY_PERSON       (KEY_INDEX) . RELATION_TO_NEXT);
        end;
        GENERATION_COUNT = LATER_KEY_INDEX - KEY_INDEX;
        if GENERATION_COUNT > 1 then
           do;  /* compress generations */
           KEY_PERSON (KEY_INDEX) . GENERATION_GAP = GENERATION_COUNT;
           call CONDENSE_KEY_PERSONS (KEY_INDEX, GENERATION_COUNT - 1);
           end;
        end;   /* if RELATION_TO_NEXT = CHILD or PARENT */
   end FIND_ANCESTORS_OR_DESCENDANTS;
```

```
   /* Resolve CHILD-SIBLING-PARENT to COUSIN,
              CHILD-SIBLING        to NEPHEW,
              SIBLING-PARENT       to UNCLE. */
FIND_COUSINS_NEPHEWS_UNCLES:
   do KEY_INDEX = 1 to 300
      while (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT ~= NULL_RELATION);
     LATER_KEY_RELATION = KEY_PERSON (KEY_INDEX + 1) . RELATION_TO_NEXT;
     if (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = CHILD) &
        (LATER_KEY_RELATION = SIBLING)
     then    /* COUSIN or NEPHEW */
        if KEY_PERSON (KEY_INDEX + 2) . RELATION_TO_NEXT = PARENT then
           /* found COUSIN */
           do;
           KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = COUSIN;
           KEY_PERSON (KEY_INDEX) . PROXIMITY  =
                KEY_PERSON (KEY_INDEX + 1) . PROXIMITY;
           KEY_PERSON (KEY_INDEX) . COUSIN_RANK =
              min (KEY_PERSON (KEY_INDEX)      . GENERATION_GAP,
                   KEY_PERSON (KEY_INDEX + 2) . GENERATION_GAP);
           KEY_PERSON (KEY_INDEX) . GENERATION_GAP =
              abs (KEY_PERSON (KEY_INDEX)      . GENERATION_GAP -
                   KEY_PERSON (KEY_INDEX + 2) . GENERATION_GAP);
           call CONDENSE_KEY_PERSONS (KEY_INDEX, 2);
           end;
        else  /* found NEPHEW */
           do;
           KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = NEPHEW;
           KEY_PERSON (KEY_INDEX) . PROXIMITY =
               KEY_PERSON (KEY_INDEX + 1) . PROXIMITY;
           call CONDENSE_KEY_PERSONS (KEY_INDEX, 1);
           end;
     else    /* not COUSIN or NEPHEW */
        if (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = SIBLING) &
           (LATER_KEY_RELATION = PARENT)
        then    /* found UNCLE */
           do;
           KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT = UNCLE;
           KEY_PERSON (KEY_INDEX) . GENERATION_GAP   =
                KEY_PERSON (KEY_INDEX + 1) . GENERATION_GAP;
           call CONDENSE_KEY_PERSONS (KEY_INDEX, 1);
           end;
   end FIND_COUSINS_NEPHEWS_UNCLES;
```

```
   /* Loop below will pick out valid adjacent strings of elements
     to be displayed.  KEY_INDEX points to first element,
     LATER_KEY_INDEX to last element, and PRIMARY_INDEX to the
     element which determines the primary English word to be used.
     Associativity of adjacent elements in condensed table
     is based on English usage. */
   KEY_INDEX = 1;
   put skip list (' Condensed path:');
CONSOLIDATE_ADJACENT_PERSONS:
   do while (KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT ~= NULL_RELATION);
     KEY_RELATION    = KEY_PERSON (KEY_INDEX) . RELATION_TO_NEXT;
     LATER_KEY_INDEX = KEY_INDEX;
     PRIMARY_INDEX   = KEY_INDEX;
     if KEY_PERSON (KEY_INDEX + 1) . RELATION_TO_NEXT ~= NULL_RELATION then
        do;   /* seek multi-element combination */
        ANOTHER_ELEMENT_POSSIBLE = TRUE;
        if KEY_RELATION = SPOUSE then
           do;
           LATER_KEY_INDEX = LATER_KEY_INDEX + 1;
           PRIMARY_INDEX   = LATER_KEY_INDEX;
           if (KEY_PERSON (LATER_KEY_INDEX) . RELATION_TO_NEXT = SIBLING) |
              (KEY_PERSON (LATER_KEY_INDEX) . RELATION_TO_NEXT = COUSIN)
           then   /* Nothing can follow SPOUSE-SIBLING or SPOUSE-COUSIN */
              ANOTHER_ELEMENT_POSSIBLE = FALSE;
           end;
        /* PRIMARY_INDEX is now correctly set.  Next if-statement
          determines if a following SPOUSE relation should be
          appended to this combination or left for the next
          combination. */
        if ANOTHER_ELEMENT_POSSIBLE &
           (KEY_PERSON (PRIMARY_INDEX + 1) . RELATION_TO_NEXT = SPOUSE)
           /* Only a SPOUSE can follow a Primary */
        then
           do;  /* check primary preceding and following SPOUSE. */
           PRIMARY_RELATION      =
              KEY_PERSON (PRIMARY_INDEX) . RELATION_TO_NEXT;
           NEXT_PRIMARY_RELATION =
              KEY_PERSON (PRIMARY_INDEX + 2) . RELATION_TO_NEXT;
           if (NEXT_PRIMARY_RELATION = NEPHEW |
               NEXT_PRIMARY_RELATION = COUSIN |
               NEXT_PRIMARY_RELATION = NULL_RELATION)
              | (PRIMARY_RELATION = NEPHEW)
              | ( ( PRIMARY_RELATION = SIBLING |
                    PRIMARY_RELATION = PARENT)
                  & (NEXT_PRIMARY_RELATION ~= UNCLE ) )
           then  /* append following SPOUSE with this combination. */
              LATER_KEY_INDEX = LATER_KEY_INDEX + 1;
           end;  /* check primary preceding and following SPOUSE */
        end;  /* multi-element combination */
     call DISPLAY_RELATION (KEY_INDEX, LATER_KEY_INDEX, PRIMARY_INDEX);
     KEY_INDEX = LATER_KEY_INDEX + 1;
   end CONSOLIDATE_ADJACENT_PERSONS;
   put skip list (' ' || PERSON (KEY_PERSON (KEY_INDEX) . PERSON_INDEX) . NAME);

/* End execution of RESOLVE_PATH_TO_ENGLISH.
```

```
   Begin utility procedures for RESOLVE_PATH_TO_ENGLISH. */

  FULL_SIBLING: procedure (INDEX1, INDEX2)
              returns (bit(1));
    /* Determines whether two PERSONs are full siblings, i.e.,
       have the same two parents. */

    declare
      (INDEX1, INDEX2) fixed binary (10,0);

  return
   ((PERSON (INDEX1) . RELATIVE_IDENTIFIER (FATHER_IDENT) ~= NULL_IDENT) &
    (PERSON (INDEX1) . RELATIVE_IDENTIFIER (MOTHER_IDENT) ~= NULL_IDENT) &
    (PERSON (INDEX1) . RELATIVE_IDENTIFIER (FATHER_IDENT) =
        PERSON (INDEX2) . RELATIVE_IDENTIFIER (FATHER_IDENT) ) &
    (PERSON (INDEX1) . RELATIVE_IDENTIFIER (MOTHER_IDENT) =
        PERSON (INDEX2) . RELATIVE_IDENTIFIER (MOTHER_IDENT) ) );
  end FULL_SIBLING;

  CONDENSE_KEY_PERSONS: procedure (AT_INDEX, GAP_SIZE);
    /* CONDENSE_KEY_PERSONS condenses superfluous entries from the
       KEY_PERSON array, starting at AT_INDEX. */
    declare
      AT_INDEX fixed binary (10,0),
      GAP_SIZE fixed binary (10,0);
    declare
      (RECEIVE_INDEX, SEND_INDEX) fixed binary (10,0);
  /* begin execution of CONDENSE_KEY_PERSONS */
    RECEIVE_INDEX = AT_INDEX + 1;
    SEND_INDEX    = RECEIVE_INDEX + GAP_SIZE;
    KEY_PERSON (RECEIVE_INDEX) = KEY_PERSON (SEND_INDEX);
    do while (KEY_PERSON (SEND_INDEX) . RELATION_TO_NEXT ~= NULL_RELATION);
      RECEIVE_INDEX = RECEIVE_INDEX + 1;
      SEND_INDEX    = RECEIVE_INDEX + GAP_SIZE;
      KEY_PERSON (RECEIVE_INDEX) = KEY_PERSON (SEND_INDEX);
    end;
  end CONDENSE_KEY_PERSONS;

/* End utility procedures.
```

```
   Begin DISPLAY_RELATION, which does major work of displaying
   under RESOLVE_PATH_TO_ENGLISH. */

DISPLAY_RELATION: procedure (FIRST_INDEX, LAST_INDEX, PRIMARY_INDEX);
  /* DISPLAY_RELATION takes 1, 2, or 3 adjacent elements in the
     condensed table and generates the English description of
     the relation between the first and last + 1 elements. */
  declare
    (FIRST_INDEX, LAST_INDEX, PRIMARY_INDEX) fixed binary (10,0);
  declare
    DISPLAY_BUFFER     character (80) varying,
    INLAW              bit (1),
    THIS_PROXIMITY     character (1),
    THIS_GENDER        character (1),
    SUFFIX_INDICATOR   fixed binary (6,0),
    (FIRST_RELATION, LAST_RELATION, PRIMARY_RELATION)
                       fixed binary (4,0),
    (THIS_GENERATION_GAP, THIS_COUSIN_RANK)
                       fixed binary (10,0);

/*  begin execution of DISPLAY_RELATION */
  FIRST_RELATION     = KEY_PERSON (FIRST_INDEX)   . RELATION_TO_NEXT;
  LAST_RELATION      = KEY_PERSON (LAST_INDEX)    . RELATION_TO_NEXT;
  PRIMARY_RELATION   = KEY_PERSON (PRIMARY_INDEX) . RELATION_TO_NEXT;
  /* set THIS_PROXIMITY */
  if ((PRIMARY_RELATION = PARENT) & (FIRST_RELATION = SPOUSE)) |
     ((PRIMARY_RELATION = CHILD) & (LAST_RELATION  = SPOUSE))
  then
     THIS_PROXIMITY = STEP;
  else
     if PRIMARY_RELATION = SIBLING |
        PRIMARY_RELATION = UNCLE   |
        PRIMARY_RELATION = NEPHEW  |
        PRIMARY_RELATION = COUSIN
     then
        THIS_PROXIMITY = KEY_PERSON (PRIMARY_INDEX) . PROXIMITY;
     else
        THIS_PROXIMITY = FULL;
  /* set THIS_GENERATION_GAP */
  if PRIMARY_RELATION = PARENT |
     PRIMARY_RELATION = CHILD  |
     PRIMARY_RELATION = UNCLE  |
     PRIMARY_RELATION = NEPHEW |
     PRIMARY_RELATION = COUSIN
  then
     THIS_GENERATION_GAP = KEY_PERSON (PRIMARY_INDEX) . GENERATION_GAP;
  else
     THIS_GENERATION_GAP = 0;
```

```
/* set INLAW */
INLAW = FALSE;
if (FIRST_RELATION = SPOUSE) &
   (PRIMARY_RELATION = SIBLING |
    PRIMARY_RELATION = CHILD   |
    PRIMARY_RELATION = NEPHEW  |
    PRIMARY_RELATION = COUSIN)
then
   INLAW = TRUE;
if (LAST_RELATION = SPOUSE) &
   (PRIMARY_RELATION = SIBLING |
    PRIMARY_RELATION = PARENT  |
    PRIMARY_RELATION = UNCLE   |
    PRIMARY_RELATION = COUSIN)
then
   INLAW = TRUE;
/* set THIS_COUSIN_RANK */
if PRIMARY_RELATION = COUSIN then
   THIS_COUSIN_RANK = KEY_PERSON (PRIMARY_INDEX) . COUSIN_RANK;
else
   THIS_COUSIN_RANK = 0;

/* parameters are set - now generate display. */

DISPLAY_BUFFER =
   ´ ´ || PERSON (KEY_PERSON (FIRST_INDEX) . PERSON_INDEX) . NAME || ´ is ´;
if PRIMARY_RELATION = PARENT |
   PRIMARY_RELATION = CHILD  |
   PRIMARY_RELATION = UNCLE  |
   PRIMARY_RELATION = NEPHEW
then
   do;   /* write generation-qualifier */
   if THIS_GENERATION_GAP >= 3 then
      do;
      DISPLAY_BUFFER = DISPLAY_BUFFER || ´great´;
      if THIS_GENERATION_GAP > 3 then
         DISPLAY_BUFFER = DISPLAY_BUFFER || ´*´ ||
           TRIM (THIS_GENERATION_GAP - 2);
      DISPLAY_BUFFER = DISPLAY_BUFFER || ´-´;
      end;
   if THIS_GENERATION_GAP >= 2 then
      DISPLAY_BUFFER = DISPLAY_BUFFER || ´grand-´;
   end;
else
   if (PRIMARY_RELATION = COUSIN) & (THIS_COUSIN_RANK > 1) then
      do;
      DISPLAY_BUFFER = DISPLAY_BUFFER || TRIM (THIS_COUSIN_RANK);
      SUFFIX_INDICATOR = mod (THIS_COUSIN_RANK, 10);
      if SUFFIX_INDICATOR > 3 then
         SUFFIX_INDICATOR = 0;
      DISPLAY_BUFFER = DISPLAY_BUFFER ||
         substr (´th st nd rd ´, 3 * SUFFIX_INDICATOR + 1, 3);
      end;
```

```
if THIS_PROXIMITY = STEP then
   DISPLAY_BUFFER = DISPLAY_BUFFER || 'step-';
else
   if THIS_PROXIMITY = HALF then
      DISPLAY_BUFFER = DISPLAY_BUFFER || 'half-';

THIS_GENDER = PERSON (KEY_PERSON (FIRST_INDEX) . PERSON_INDEX) . GENDER;
if PRIMARY_RELATION = PARENT then
   if THIS_GENDER = MALE then DISPLAY_BUFFER = DISPLAY_BUFFER || 'father';
   else                       DISPLAY_BUFFER = DISPLAY_BUFFER || 'mother';
else if PRIMARY_RELATION = CHILD  then
   if THIS_GENDER = MALE then DISPLAY_BUFFER = DISPLAY_BUFFER || 'son';
   else                       DISPLAY_BUFFER = DISPLAY_BUFFER || 'daughter';
else if PRIMARY_RELATION = SPOUSE then
   if THIS_GENDER = MALE then DISPLAY_BUFFER = DISPLAY_BUFFER || 'husband';
   else                       DISPLAY_BUFFER = DISPLAY_BUFFER || 'wife';
else if PRIMARY_RELATION = SIBLING then
   if THIS_GENDER = MALE then DISPLAY_BUFFER = DISPLAY_BUFFER || 'brother';
   else                       DISPLAY_BUFFER = DISPLAY_BUFFER || 'sister';
else if PRIMARY_RELATION = UNCLE then
   if THIS_GENDER = MALE then DISPLAY_BUFFER = DISPLAY_BUFFER || 'uncle';
   else                       DISPLAY_BUFFER = DISPLAY_BUFFER || 'aunt';
else if PRIMARY_RELATION = NEPHEW then
   if THIS_GENDER = MALE then DISPLAY_BUFFER = DISPLAY_BUFFER || 'nephew';
   else                       DISPLAY_BUFFER = DISPLAY_BUFFER || 'niece';
else if PRIMARY_RELATION = COUSIN then
                              DISPLAY_BUFFER = DISPLAY_BUFFER || 'cousin';
else
                              DISPLAY_BUFFER = DISPLAY_BUFFER || 'null';

if INLAW then
   DISPLAY_BUFFER = DISPLAY_BUFFER || '-in-law';

if (PRIMARY_RELATION = COUSIN) & (THIS_GENERATION_GAP > 0) then
   if THIS_GENERATION_GAP > 1 then
      DISPLAY_BUFFER = DISPLAY_BUFFER || ' ' ||
           TRIM (THIS_GENERATION_GAP) || ' times removed';
   else
      DISPLAY_BUFFER = DISPLAY_BUFFER || ' once removed';

DISPLAY_BUFFER = DISPLAY_BUFFER || ' of';
put skip list (DISPLAY_BUFFER);
```

```
/* Begin utility procedure for DISPLAY_RELATION */

TRIM: procedure (NUMERIC_VALUE) returns (character (20) varying);
  /* Returns character representation of numeric values
     with no leading or trailing spaces. */
  declare
    NUMERIC_VALUE  fixed binary (10,0);
  declare
    STRING_REPRESENTATION character (20),
    (START_LOCATION, STOP_LOCATION)
                           fixed binary (10,0);
/* Begin execution of TRIM */
  STRING_REPRESENTATION = NUMERIC_VALUE;
  do START_LOCATION = 1 to 20
     while (substr (STRING_REPRESENTATION, START_LOCATION, 1) = ' ');
  end;
  do STOP_LOCATION = 20 to 1 by -1
     while (substr (STRING_REPRESENTATION, STOP_LOCATION, 1) = ' ');
  end;
  return (substr (STRING_REPRESENTATION, START_LOCATION,
                 STOP_LOCATION - START_LOCATION + 1));
end TRIM;

end DISPLAY_RELATION;

end RESOLVE_PATH_TO_ENGLISH;

/* COMPUTE_COMMON_GENES is second major procedure (after
   RESOLVE_PATH_TO_ENGLISH) under FIND_RELATIONSHIP. */

COMPUTE_COMMON_GENES: procedure (INDEX1, INDEX2);
  /* COMPUTE_COMMON_GENES assumes that each ancestor contributes
     half of the genetic material to a PERSON.  It finds common
     ancestors between two PERSONs and computes the expected
     value of the PROPORTION of common material. */
  declare
    (INDEX1, INDEX2) fixed binary (10,0);
  declare
    COMMON_PROPORTION float decimal (6);

/* begin execution of COMPUTE_COMMON_GENES */
  /* First zero out all ancestors to allow adding.  This is necessary
     because there might be two paths to an ancestor. */
  call ZERO_PROPORTION (INDEX1);
  /* now mark with shared PROPORTION */
  call MARK_PROPORTION (PERSON (INDEX1) . IDENTIFIER, 1.0, INDEX1);
  COMMON_PROPORTION = 0.0;
  call CHECK_COMMON_PROPORTION (COMMON_PROPORTION,
     PERSON (INDEX1) . IDENTIFIER, 1.0, 0.0, INDEX2);
  put skip list (' Proportion of common genetic material = ');
  put edit (COMMON_PROPORTION) (e(13,5,6));

/* End execution of COMPUTE_COMMON_GENES.
```

```
 Begin utility procedures. */

ZERO_PROPORTION: procedure (ZERO_INDEX) recursive;
  /* ZERO_PROPORTION recursively seeks out all ancestors and
     zeros them out. */

  declare
    ZERO_INDEX       fixed binary (10,0),
    THIS_NEIGHBOR    pointer;
/* begin execution of ZERO_PROPORTION */
    PERSON (ZERO_INDEX) . DESCENDANT_GENES = 0.0;
    THIS_NEIGHBOR = PERSON (ZERO_INDEX) . NEIGHBOR_LIST_HEADER;
    do while (THIS_NEIGHBOR ~= null());
      if THIS_NEIGHBOR -> NEIGHBOR_EDGE = PARENT then
         call ZERO_PROPORTION (THIS_NEIGHBOR -> NEIGHBOR_INDEX);
      THIS_NEIGHBOR = THIS_NEIGHBOR -> NEXT_NEIGHBOR;
    end;
end ZERO_PROPORTION;

MARK_PROPORTION: procedure (MARKER, PROPORTION, MARKED_INDEX) recursive;
  /* MARK_PROPORTION recursively seeks out all ancestors and
     marks them with the sender's PROPORTION of shared
     genetic material.  This PROPORTION is diluted by one-half
     for each generation. */

  declare
    MARKER           picture '999',
    PROPORTION       float decimal (6),
    MARKED_INDEX     fixed binary (10,0),
    THIS_NEIGHBOR    pointer;

/* begin execution of MARK_PROPORTION */
  PERSON (MARKED_INDEX) . DESCENDANT_IDENTIFIER = MARKER;
  PERSON (MARKED_INDEX) . DESCENDANT_GENES      =
     PERSON (MARKED_INDEX) . DESCENDANT_GENES + PROPORTION;
  THIS_NEIGHBOR = PERSON (MARKED_INDEX) . NEIGHBOR_LIST_HEADER;
  do while (THIS_NEIGHBOR ~= null());
    if THIS_NEIGHBOR -> NEIGHBOR_EDGE = PARENT then
       call MARK_PROPORTION (MARKER, PROPORTION / 2.0,
                    THIS_NEIGHBOR -> NEIGHBOR_INDEX);
    THIS_NEIGHBOR = THIS_NEIGHBOR -> NEXT_NEIGHBOR;
  end;
end MARK_PROPORTION;
```

```
  CHECK_COMMON_PROPORTION: procedure
          (COMMON_PROPORTION, MATCH_IDENTIFIER, PROPORTION,
           ALREADY_COUNTED, CHECK_INDEX) recursive;
    /* CHECK_COMMON_PROPORTION searches all the ancestors of
       CHECK_INDEX to see if any have been marked, and if so
       adds the appropriate amount to COMMON_PROPORTION. */

    declare
       COMMON_PROPORTION float decimal (6),
       MATCH_IDENTIFIER  picture '999',
       PROPORTION        float decimal (6),
       ALREADY_COUNTED   float decimal (6),
       CHECK_INDEX       fixed binary (10,0),
       THIS_NEIGHBOR     pointer,
       THIS_CONTRIBUTION float decimal (6);

  /* begin execution of CHECK_COMMON_PROPORTION */
    if PERSON (CHECK_INDEX) . DESCENDANT_IDENTIFIER = MATCH_IDENTIFIER then
       /* Increment COMMON_PROPORTION by the contribution of
          this common ancestor, but discount for the contribution
          of less remote ancestors already counted. */
       do;
       THIS_CONTRIBUTION = PERSON (CHECK_INDEX) . DESCENDANT_GENES
                              * PROPORTION;
       COMMON_PROPORTION = COMMON_PROPORTION
          + THIS_CONTRIBUTION - ALREADY_COUNTED;
       end;
    else
       THIS_CONTRIBUTION = 0.0;
    THIS_NEIGHBOR = PERSON (CHECK_INDEX) . NEIGHBOR_LIST_HEADER;
    do while (THIS_NEIGHBOR ^= null());
      if THIS_NEIGHBOR -> NEIGHBOR_EDGE = PARENT then
         call CHECK_COMMON_PROPORTION (COMMON_PROPORTION,
              MATCH_IDENTIFIER, PROPORTION / 2.0,
              THIS_CONTRIBUTION / 4.0,
              THIS_NEIGHBOR -> NEIGHBOR_INDEX);
      THIS_NEIGHBOR = THIS_NEIGHBOR -> NEXT_NEIGHBOR;
    end;
  end CHECK_COMMON_PROPORTION;

end COMPUTE_COMMON_GENES;

end FIND_RELATIONSHIP;

end RELATE;
```

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11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Programming languages have been and will continue to be an important instrument for the automation of a wide variety of functions within industry and the Federal Government. Other instruments, such as program generators, application packages, query languages, and the like, are also available and their use is preferable in some circumstances.

Given that conventional programming is the appropriate technique for a particular application, the choice among the various languages becomes an important issue. There are a great number of selection criteria, not all of which depend directly on the language itself. Broadly speaking, the criteria are based on 1) the language and its implementation, 2) the application to be programmed, and 3) the user's existing facilities and software.

This study presents a survey of selection factors for the major general-purpose languages: Ada, BASIC, C, COBOL, FORTRAN, Pascal, and PL/I. The factors covered include not only the logical operations within each language, but also the advantages and disadvantages stemming from the current computing environment, e.g., software packages, microcomputers, and standards. The criteria associated with the application and the user's facilities are explained. Finally, there is a set of program examples to illustrate the features of the various languages.

This volume includes the program examples. Volume 1 contains the discussion of language selection criteria.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Ada; alternatives to programming; BASIC; C; COBOL; FORTRAN; Pascal; PL/I; programming language features; programming languages; selection of programming language.

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