CÓRDOBA UNIVERSITY

SUPERIOR POLYTECHNIC SCHOOL

DEPARTMENT OF
COMPUTER SCIENCE AND NUMERICAL ANALYSIS

DECLARATIVE PROGRAMMING

COMPUTER ENGINEERING

COMPUTATION ESPECIALITY

FOURTH YEAR

FIRST FOUR-MONTH PERIOD

Subject 1.- Introduction to Scheme language

First part: Scheme

- Subject 1.- Introduction to Scheme language
- Subject 2.- Expressions and Functions
- Subject 3.- Conditional Predicates and Sentences
- Subject 4.- Iteration and Recursion
- Subject 5.- Compound Data Types
- Subject 6.- Data Abstraction
- Subject 7.- Reading and Writing

Second part: Prolog

- Subject 8.- Introduction to Prolog language
- Subject 9.- Basic Elements of Prolog
- Subject 10.- Lists
- Subject 11.- Re-evaluation and the "cut"
- Subject 12.- Input and Output

First part: Scheme

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Contents

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1. Fundamental Characteristics of Functional Programming

✓ **Functional** Programming is a **subtype** of **Declarative** Programming

1. Fundamental Characteristics of Functional Programming

- ✓ **Declarative Programming (1 / 2)**
  - ➢ **Objective**: **Problem description**

    “What” problem must be resolved?

    - ▪ **Notice**:
      - It does **not** mind “**how”** the problem is resolved
      - It **avoids** the implementation features.

1. Fundamental Characteristics of Functional Programming

✓ **Declarative Programming (2 / 2)**

➢ **Features**

- Expressivity
- Extensible: 10% - 90% rule
- Protection
- Mathematic Elegance

➢ **Types**:

- **Functional** *or* Applicative Programming:
  - Lisp, **Scheme**, Haskell, ...
- **Logic** Programming: **Prolog**

1. Fundamental Characteristics of Functional Programming

- ✓ **Principle** of the **“Pure” Functional** Programming

  *“The **expression value** only **depends on** its **sub-expressions** values, if such sub-expressions exist ”.*

- ✓ **Non collateral effects**

  The value of “a + b” **only** depends on “a” and “b”.

- ✓ The **function** term is used in its **mathematical** sense.

- ✓ **No instructions**: programming **without** assignments

  - ➢ The **impure** Functional programming **allows** the

    “assignment instruction”

1. Fundamental Characteristics of Functional Programming

- ✓ **Program structure** in **Functional** Programming
  - ➢ **The program is a function composed of simpler functions**
  - ➢ **Function execution:**
    - ▪ **Receives the input data**: functions arguments or parameters
    - ▪ **Evaluates the expressions**
    - ▪ **Returns the Result**: computed value of the function

1. Fundamental Characteristics of Functional Programming

- ✓ **Type of Functional Languages**
  - ➢ **Most** of them are **interpreted** languages
  - ➢ Some of them have **compiled** versions
- ✓ **Memory management**
  - ➢ **Implicit memory management**:
    - ▪ Memory management is a task of the interpreter.
    - ▪ The programmer must **not** worry about memory management.
  - ➢ **Garbage collection**: task of the interpreter.

In short: the programmer must only worry about the **Problem description**

Contents

2. Historic Summary of Scheme

- ✓ LISP
- ✓ Compilation versus Interpretation
- ✓ Lexical (or static) versus dynamical scope
- ✓ Origin of Scheme

2. **Historic Summary of Scheme**

- ✓ **LISP**
- ✓ Compilation versus Interpretation
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2. Historic Summary of Scheme

- ✓ **LISP**
  - ➢ **John McCarthy** (MIT)
  - ➢ **“Advice Taker”** program:
    - ▪ Theoretical basis: Logic Mathematics
    - ▪ Objective: Deduction and Inferences
  - ➢ **LISP**: **LIS**t **P**rocessing (1956 – 1958)
    - ▪ Second historic language of **Artificial Intelligence** (after IPL)
    - ▪ At present time, second historic language **in use** (after Fortran)
    - ▪ LISP is based on Lambda Calculus (**Alonzo Church**)
  - ➢ **Scheme** is a **dialect** of **LISP**

2. **Historic Summary of Scheme**

- ✓ **LISP**
  - ➢ **Functional Programming Characteristics**
    - ▪ **Recursion**
    - ▪ **Lists**
    - ▪ **Implicit** memory management
    - ▪ Interactive and **interpreted** programs
    - ▪ **Symbolic** Programming
    - ▪ **Dynamically scoped** for **non** local variables

2. Historic Summary of Scheme

- ✓ **LISP**
  - ➢ LISP's **contributions**:
    - **Built - in** functions
    - **Garbage collection**
    - **Definition Formal Language**: **LISP itself**

2. **Historic Summary of Scheme**

- ✓ **LISP**
  - ➢ **Applications**: **Artificial Intelligence** Programs
    - Theorem verification and testing
    - Symbolic differentiation and integration
    - Search Problems
    - Natural Language Processing
    - Computer Vision
    - Robotics
    - Knowledge Representation Systems
    - Expert Systems
    - And so on

2. Historic Summary of Scheme

- ✓ **LISP**
  - ➢ **Dialects (1 /2)**
    - ▪ **Mac LISP** (Man and computer or Machine – aided cognition): **East** Coast Version
    - ▪ **Inter LISP** (Interactive LISP): **West** Coast Version
      - - Bolt, Beranek y Newman Company (BBN)
      - - Research Center of Xerox at Palo Alto (Texas)
      - - **LISP Machine**

2. Historic Summary of Scheme

- ✓ **LISP**
  - ➢ **Dialects** (2 / 2)
    - **Mac LISP** (Man and computer or Machine – aided cognition): East Coast Version
      - C-LISP: Massachusetts University
      - Franz LISP: California University (Berkeley). **Compiled version.**
      - NIL (New implementation of LISP): MIT.
      - PSL (Portable Standard LISP): Utah University
      - **Scheme**: MIT.
      - T (True):Yale University.
      - Common LISP

2. **Historic Summary of Scheme**

- ✓ LISP
- ✓ **Compilation versus Interpretation**
- ✓ Lexical (or static) versus dynamical scope
- ✓ Origin of Scheme

2. Historic Summary of Scheme

- ✓ **Compilation versus interpretation**
  - ➢ **Compilation**:
    - ▪ The **source code** (**high level**) is **transformed** into **executable code** (**low level**), which can be independently run.

2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Compilation**

Source code $\rightarrow$ $\boxed{\textbf{Compiler}}$

2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Compilation**

$$\begin{tikzcd}\text{Source code} \arrow[r] & \boxed{\text{Compiler}} \arrow[d] \\ & \text{Compilation errors}\end{tikzcd}$$

2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Compilation**

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- ✓ **Compilation versus interpretation**
  - ➢ **Compilation**

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2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Interpretation**

2. **Historic Summary of Scheme**

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  - ➢ **Interpretation** or **simulation**: consists of a cycle of three stages

2. **Historic Summary of Scheme**

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    1. **Analysis**: the source code is analysed to determine the following correct sentence to be run.

2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Interpretation** or simulation: consists of a cycle of three stages
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    2. **Generation**: the sentence is transformed into executable code.

2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Interpretation** or simulation: consists of a cycle of **three** stages
    1. **Analysis**: the source code is analysed to determine the following correct sentence to be run.
    2. **Generation**: the sentence is transformed into executable code.
    3. **Execution**: the executable code is run.

2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Interpretation**

$$\text{Source code} \rightarrow \boxed{\text{Interpreter}}$$

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$$\begin{tikzcd}
 & \text{Input data} \arrow[d] & \text{Interpretation errors} \\
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2. **Historic Summary of Scheme**

- ✓ **Compilation versus interpretation**
  - ➢ **Interpretation**

$$\begin{tikzcd}
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2. Historic Summary of Scheme

- ✓ **Compilation versus interpretation**
  - ➢ **Interpretation**

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 & \text{Output} &
\end{tikzcd}$$

2. **Historic Summary of Scheme**

✓ **Compilation versus interpretation**

▪ **Compilation**	▪ **Interpretation**
- Independent	- Dependent
- Memory necessities	- No memory necessities
- Efficient	- Less efficient
- Global	- Local
- No interaction	- Interaction
- Closed code during execution	- Open code during execution

2. **Historic Summary of Scheme**

- ✓ LISP
- ✓ Compilation versus Interpretation
- ✓ **Lexical (or static) versus dynamical scope**
- ✓ Origin of Scheme

2. Historic Summary of Scheme

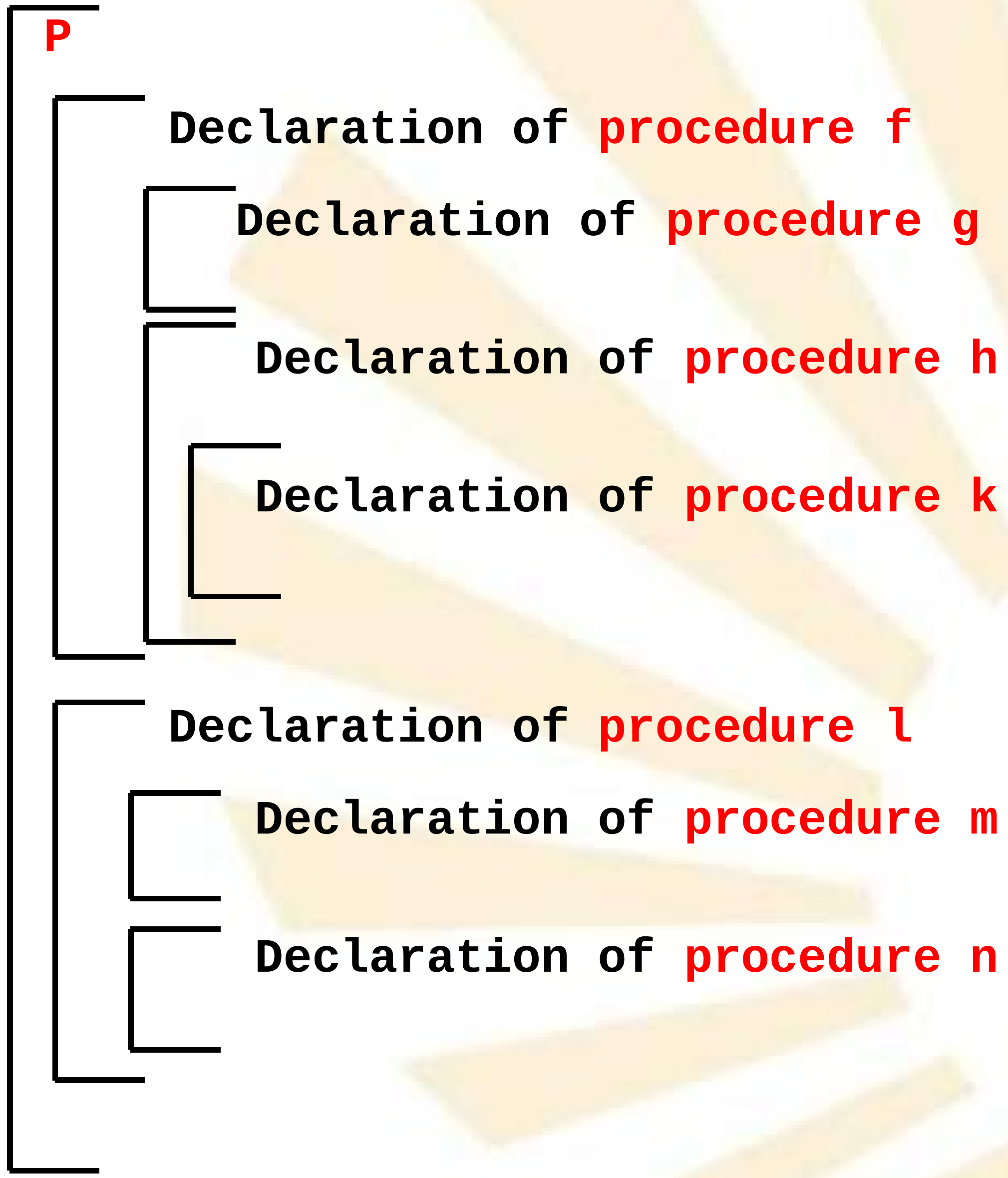
✓ Lexical (or static) versus dynamical scope

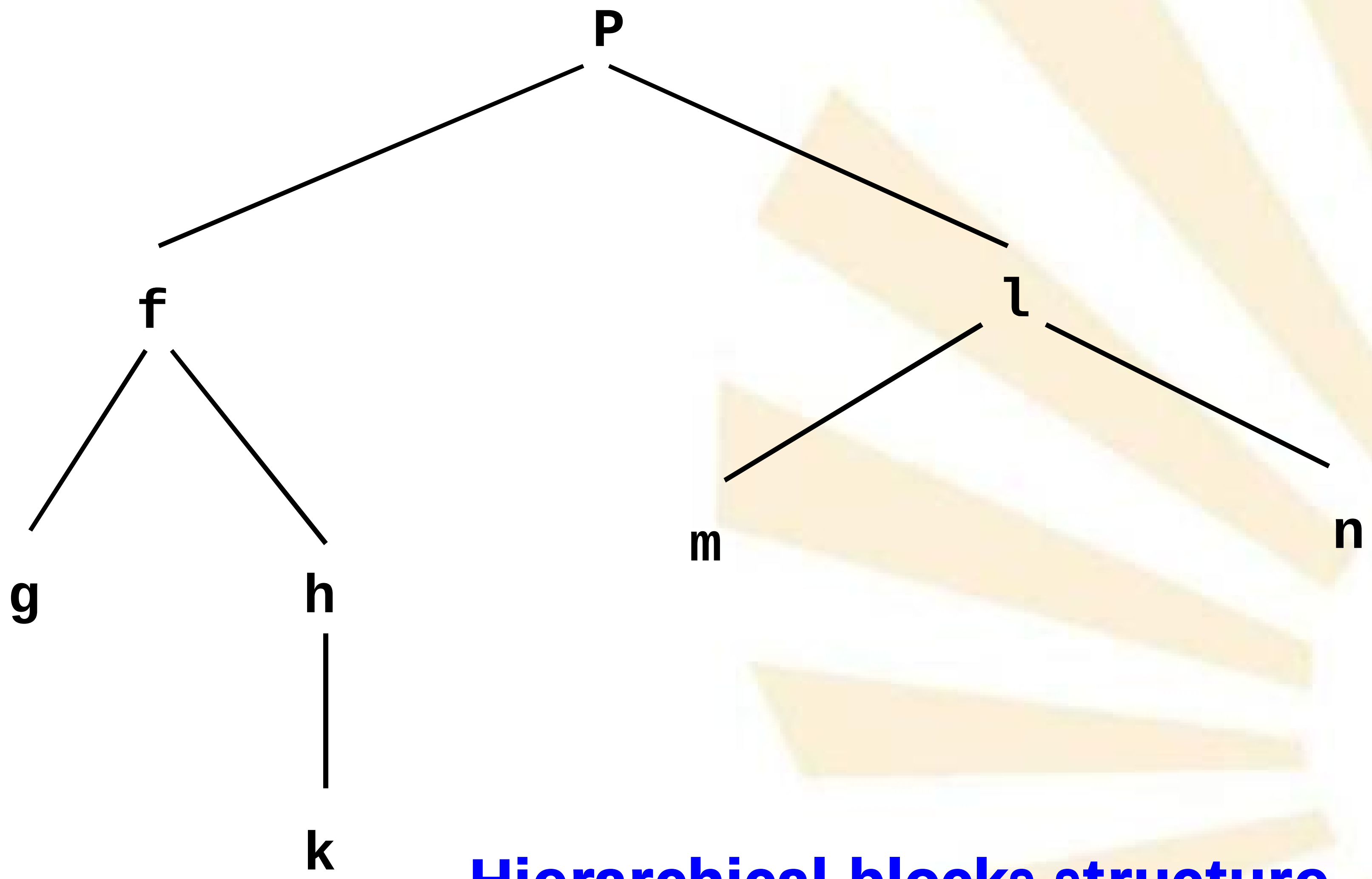
- The **scope rules** determine the **declaration** of **non** local identifiers
- **Non** local identifiers:
  - **Variables** or **functions** which can be **used** in a function or procedure but are **not** declared in that function or procedure
- **Two types**
  - **Lexical or static scope**
    - **With** "blocks structure": Pascal, **Scheme**
    - **Without** "blocks structure": C, Fortran
  - **Dynamical scope:**
    - **Always with** "blocks structure": Lisp, SNOBOL, APL

2. **Historic Summary of Scheme**

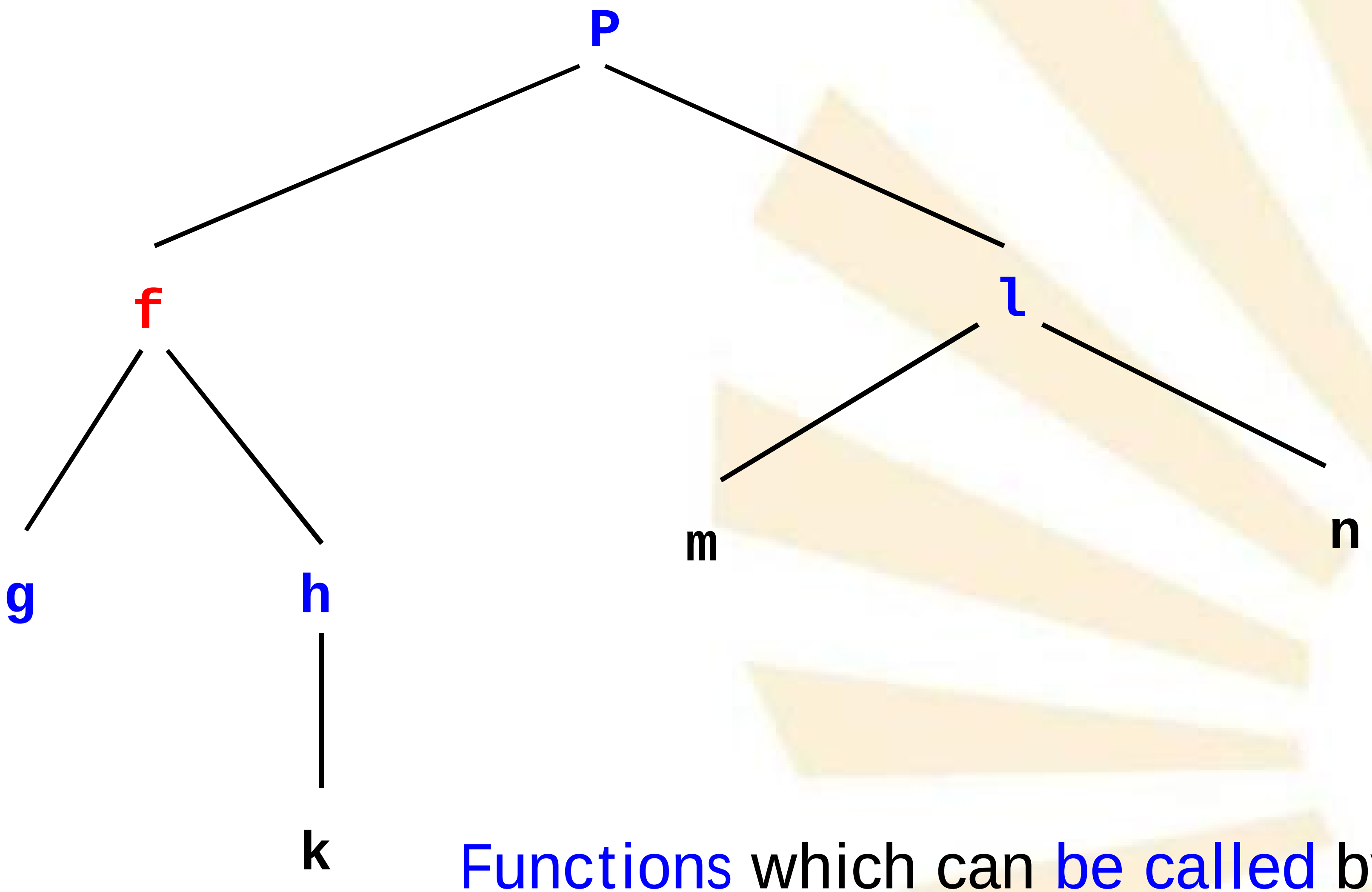
- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Block structure**
    - ▪ A procedure or function can **call**
      - Itself
      - Its children (but **not** its grandchildren...)
      - Its brothers (but **not** its nephews)
      - Its father, grandfather, great-grandfather, ...
      - The brothers of its father, grandfather, ...
    - ▪ A procedure or function can **be called** by
      - Itself
      - Its father (but **not** by its grandfather, ...)
      - Its children, grandchildren, great-grandchildren, ...
      - Its brothers and their children, grandchildren, ...

Example of blocks structure

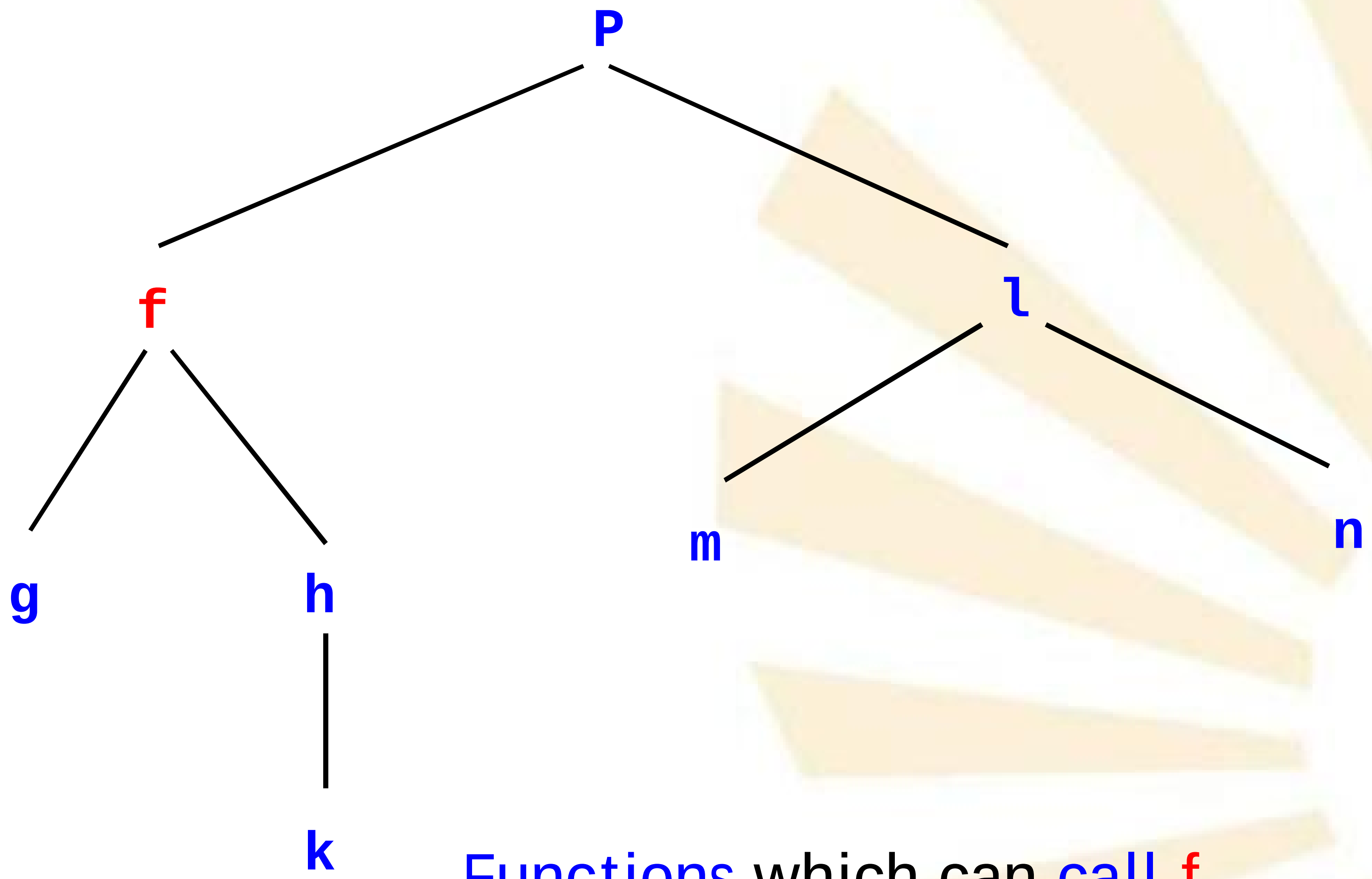

P
Declaration of procedure f
Declaration of procedure g
Declaration of procedure h
Declaration of procedure k
Declaration of procedure l
Declaration of procedure m
Declaration of procedure n



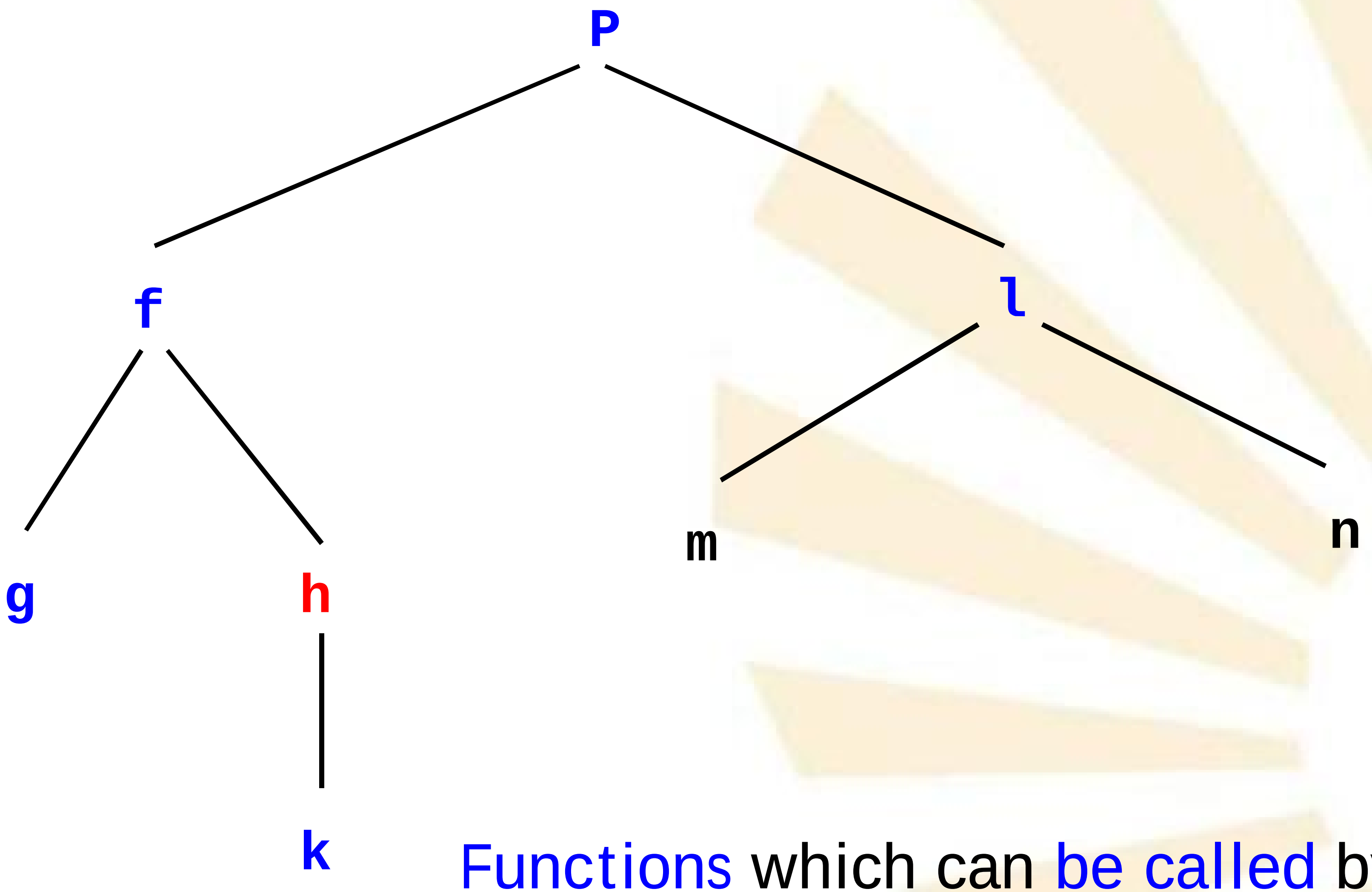
Hierarchical blocks structure



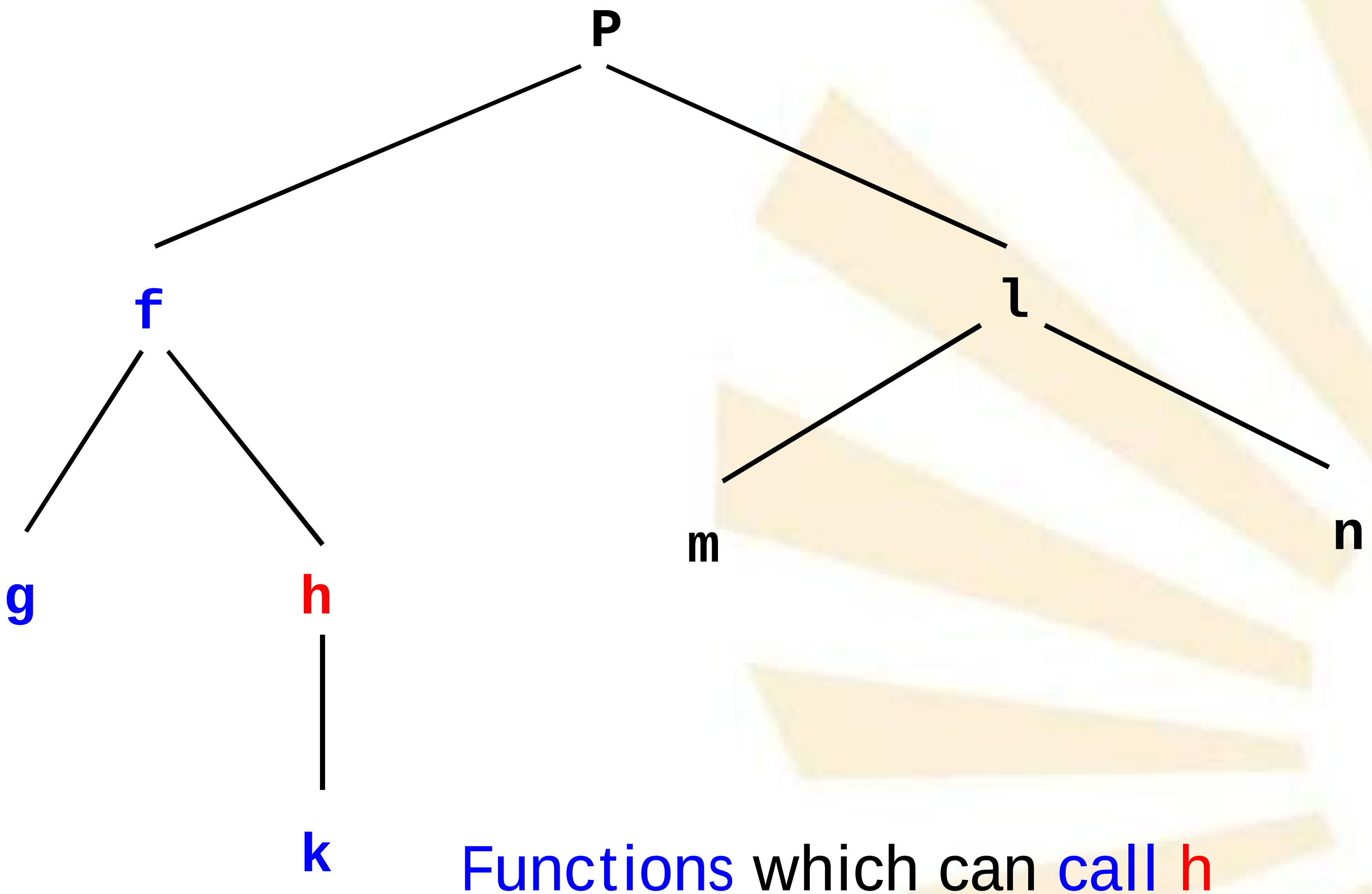
Functions which can be called by **f**



Functions which can call f



Functions which can be called by h



Functions which can call h

2. **Historic Summary of Scheme**

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Lexical or static scope**
    - The **declaration** of a **non** local identifier depends on the **closest lexical context**
    - **The closest nesting rules**

2. **Historic Summary of Scheme**

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Lexical or static scope**
    - ▪ The **declaration** of a **non** local identifier depends on the **closest lexical context:**

      You only have to **read** the program

      to determine the declaration of an identifier.

2. Historic Summary of Scheme

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Lexical or static scope**
    - ▪ **The closest nesting rules:**
      - The **scope** of a procedure (*****) **f** includes the procedure **f**.
      - If a **non** local identifier **x** is used in **f** then the declaration of **x** must be found in the **closest** procedure **g** which includes **f**
      - **Notice** (*****) : procedure, function or block

Example.

Lexical scope

with

“block structure”

```
Declaration of procedure h
 Declaration of variable x   (x1)
 Declaration of variable y   (y1)
 Declaration of variable z   (z1)

 Declaration of procedure g
  Declaration of variable x (x2)
  Declaration of variable y (y2)

  Declaration of procedure f
    Declaration of variable x (x3)

    Use of x   (→ x3)
    Use of y   (→ y2)
    Use of z   (→ z1)

    Use of x   (→ x2)
    Use of y   (→ y2)
    Use of z   (→ z1)
    Call to f

    Use of x   (→ x1)
    Use of y   (→ y1)
    Use of z   (→ z1)
    Call to g
```

2. Historic Summary of Scheme

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Lexical or static scope**
    - ▪ **Without** block structure:
      - If **x** is **not** local for a **specific** function then it is **not** local for **all** functions

Example in C:

without

“block structure”

```
int x;   /* x1 */
int y;   /* y1 */
int z;   /* z1 */

main()
        {
   int x;  /* x2 */
   int y;  /* y2 */

   /* Use of x → x2 */
   /* Use of y → y2 */
   /* Use of z → z1 */
   /* Call to f */
   f ();
  }

 f()
  {
   int x;  /* x3 */
   /* Use of x → x3 */
   /* Use of y → y1 */
   /* Use of z → z1 */
   }
```

Global variables are not recommended

2. **Historic Summary of Scheme**

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Dynamical scope:**
    - The **declaration** of an **identifier** depends on the **execution of the program**
    - **The closest activation rules**

2. **Historic Summary of Scheme**

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Dynamical scope:**
    - ▪ The **declaration** of an **identifier** depends on the **execution of the program**

You have to **run** the program

to determine the declaration of an identifier

2. **Historic Summary of Scheme**

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Dynamical scope:**

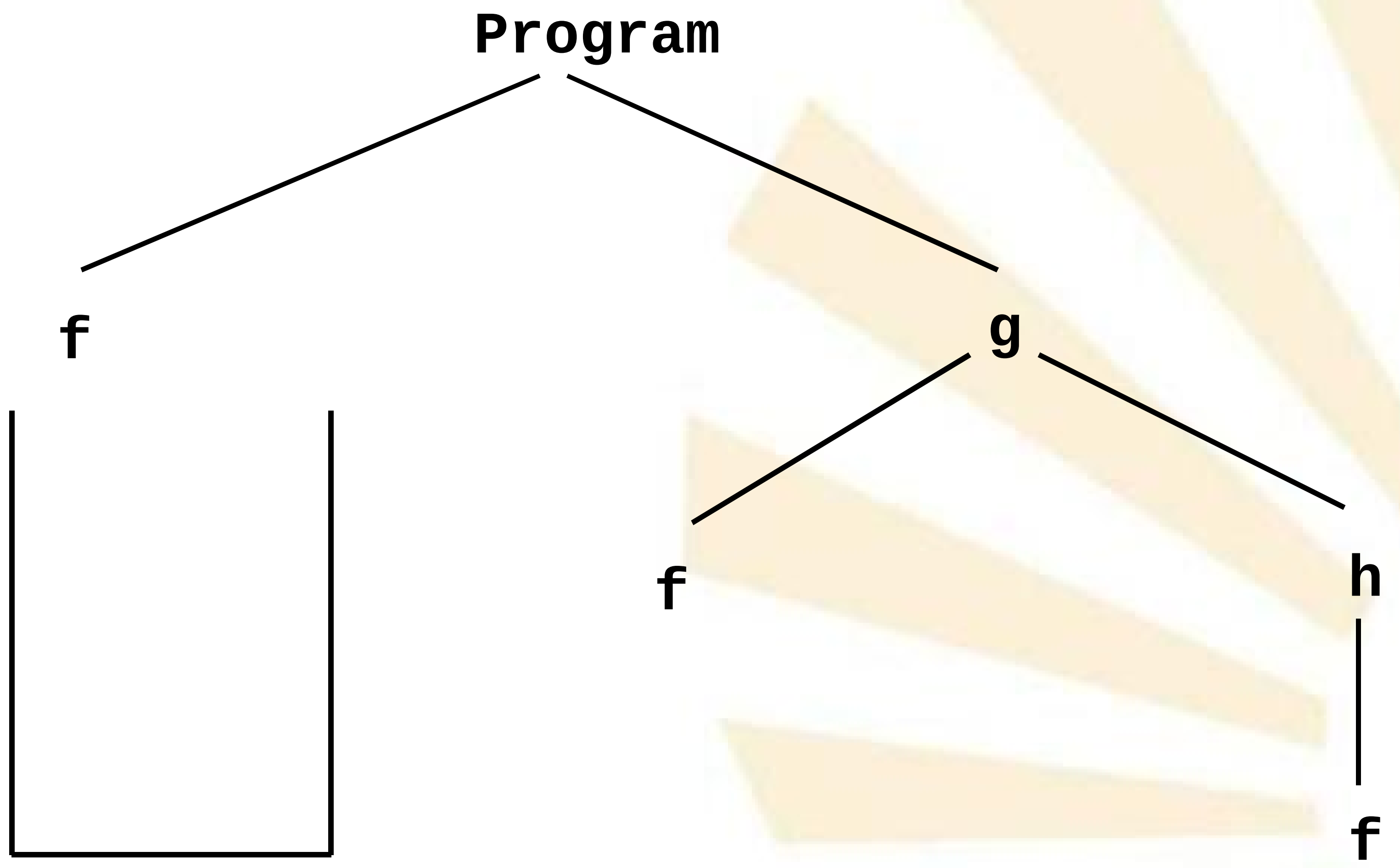
    - ▪ **The closest activation rules:**
      - The **scope** of a procedure (*****) **f** includes the procedure **f**.
      - If a **non** local identifier **x** is used in the **activation** of **f** then the declaration of **x** must be found in the **closest active** procedure **g** with a declaration of x
      - **Notice** (*****) : procedure, function or block

2. **Historic Summary of Scheme**

- ✓ **Lexical (or static) versus dynamical scope**
  - ➢ **Notice**:
    - ▪ The **dynamical scope** allows that an **identifier** can be associated to **different declarations** during the program execution

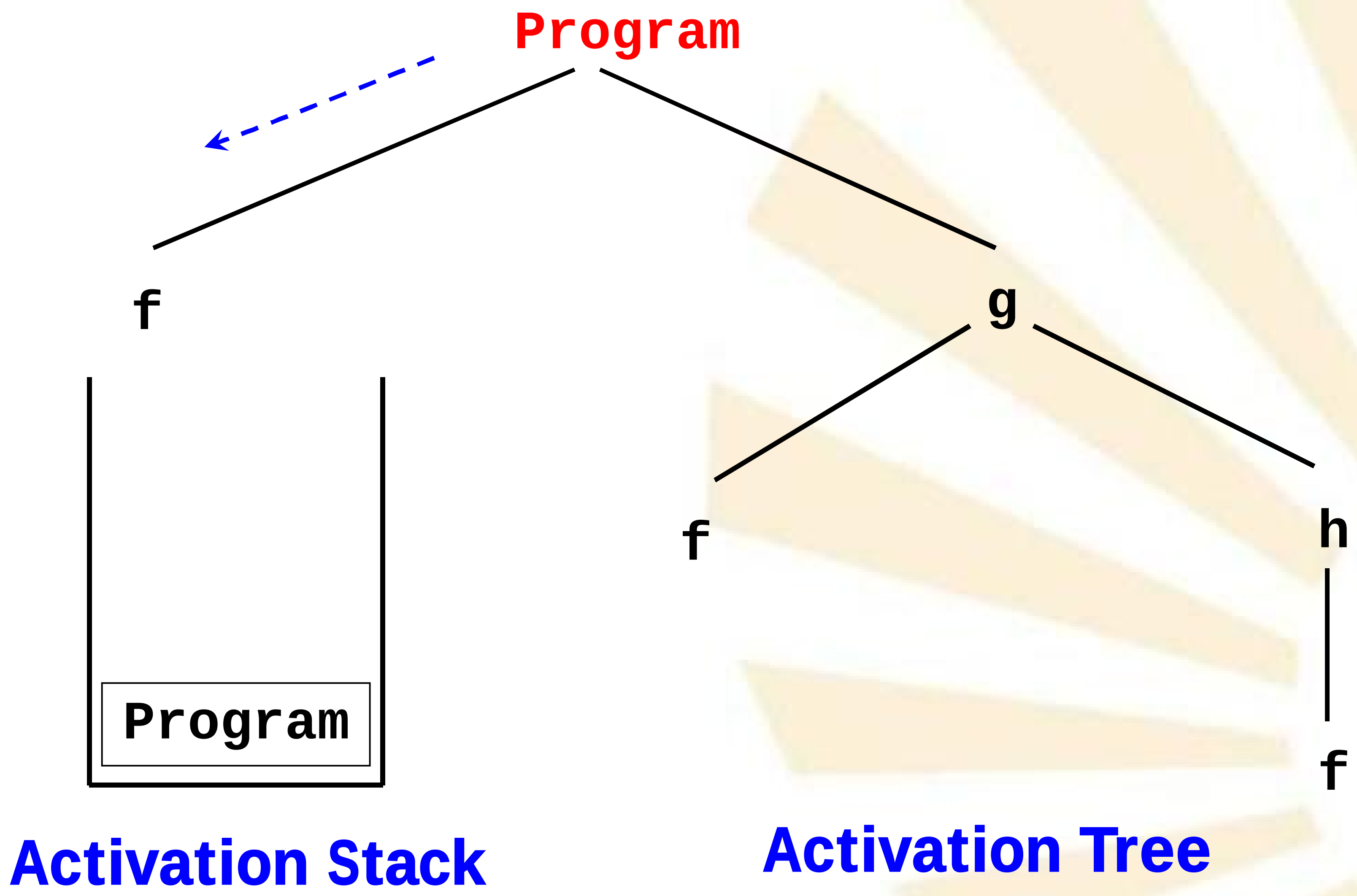
Example: Lexical versus Dynamical scope

```
Program
    Declaration of variable x

    Declaration of procedure f
     Use of x


    Declaration of procedure g
      Declaration of variable x

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f
     Call to g
```



Activation Stack

Activation Tree


Program
f
g
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h
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Program
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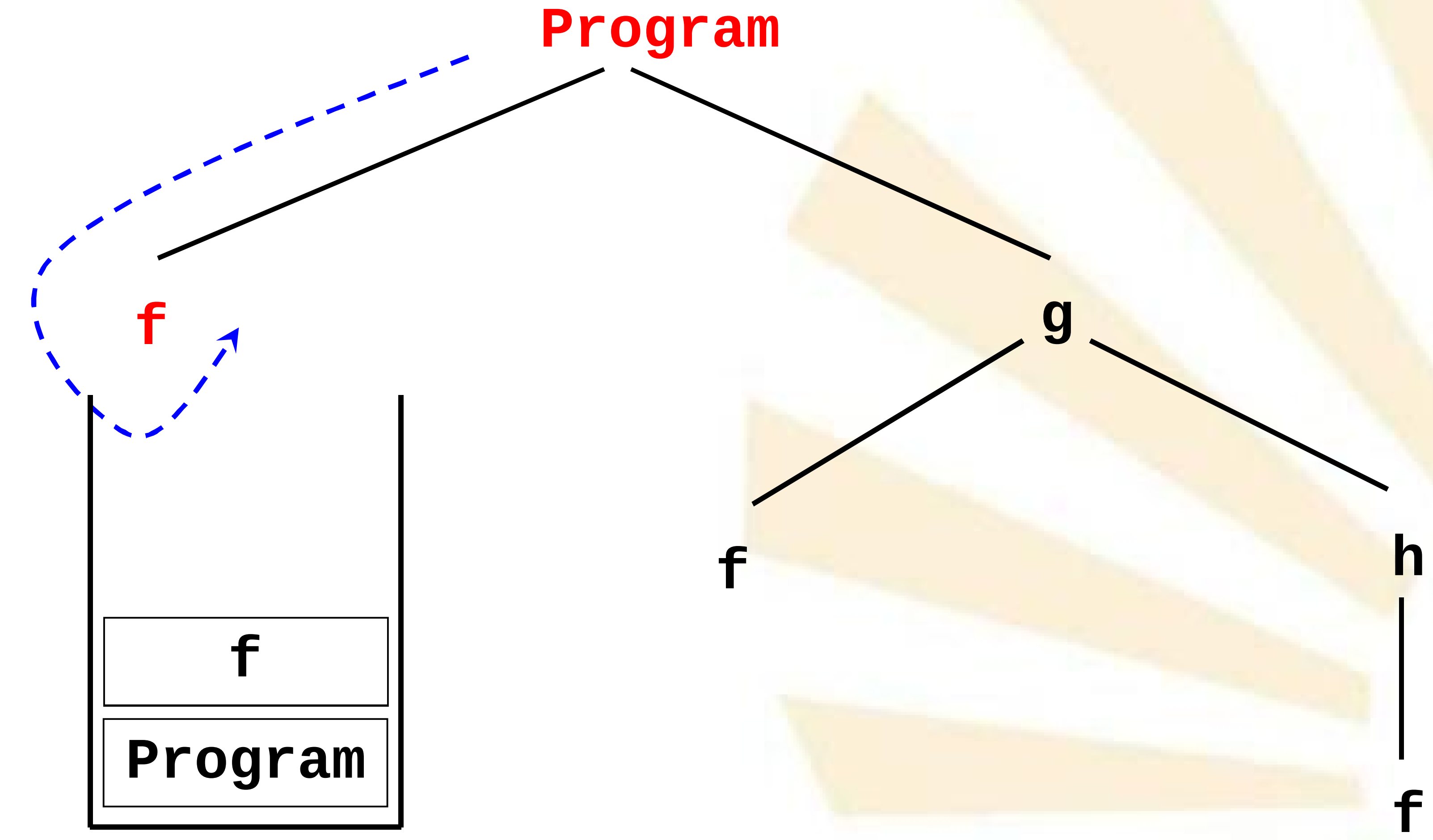

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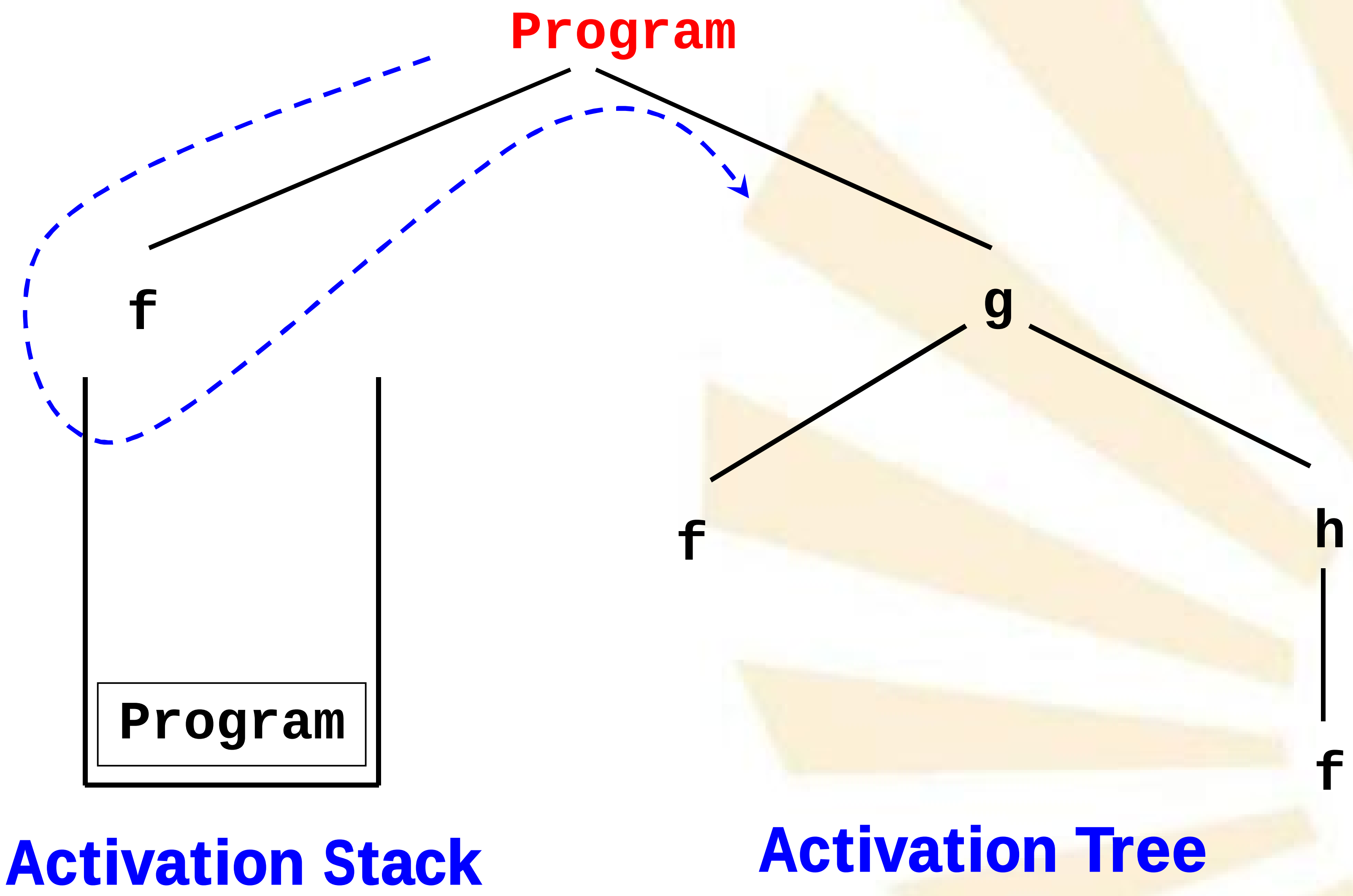
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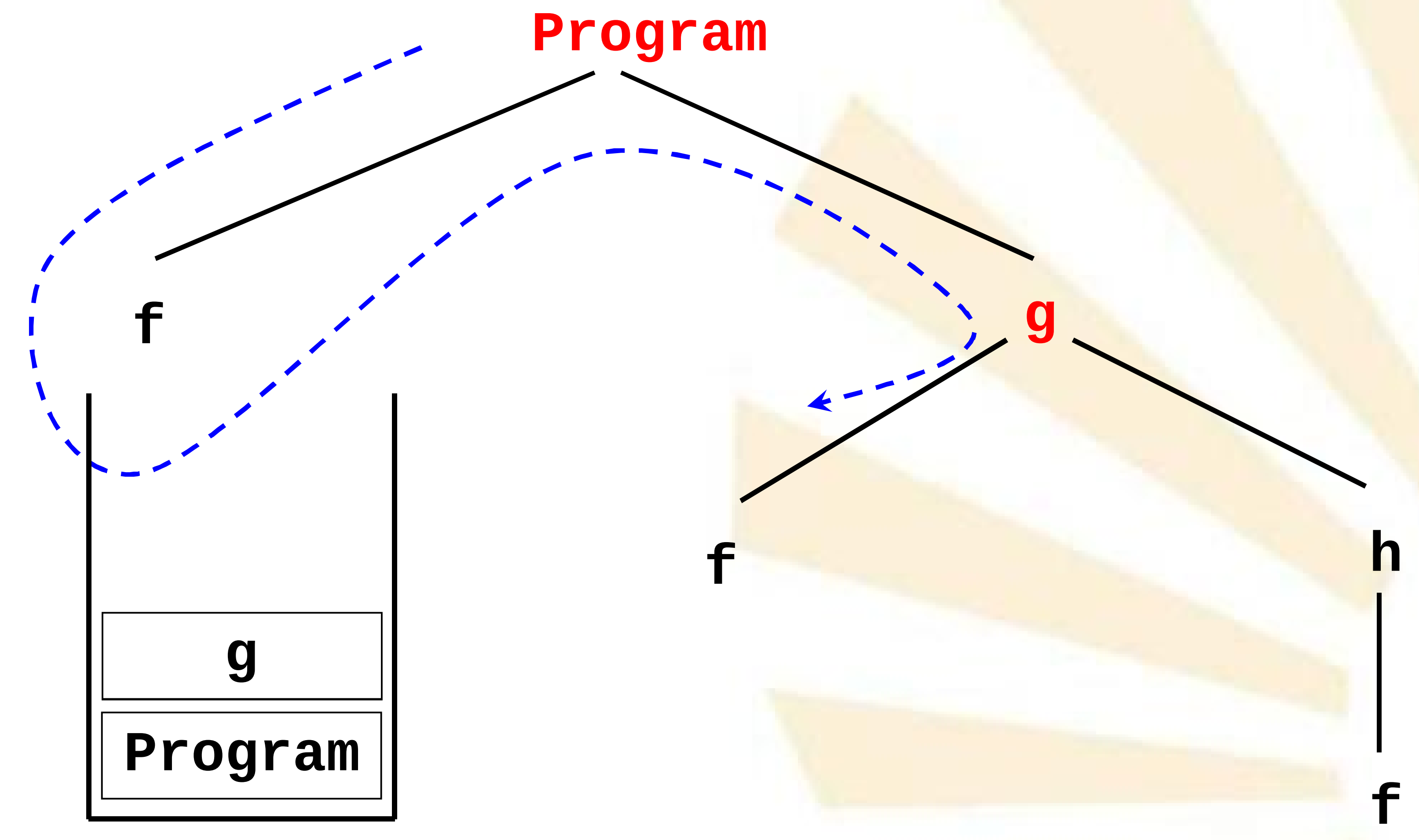

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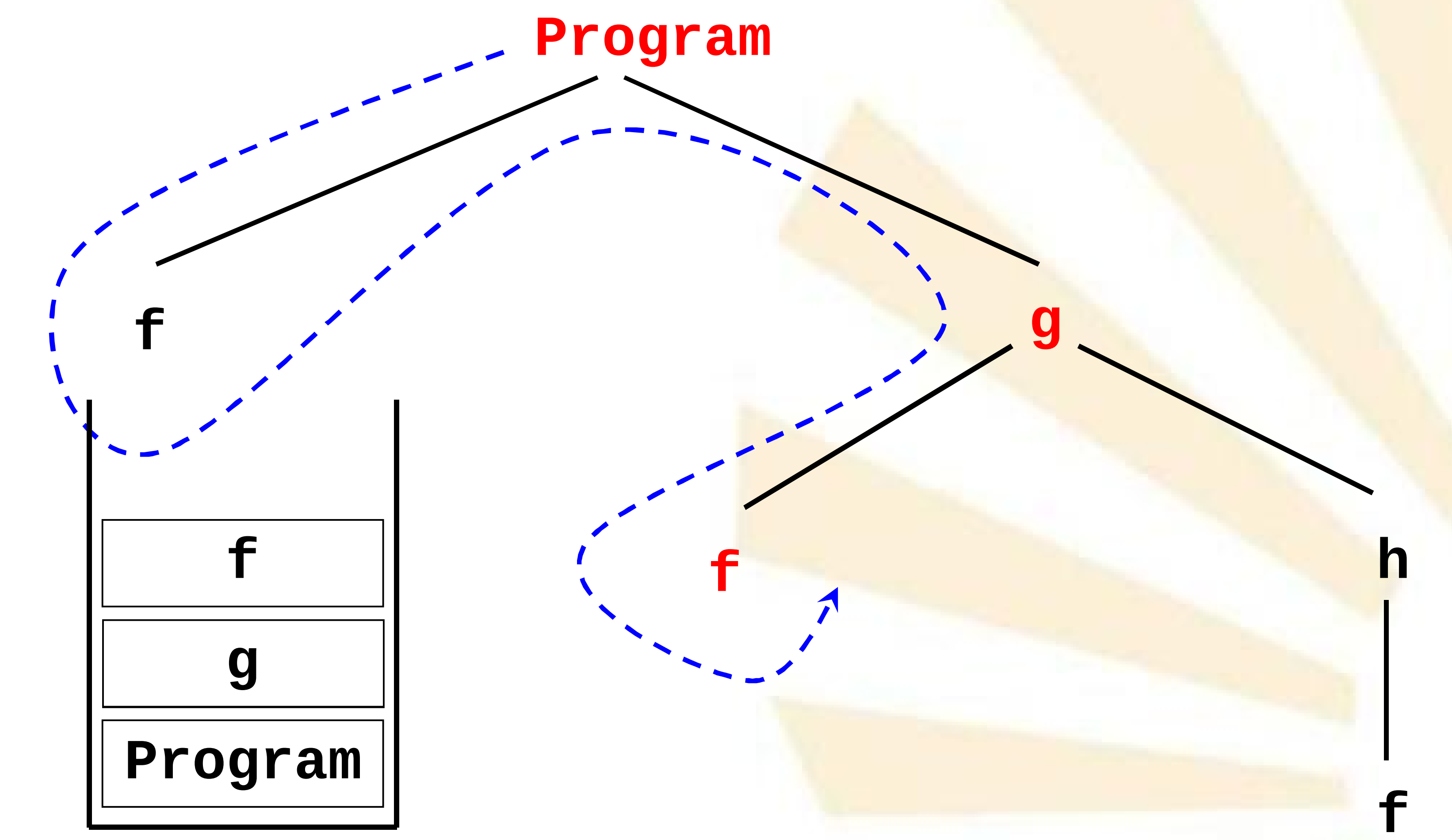

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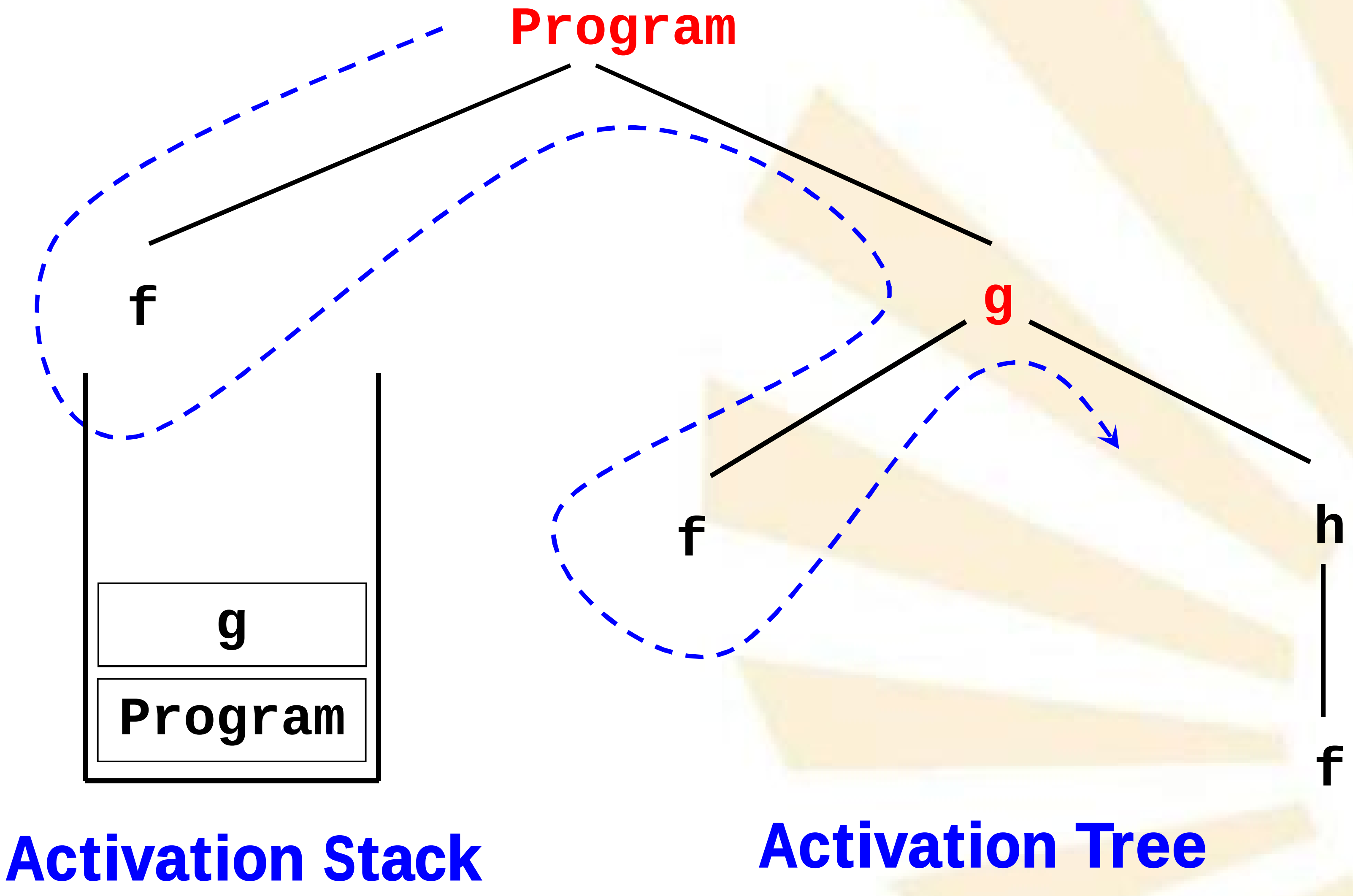
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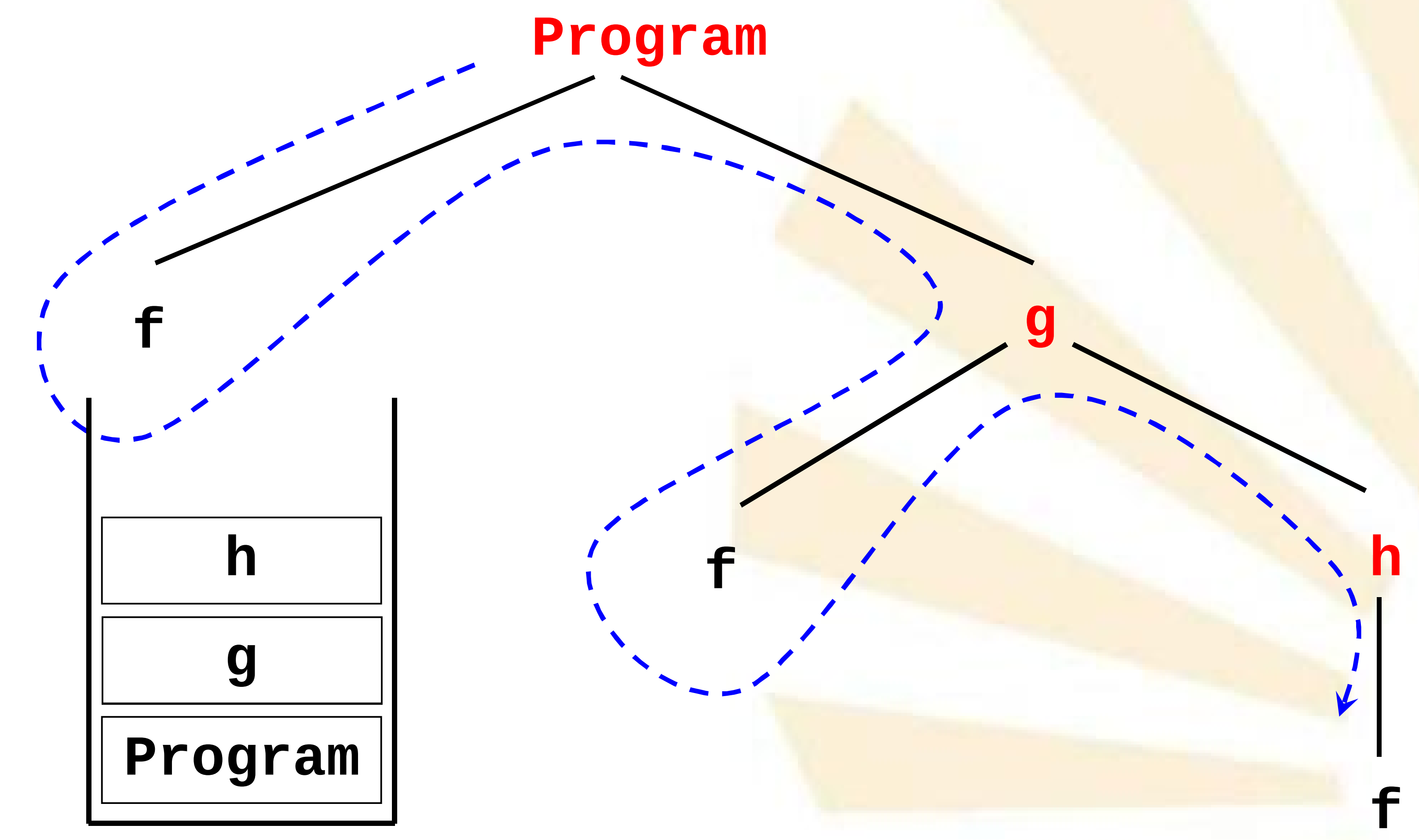

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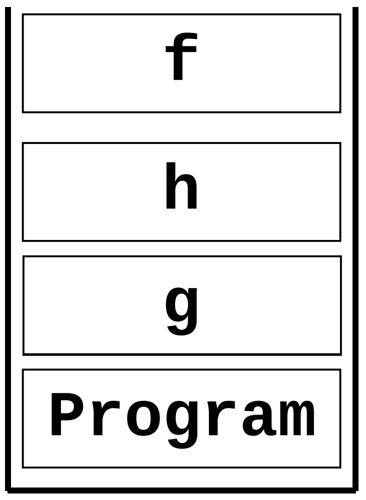

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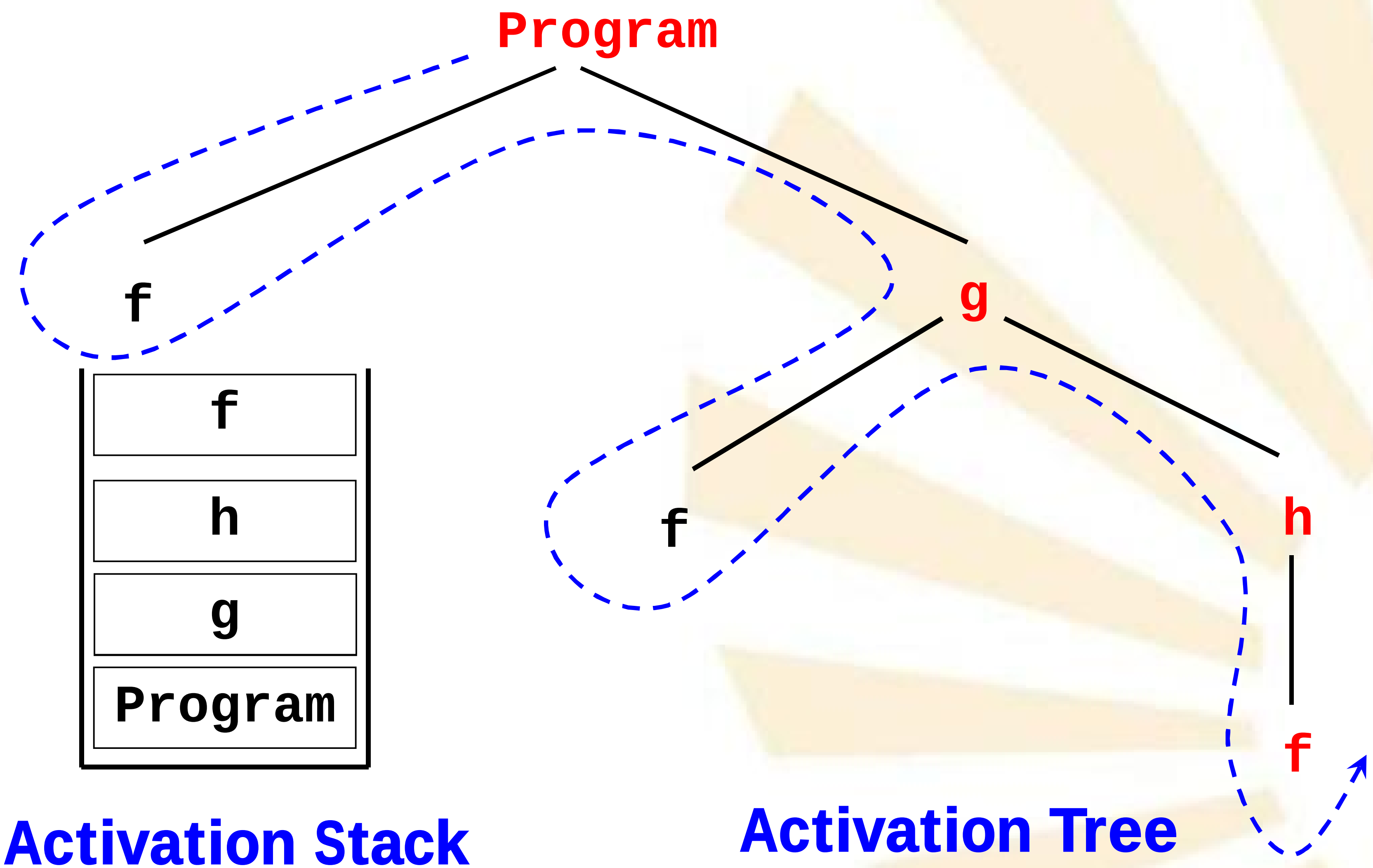

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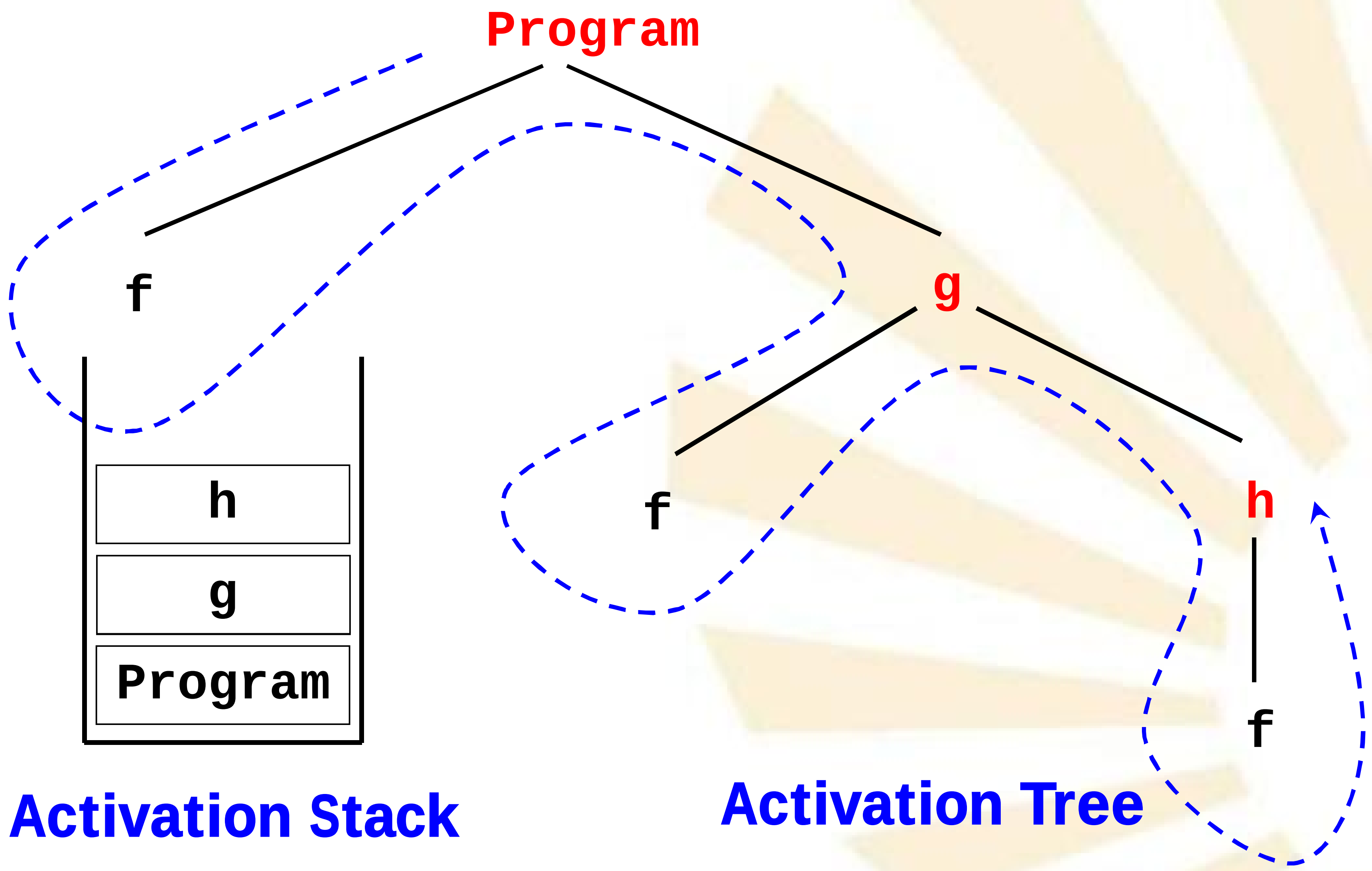

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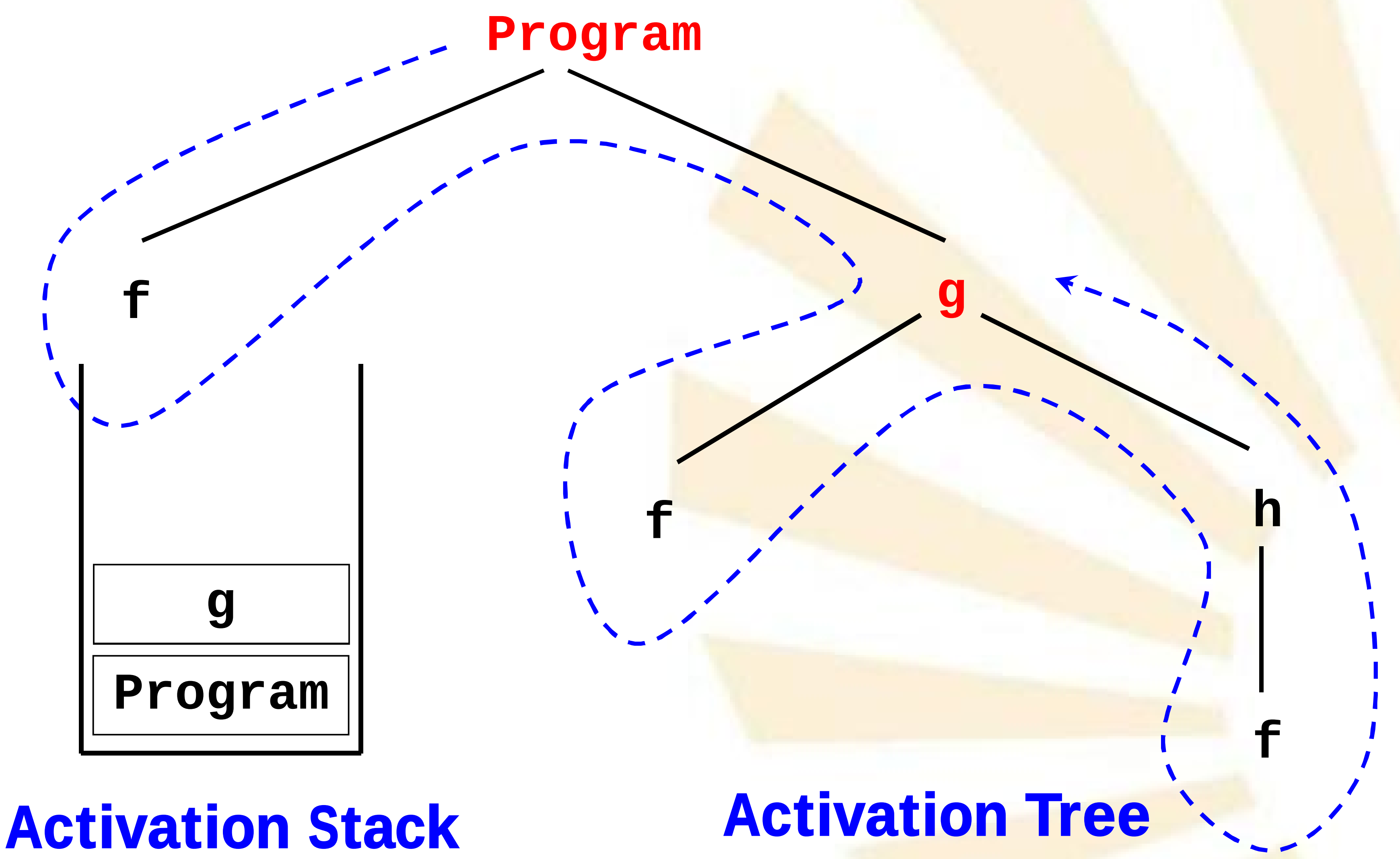
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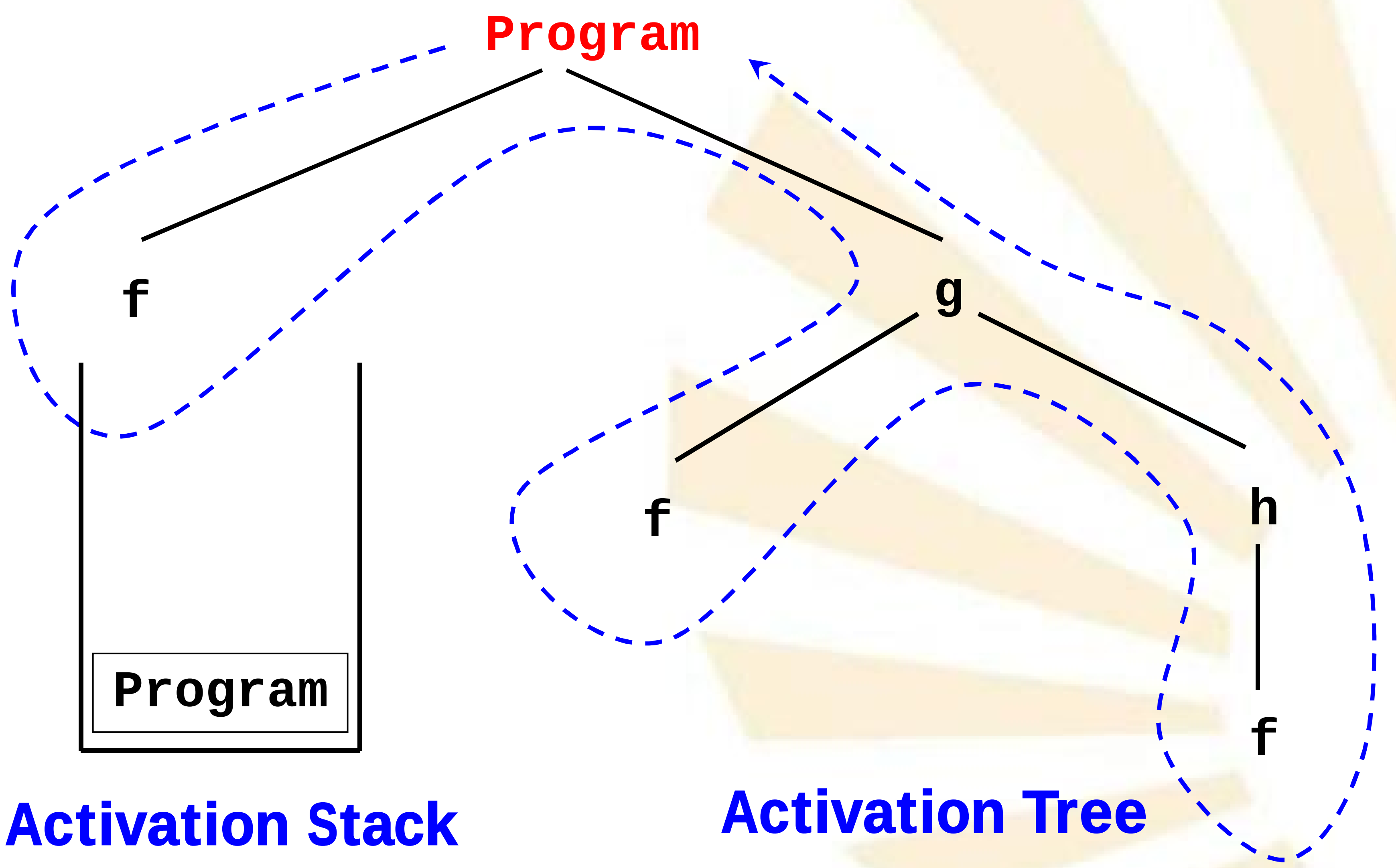
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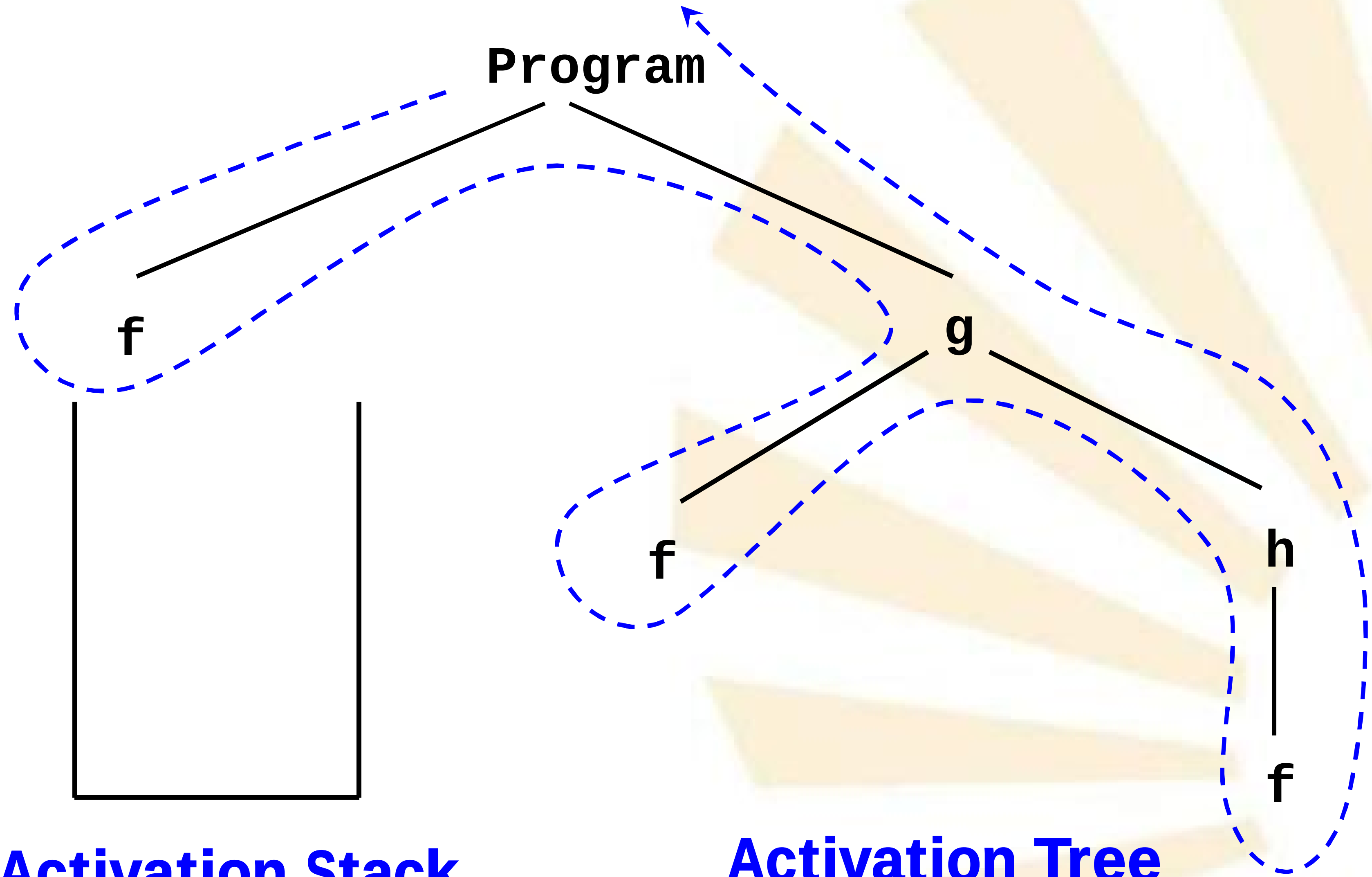

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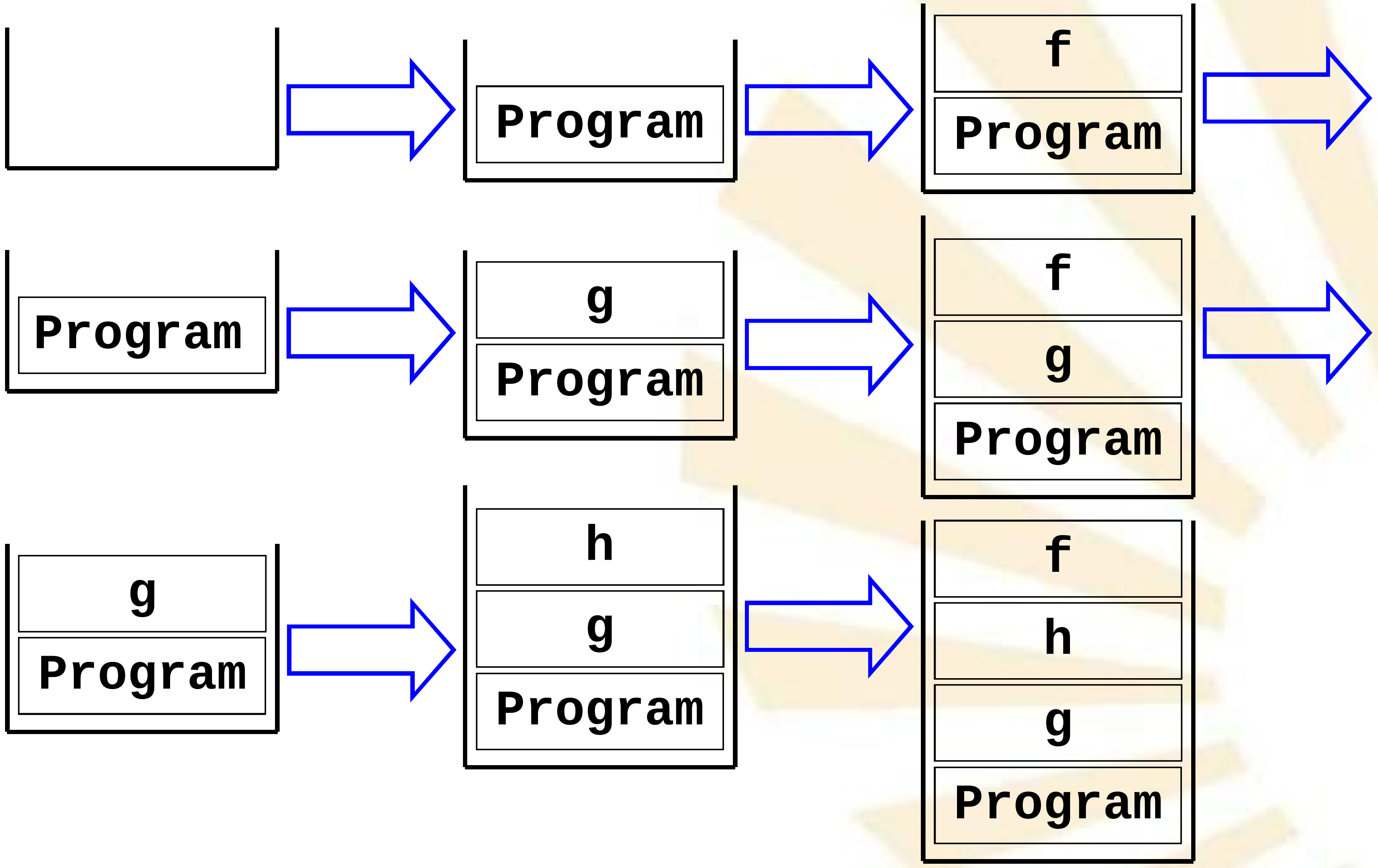
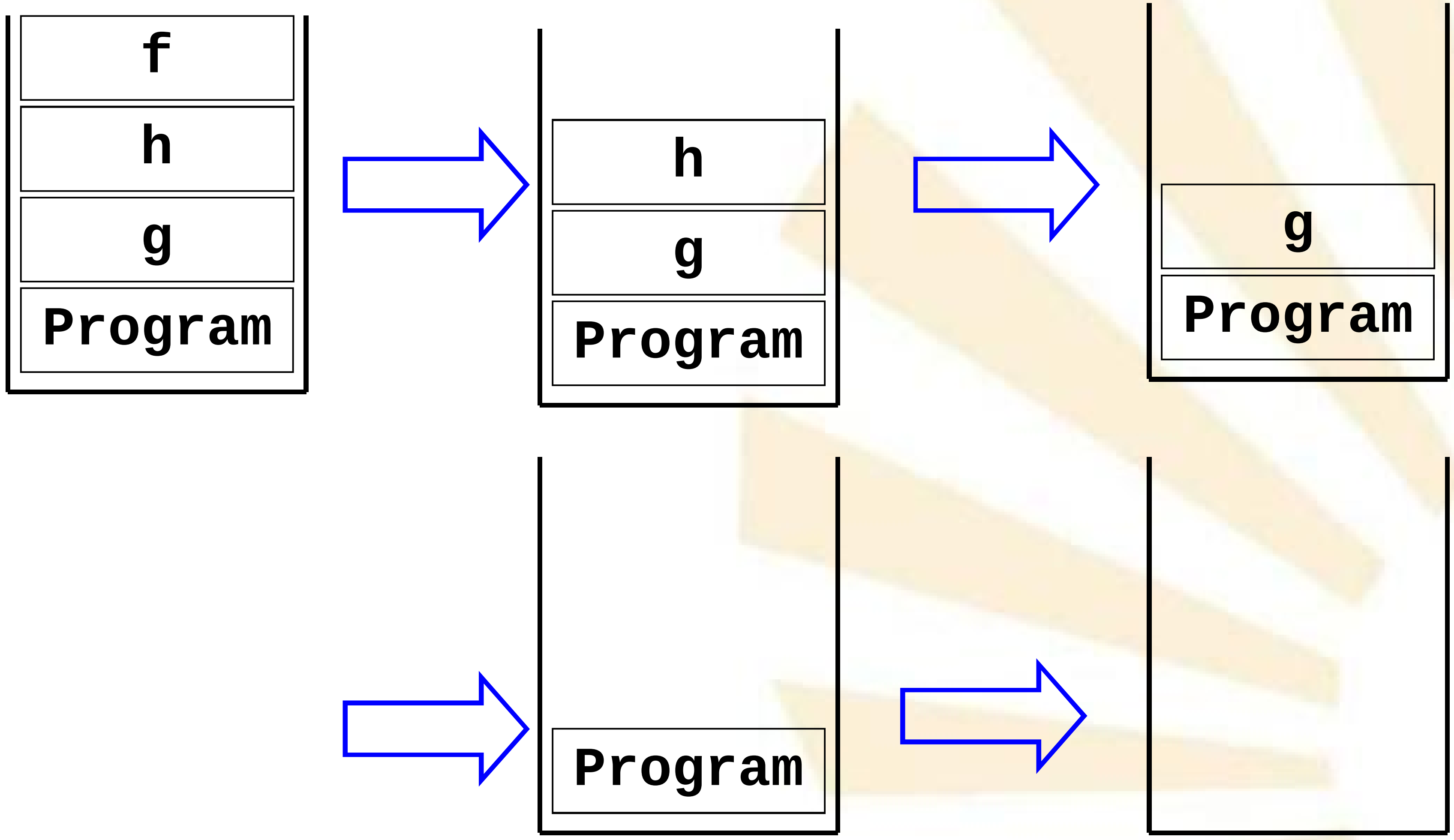
Activation Tree



Changes in the activation Stack (1 / 2)

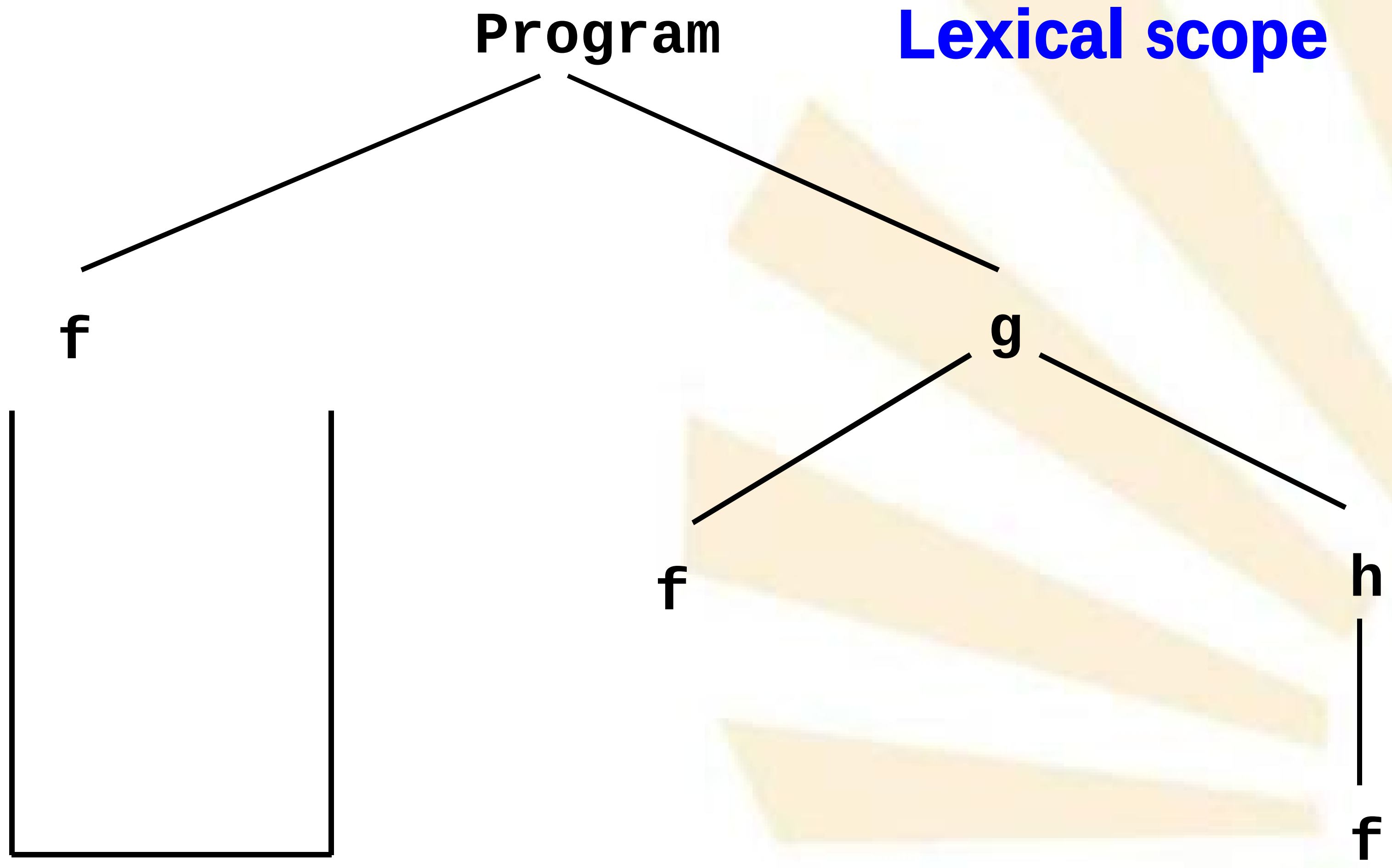


Changes in the activation Stack (2 / 2)

Run with lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f
     Call to g
```

Lexical scope



Activation Stack

Activation Tree

Run with lexical scope

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    Declaration of procedure g
      Declaration of variable x  (x2)

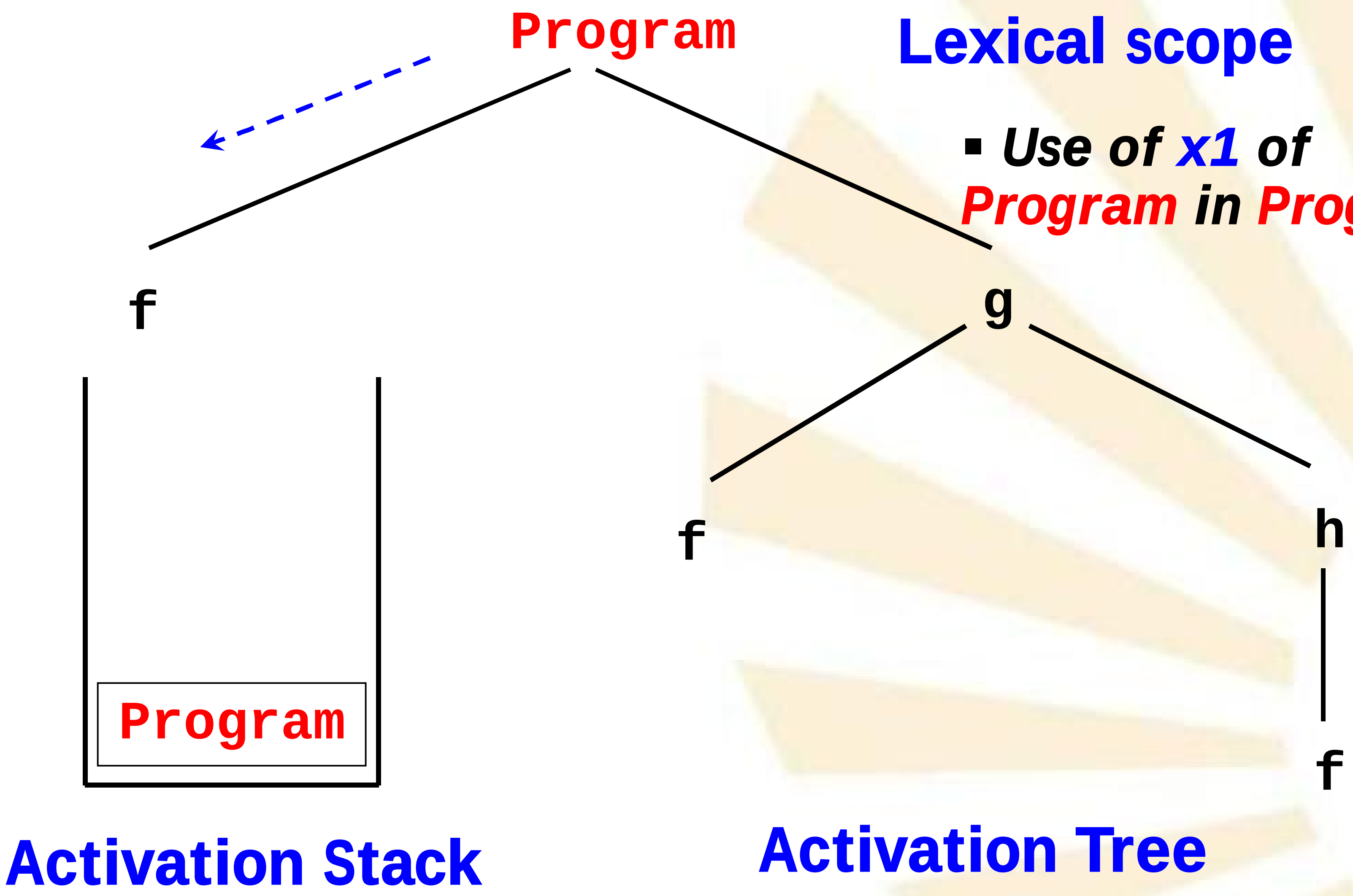
     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

     Use of x1
     Call to f
     Call to g
```

Lexical scope

- *Use of x1 of Program in Program*



Run with lexical scope

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     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f   <-
     Call to g
```
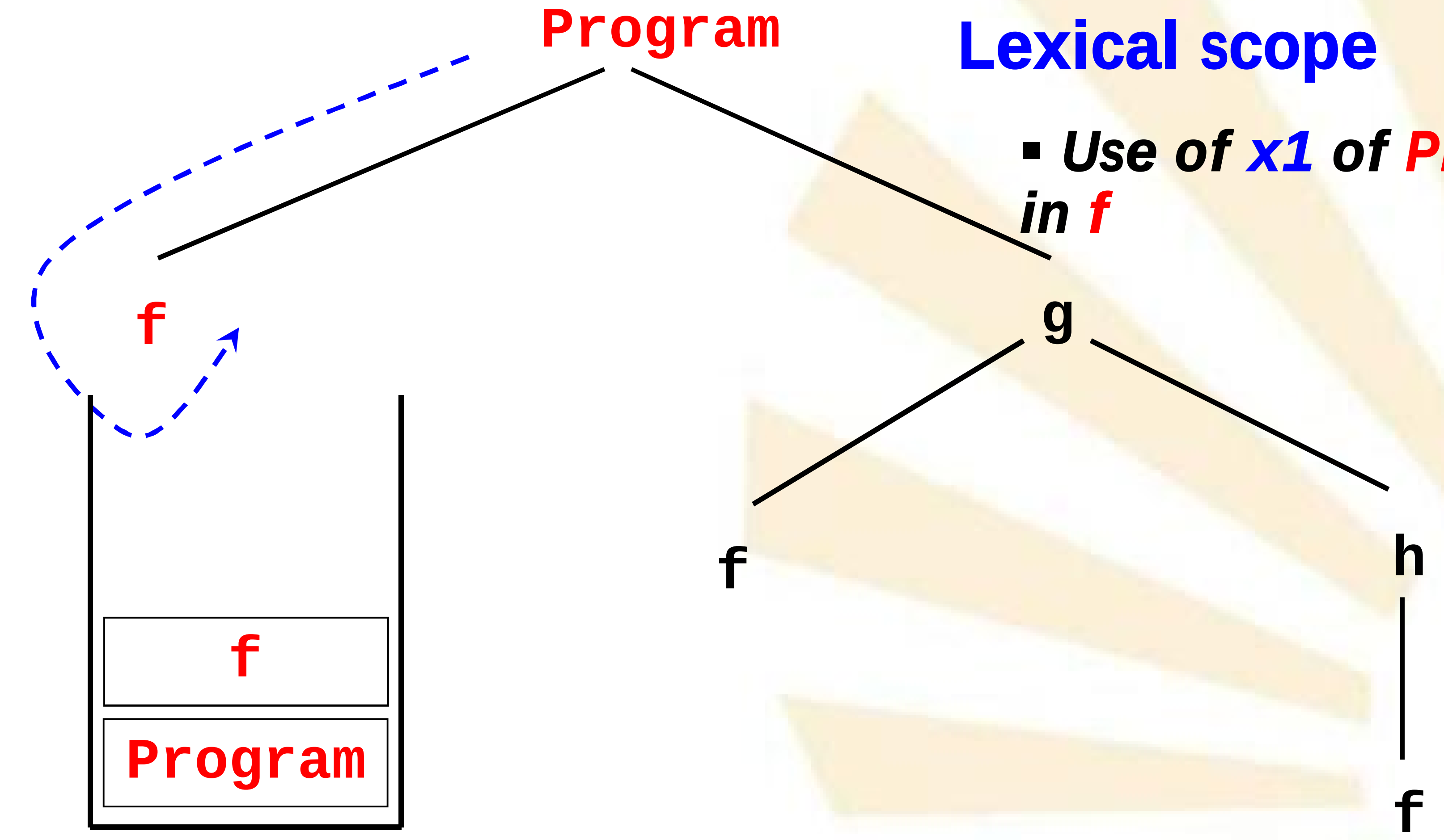

Run with lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x1  ←


    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x

     Use of x
     Call to f  ←
     Call to g
```

Lexical scope

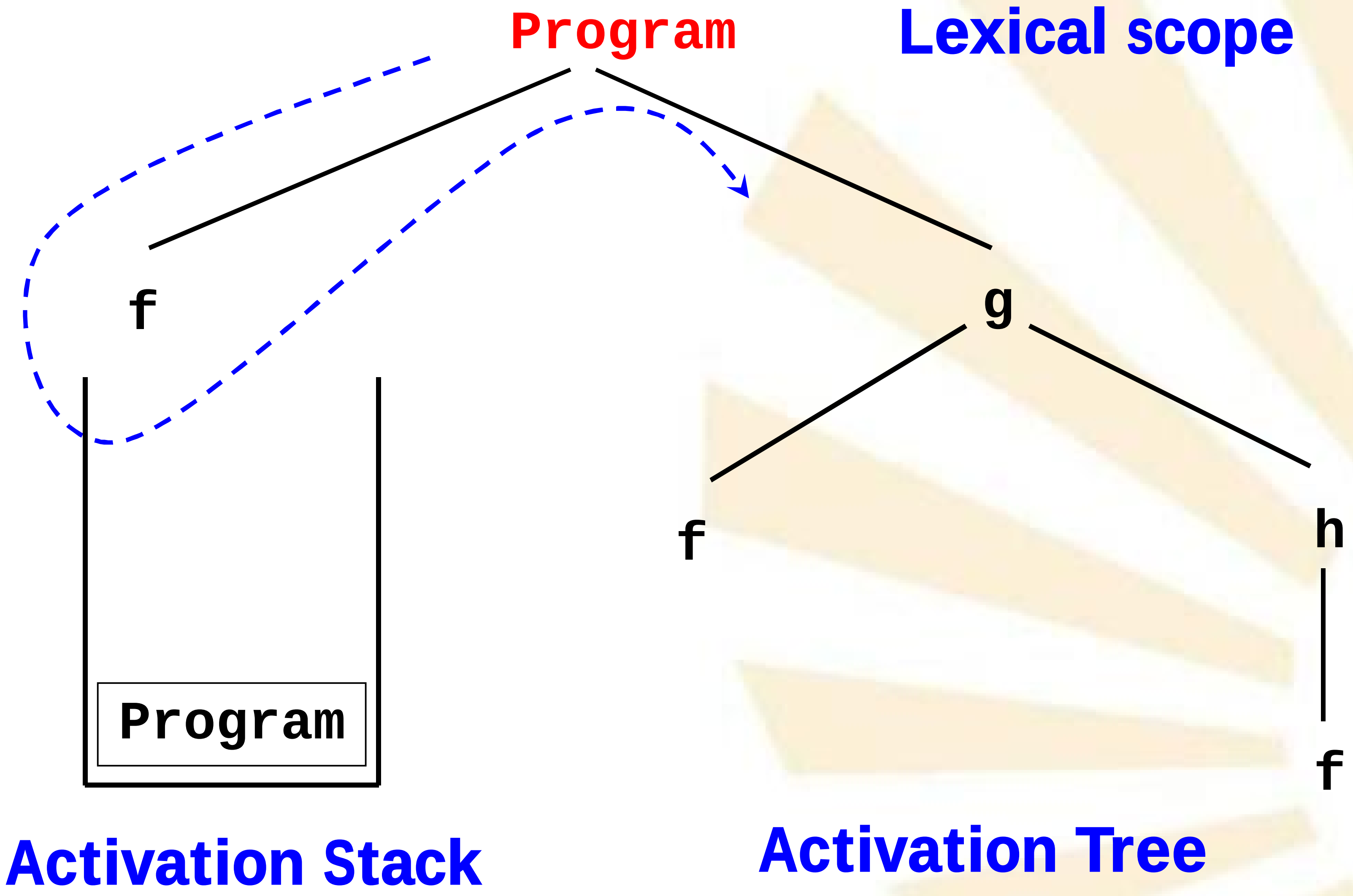
- ***Use of x1 of Program in f***



Activation Stack

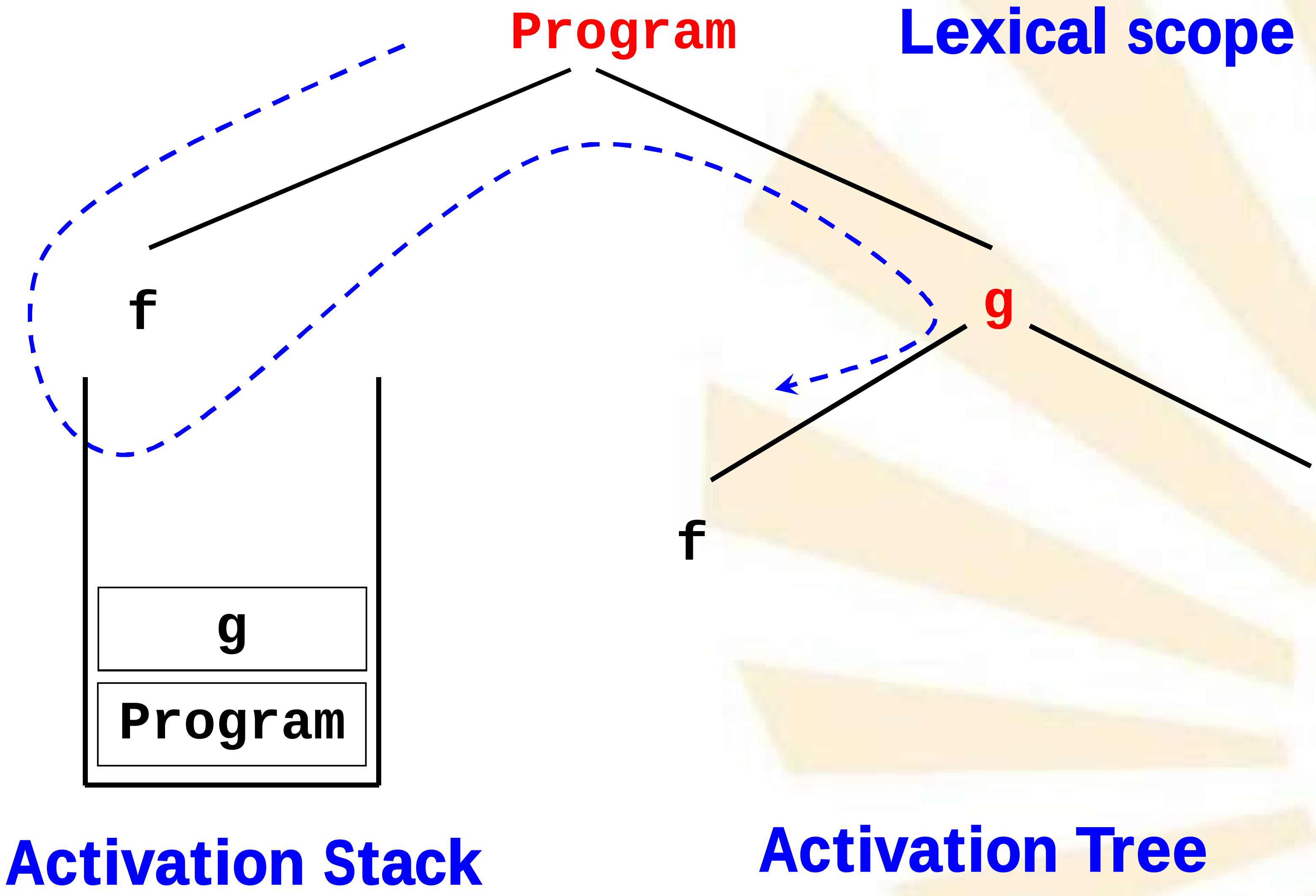
Activation Tree

Lexical scope



Run with lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x


    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f
     Call to g  <==
```

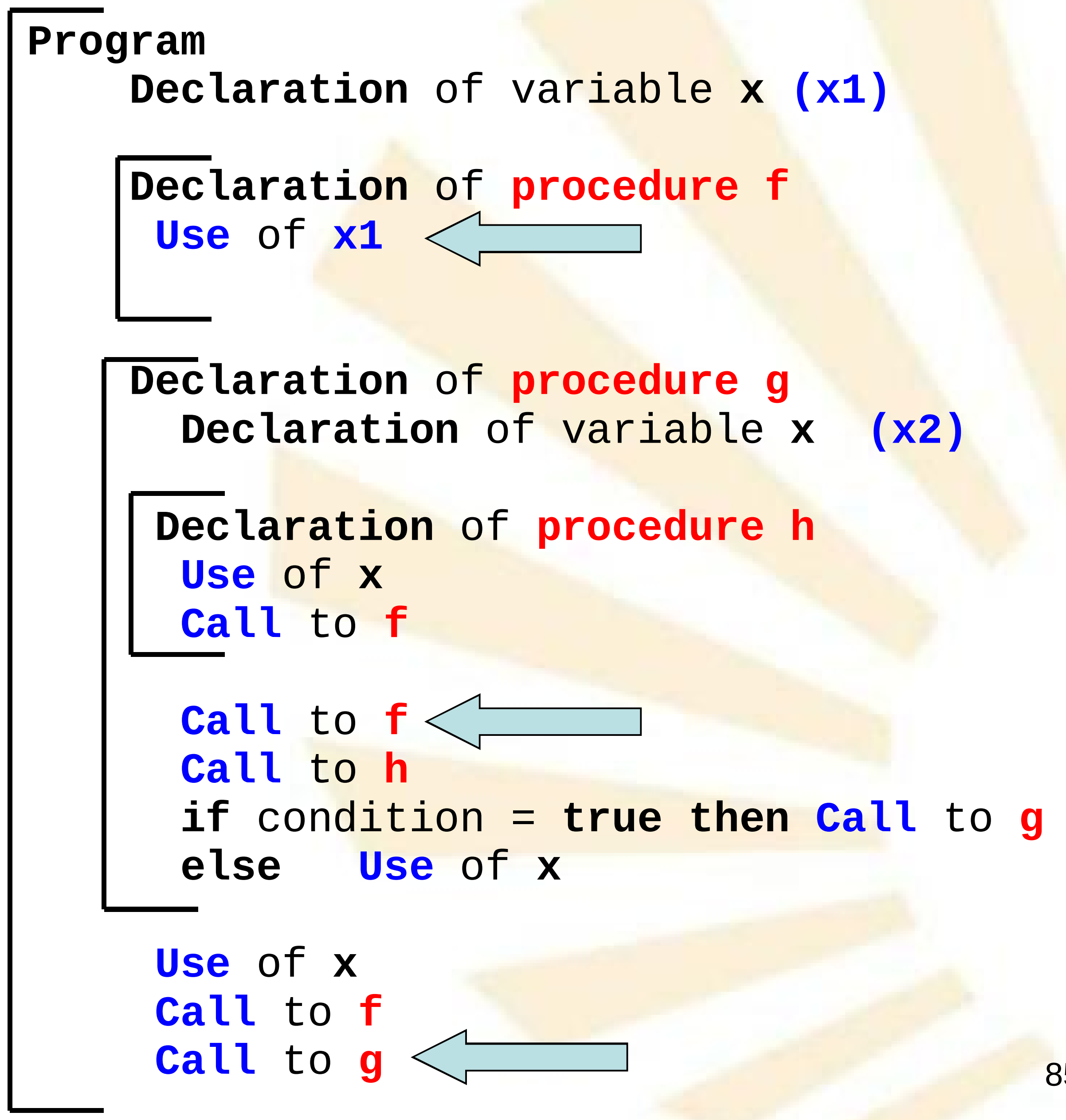


Program
Lexical scope
f
g
f
h
f
g
Program
Activation Stack
Activation Tree

Run with lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f  ←
      Call to h
      if condition = true then Call to g
      else    Use of x

     Use of x
     Call to f
     Call to g  ←
```

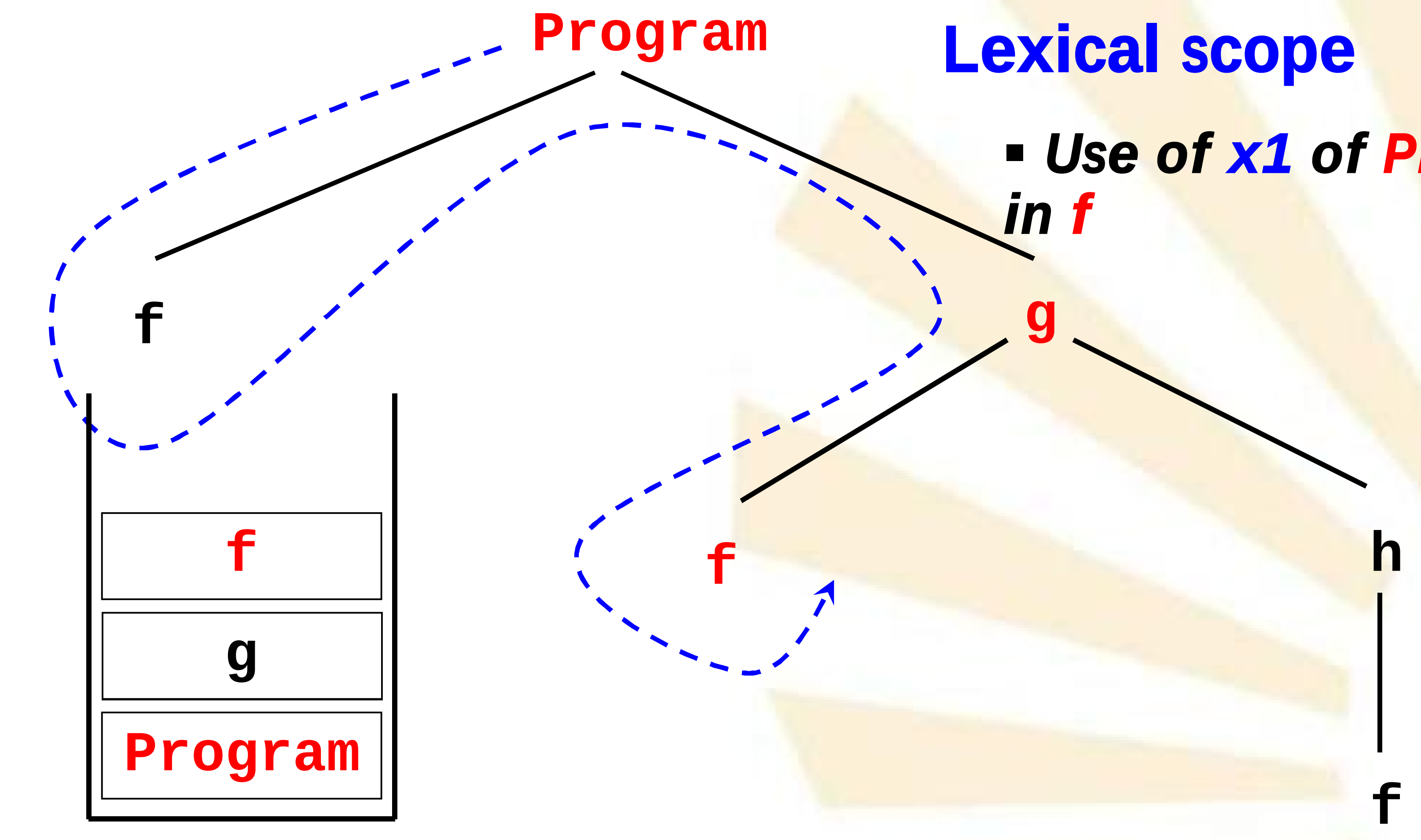
Run with lexical scope



```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x1

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

    Use of x
    Call to f
    Call to g
```

Lexical scope

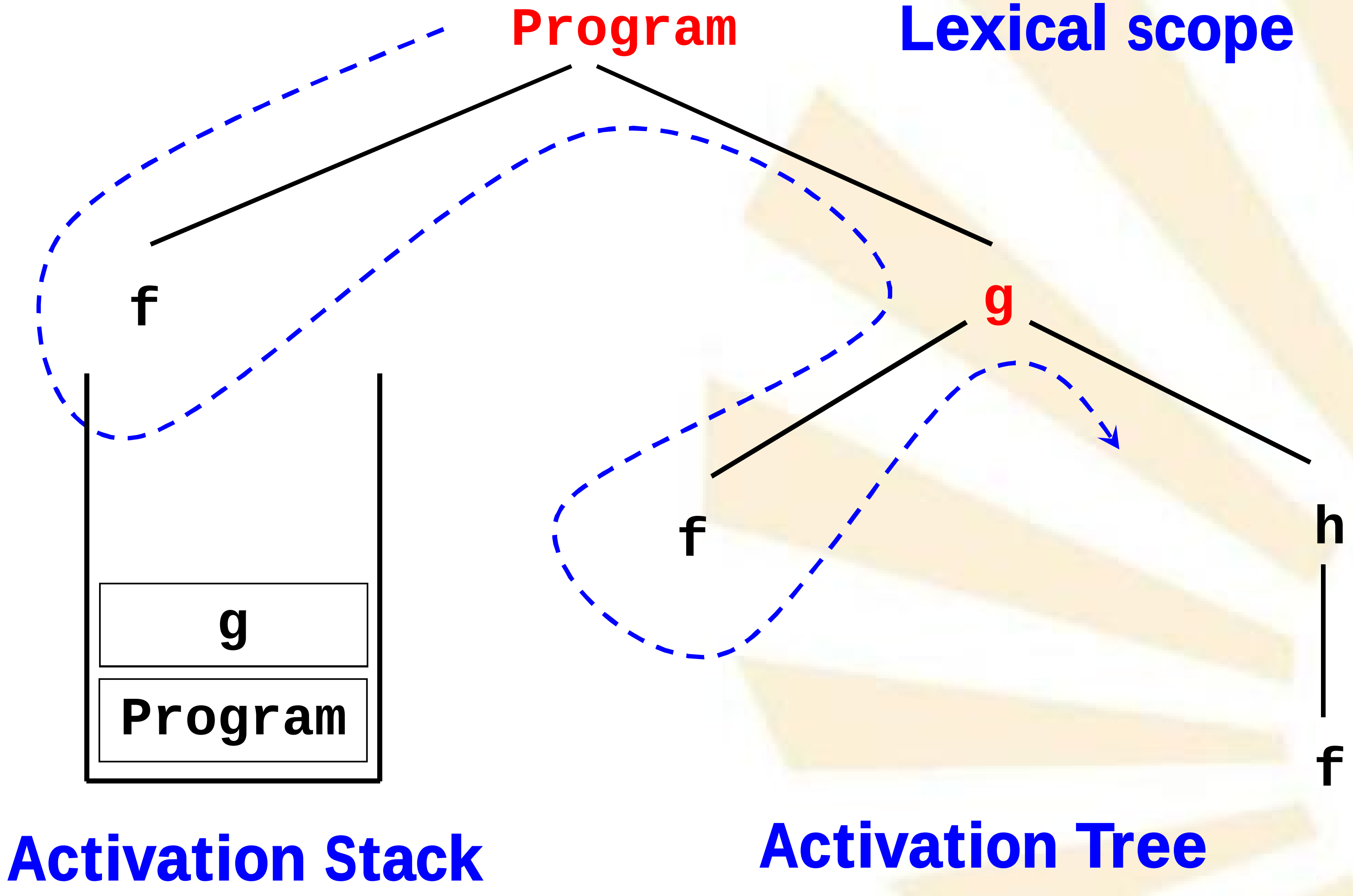
- *Use of x1 of Program in f*



Activation Stack

Activation Tree

Lexical scope



Run with

lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

    Use of x
    Call to f
    Call to g
```

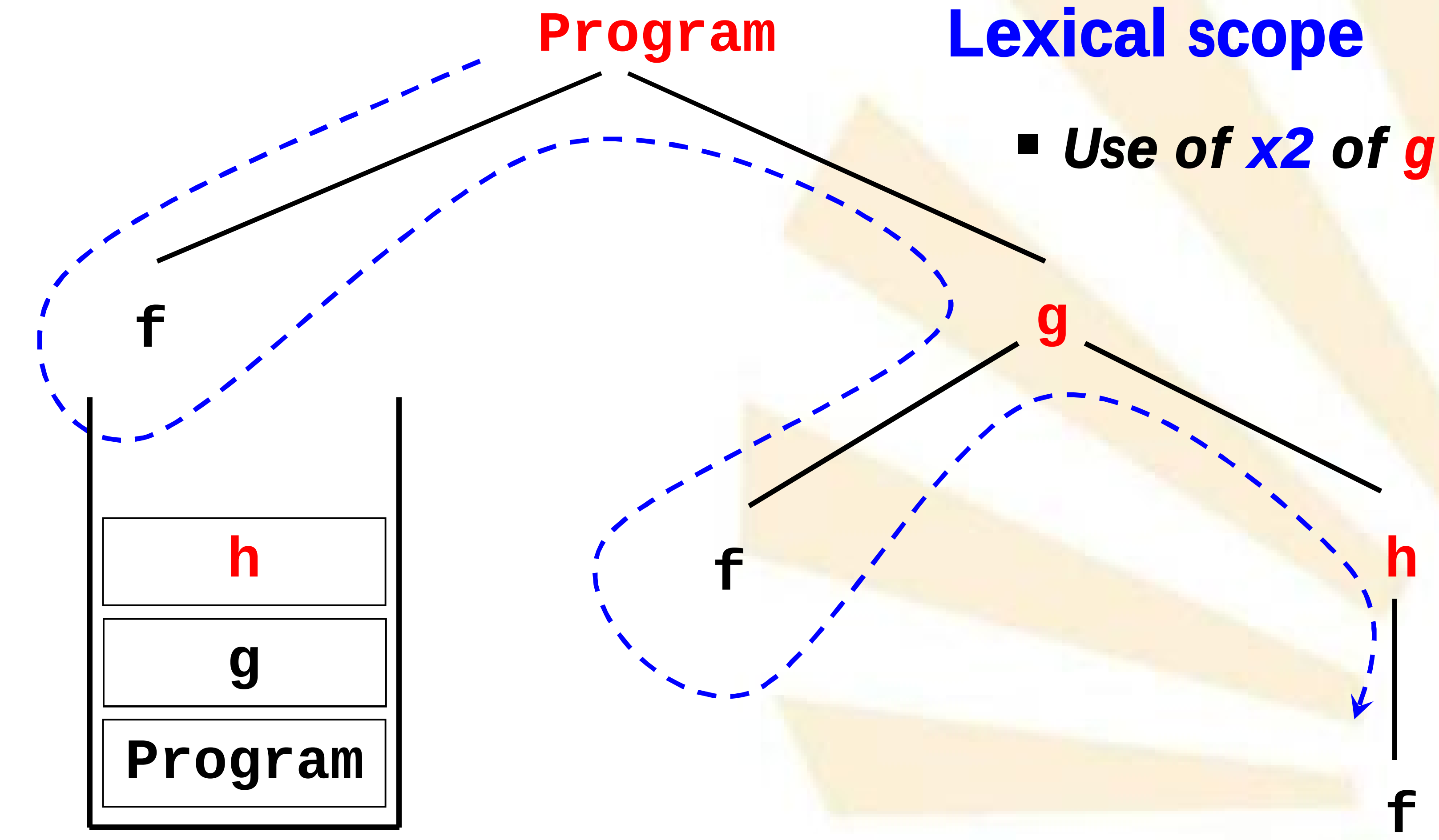
Run with

lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x2  <=
      Call to f

      Call to f
      Call to h  <=
      if condition = true then Call to g
      else   Use of x

    Use of x
    Call to f
    Call to g  <=
```

Lexical scope

- *Use of x2 of g in h*



Activation Stack

Activation Tree

Run with lexical scope

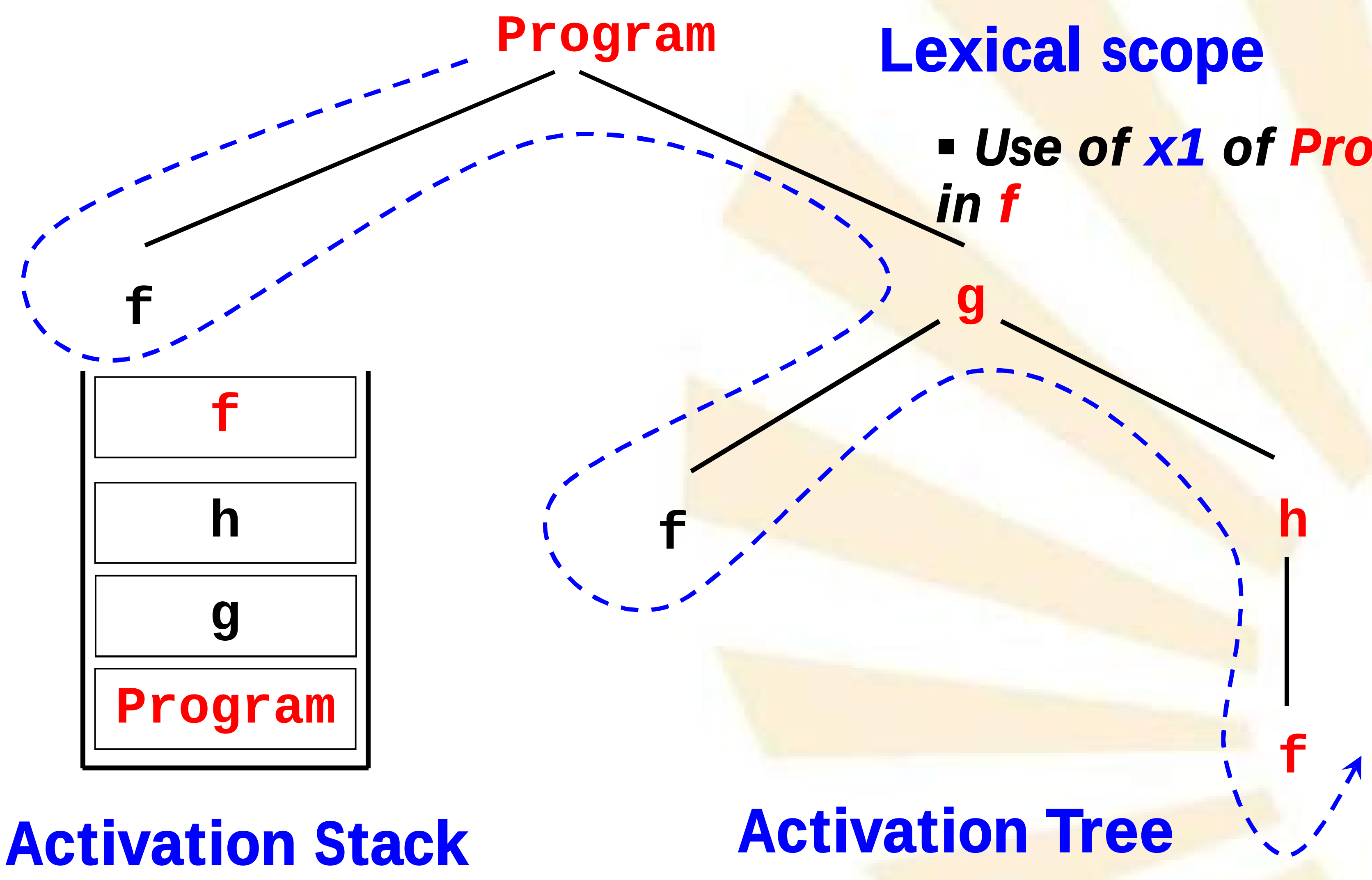
```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x


    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f  <==

      Call to f
      Call to h  <==
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f
     Call to g  <==
```

Run with lexical scope

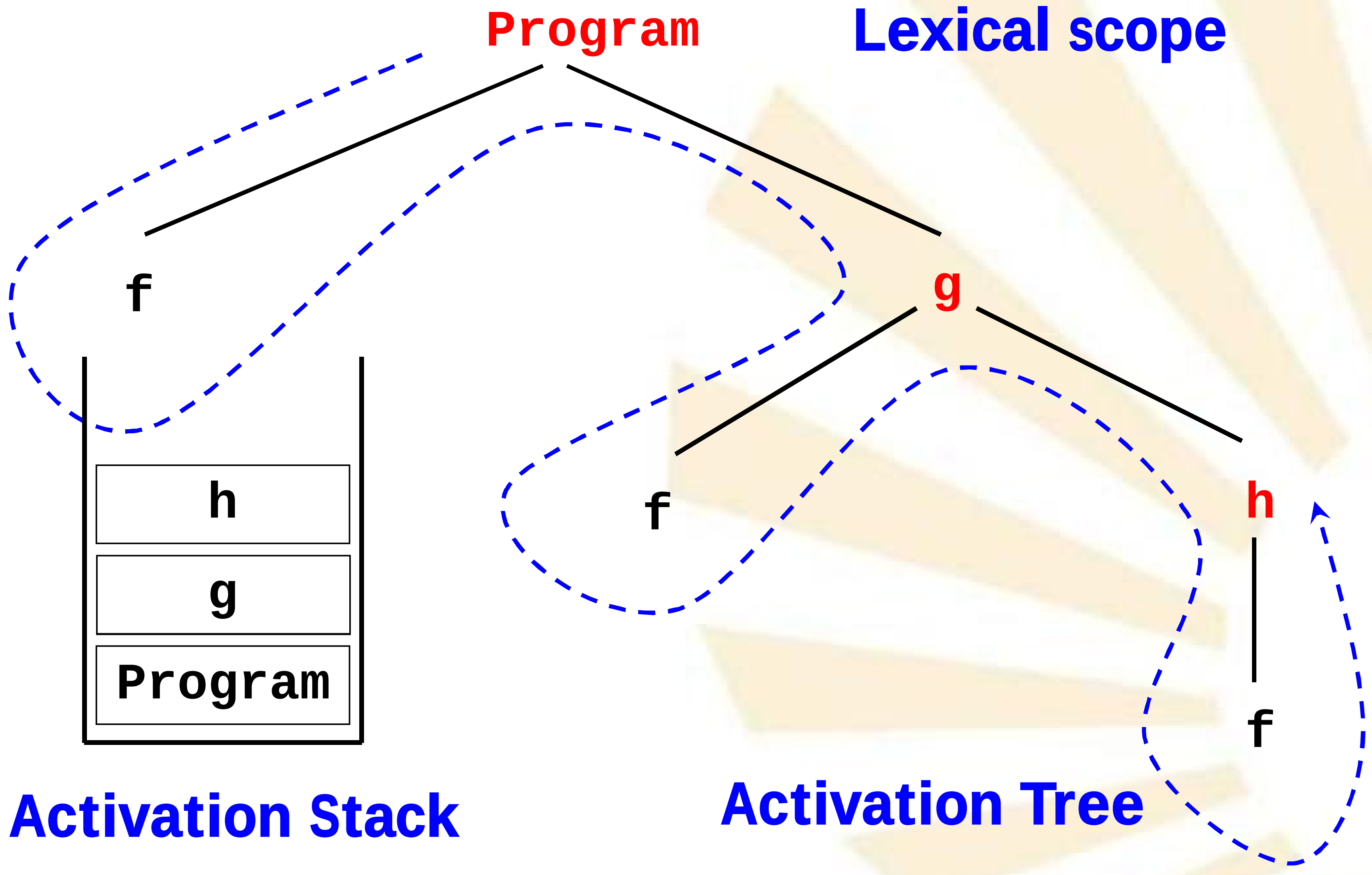
```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x1   ⟸


    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f  ⟸

      Call to f
      Call to h  ⟸
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f
     Call to g  ⟸
```

Lexical scope

- *Use of x1 of Program in f*



Lexical scope



Activation Stack

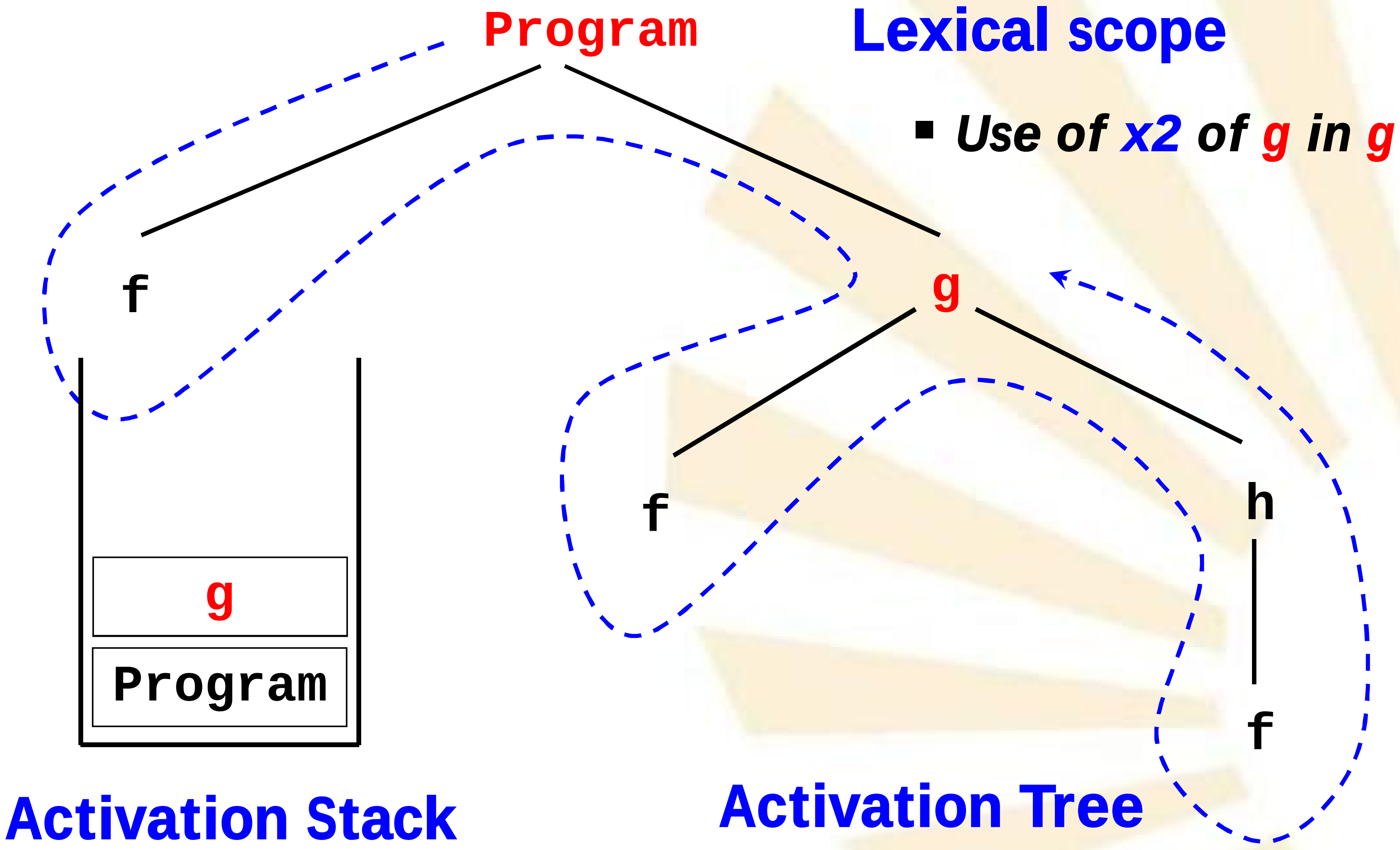
Activation Tree

Run with lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x2


   Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x2  <--

     Use of x
     Call to f
     Call to g  <--
```

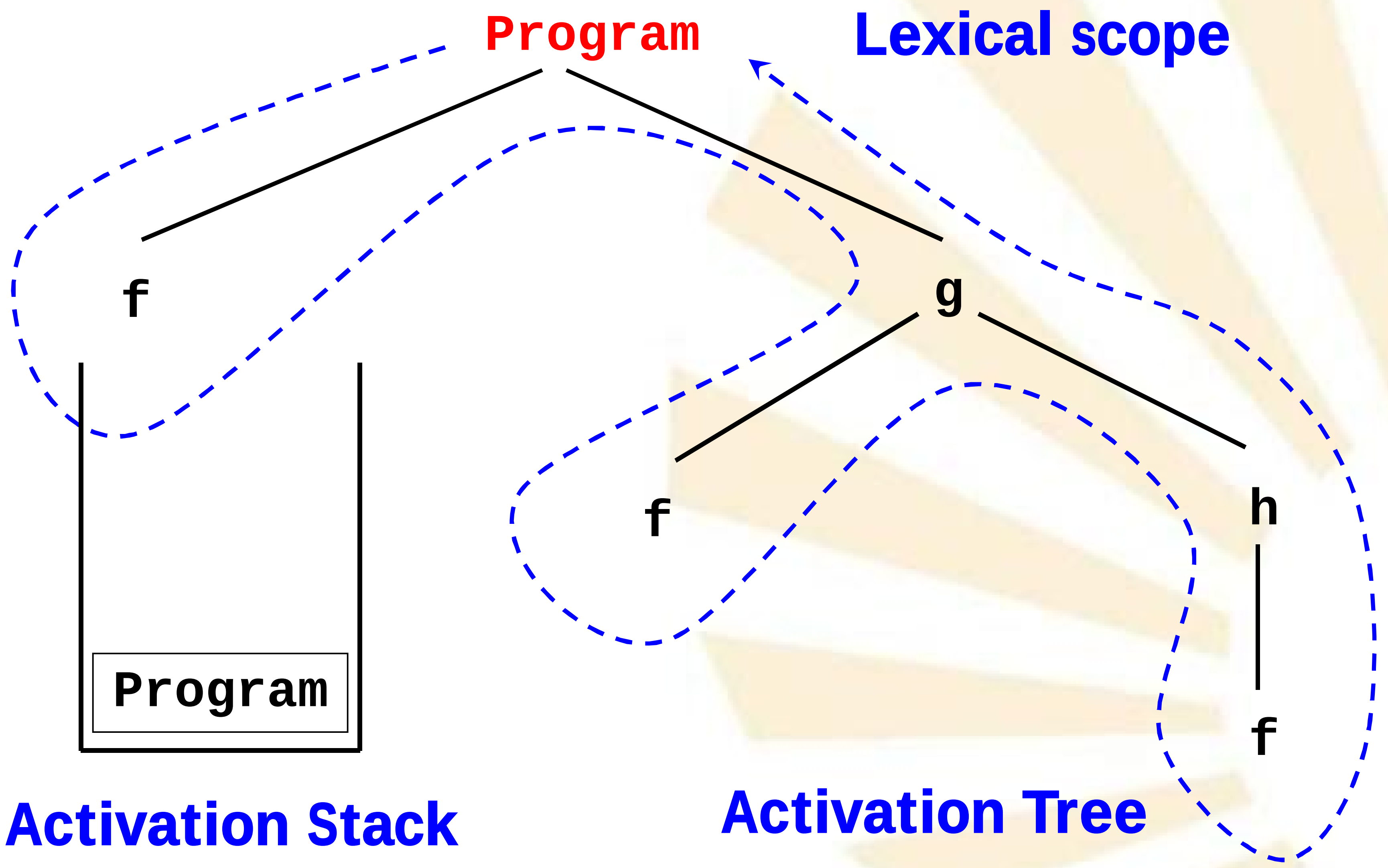
Lexical scope

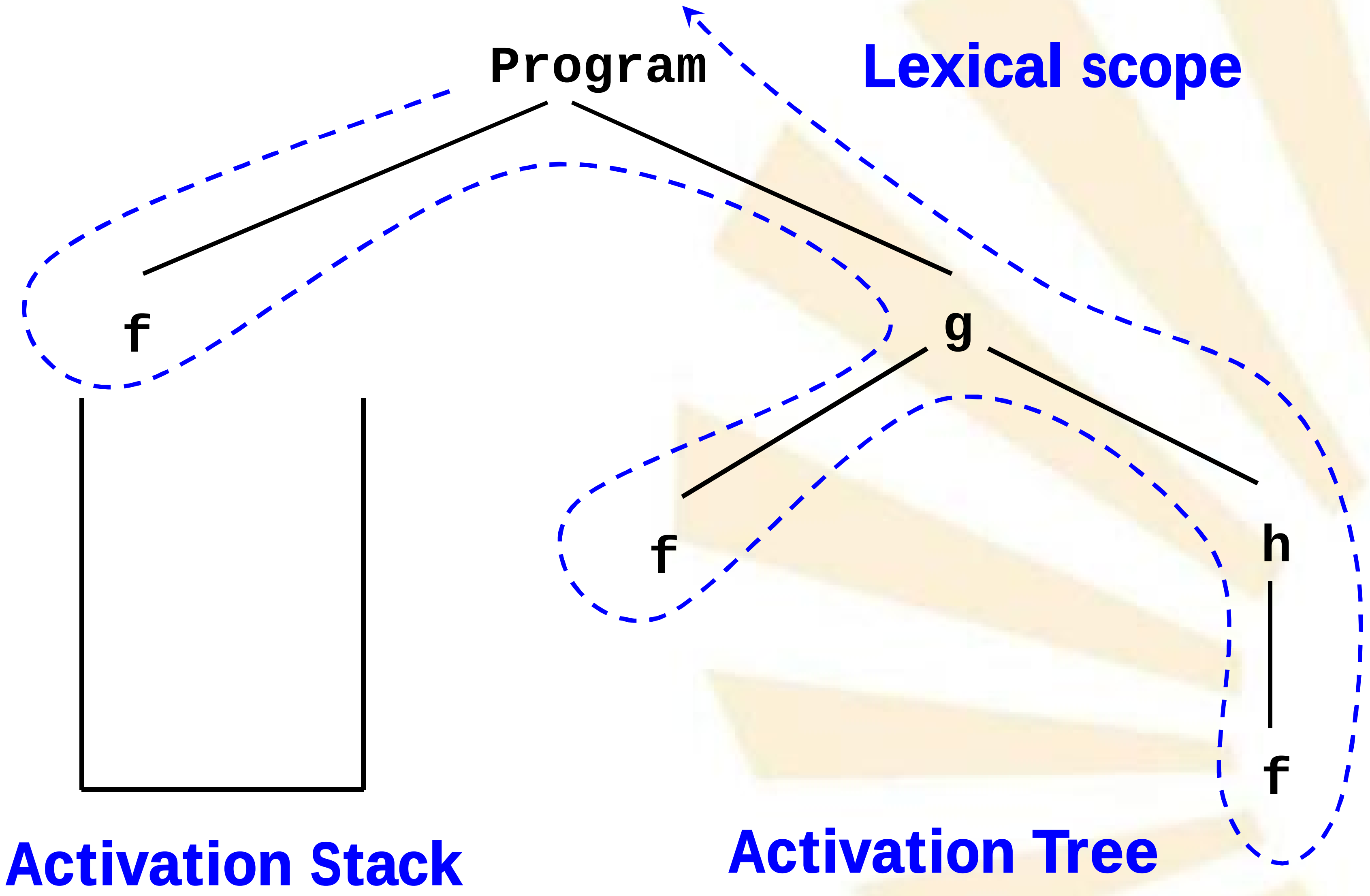
- ***Use of x2 of g in g***



Run with lexical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x2


    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x2

     Use of x
     Call to f
     Call to g
```

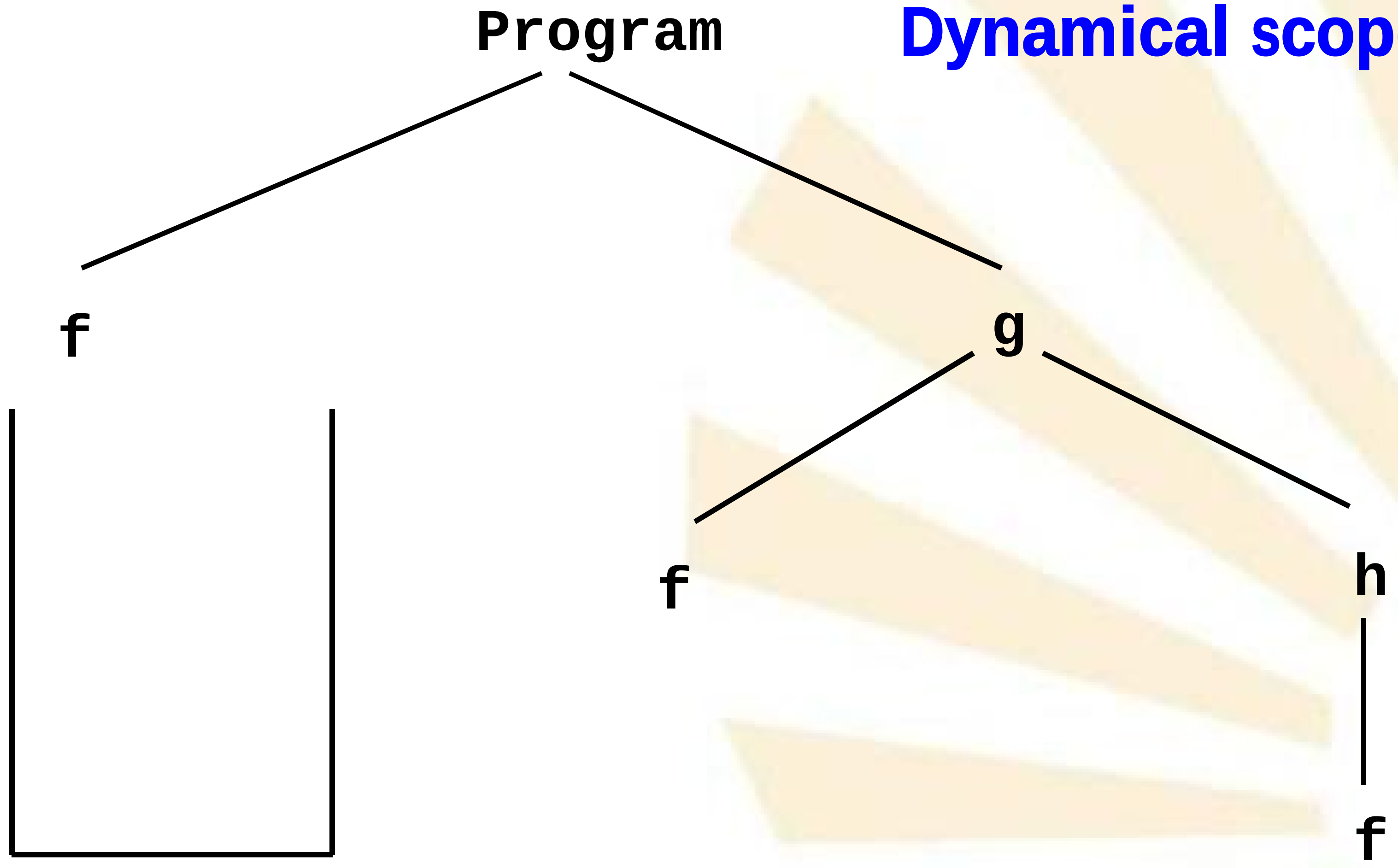

Program
Lexical scope
f
g
f
h
f
Program
Activation Stack
Activation Tree


Program
Lexical scope
f
g
f
h
f
Activation Stack
Activation Tree

Run with dynamical scope

```
Program
    Declaration of variable x (x_1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x_2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f
     Call to g
```

Dynamical scope



Activation Stack

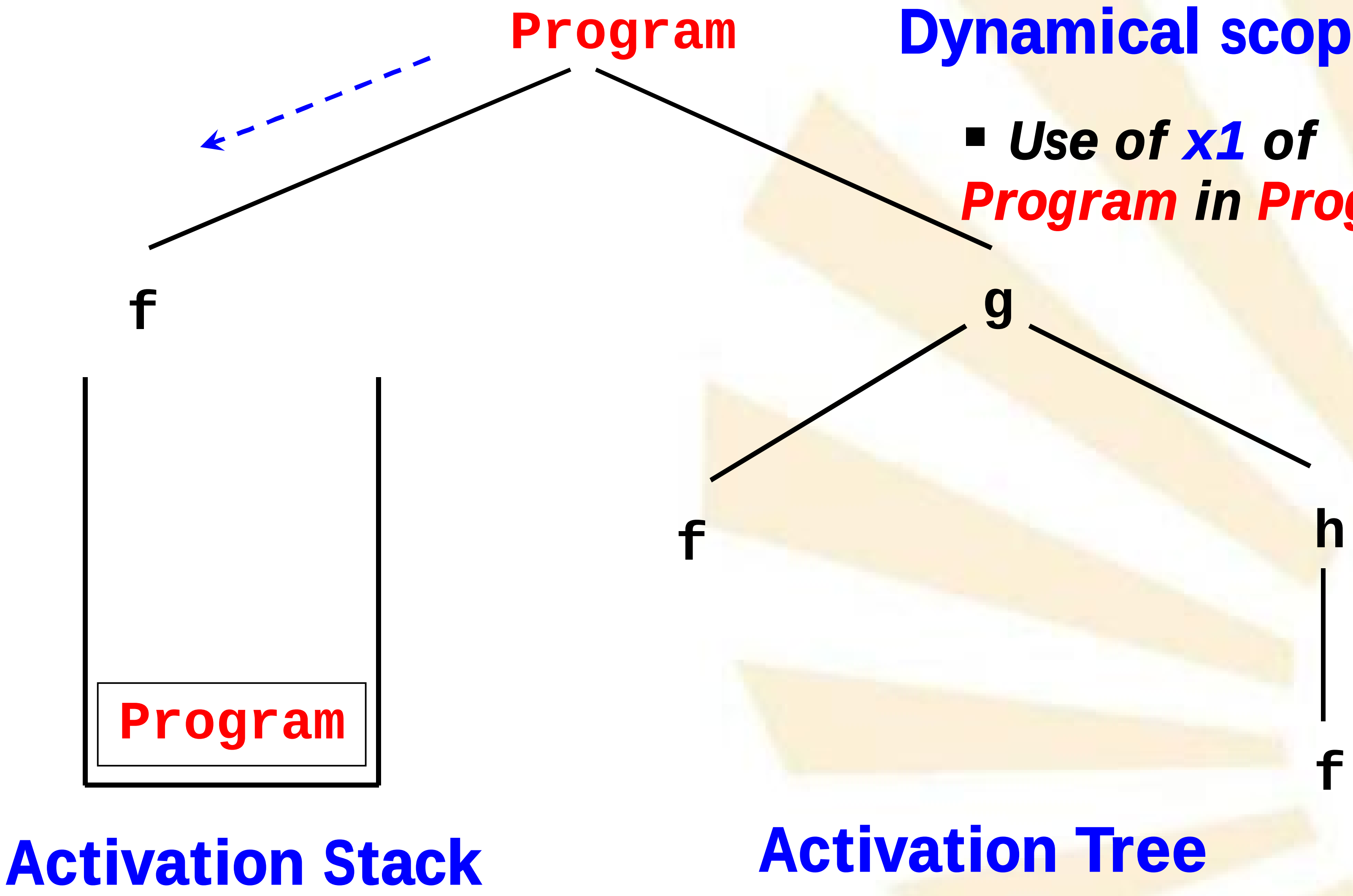
Activation Tree

Run with dynamical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x

     Use of x1 <-
     Call to f
     Call to g
```

Dynamical scope

- *Use of x1 of Program in Program*



Run with dynamical scope

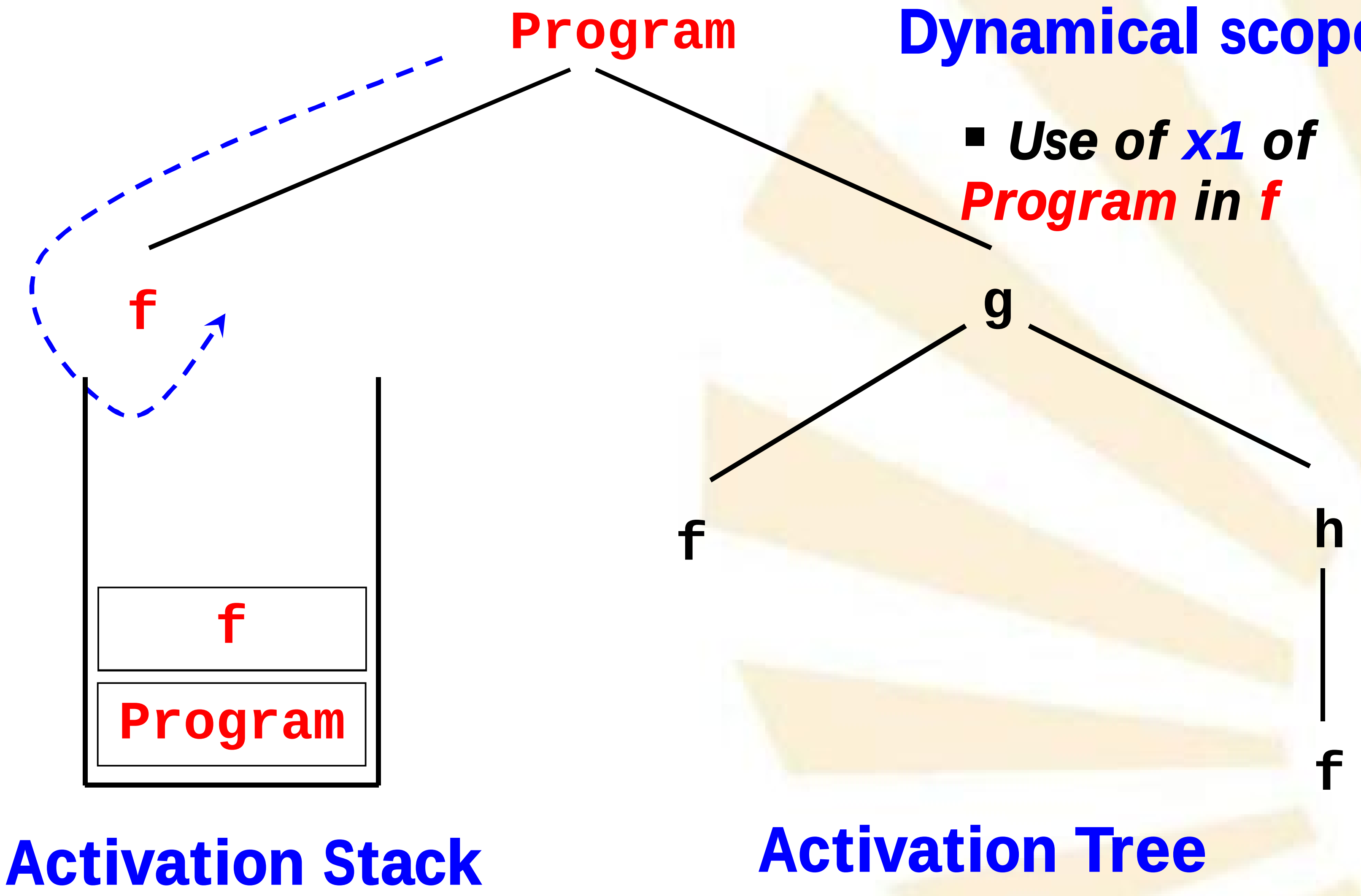
```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x

     Use of x
     Call to f
     Call to g
```

Run with dynamical scope

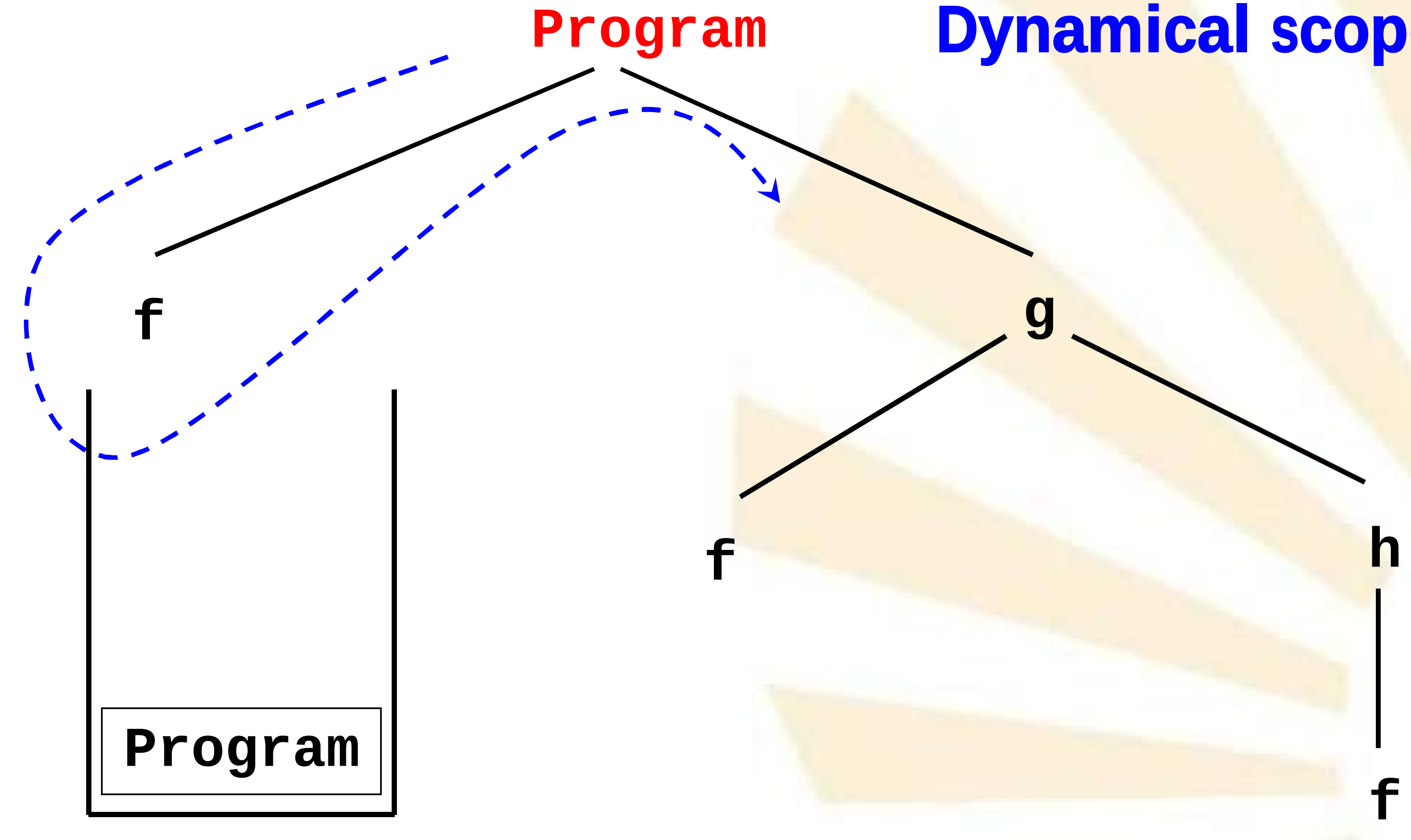
```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x1  <=

    Declaration of procedure g
      Declaration of variable x   (x2)

      Declaration of procedure h
       Use of x
       Call to f

       Call to f
       Call to h
       if condition = true then Call to g
       else    Use of x

     Use of x
     Call to f  <=
     Call to g
```

Dynamical scope

- *Use of x1 of Program in f*



Dynamical scope



Activation Stack

Activation Tree

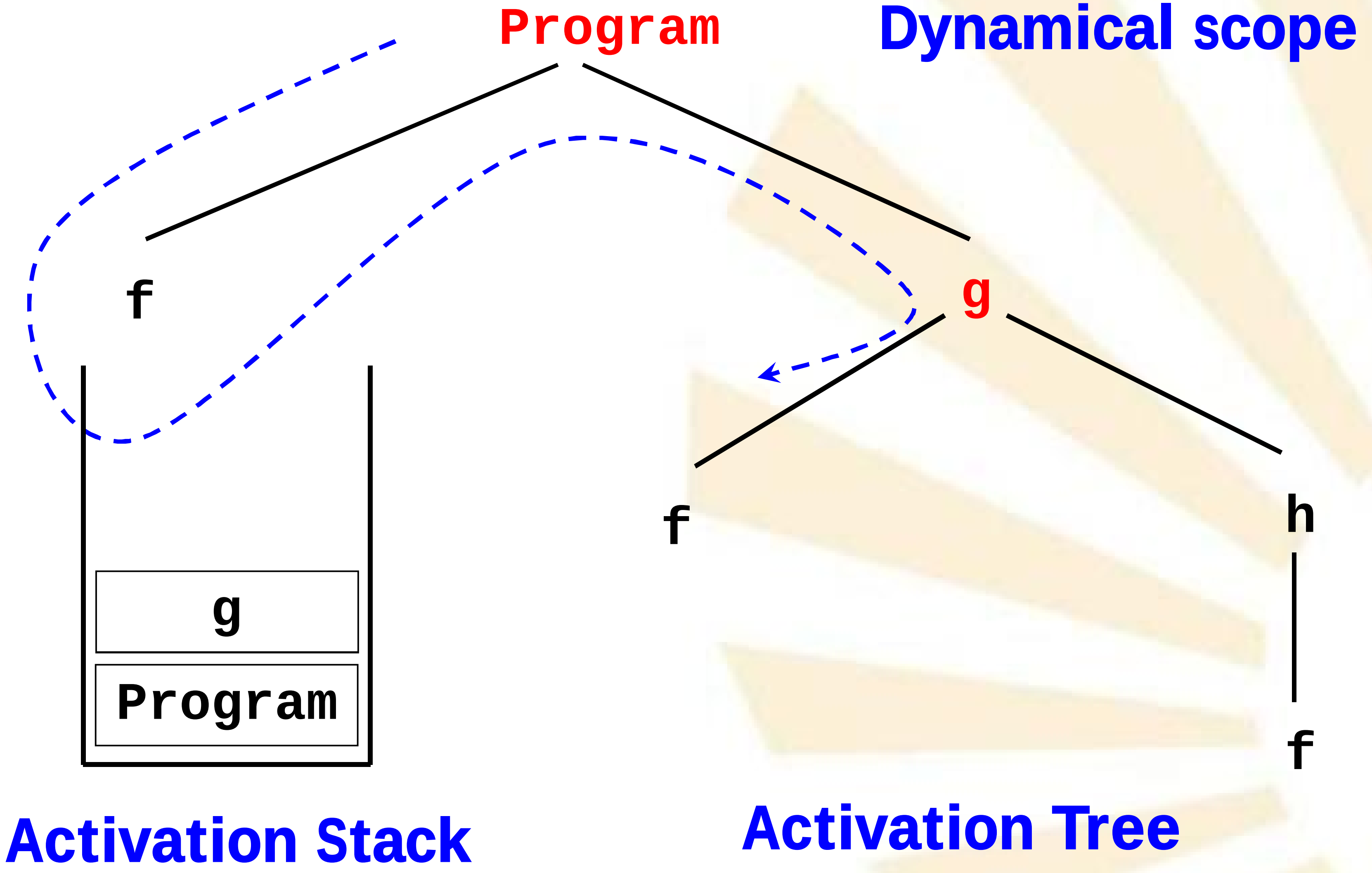
Run with

dynamical

scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x

     Use of x
     Call to f
     Call to g  <=
```

Dynamical scope



Run with

dynamical

scope

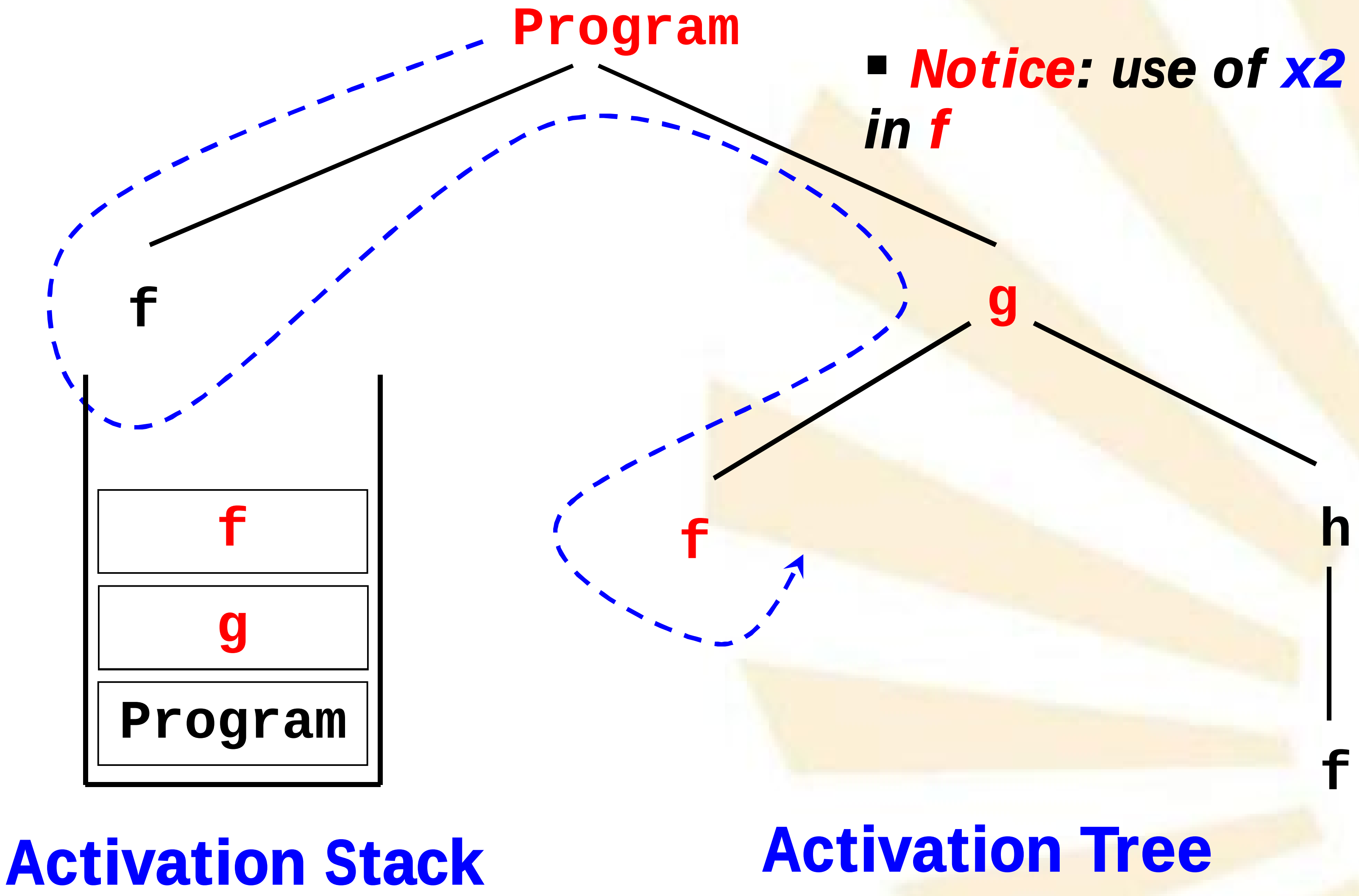
```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f  <=
      Call to h
      if condition = true then Call to g
      else   Use of x

    Use of x
    Call to f
    Call to g  <=
```

Run with dynamical scope

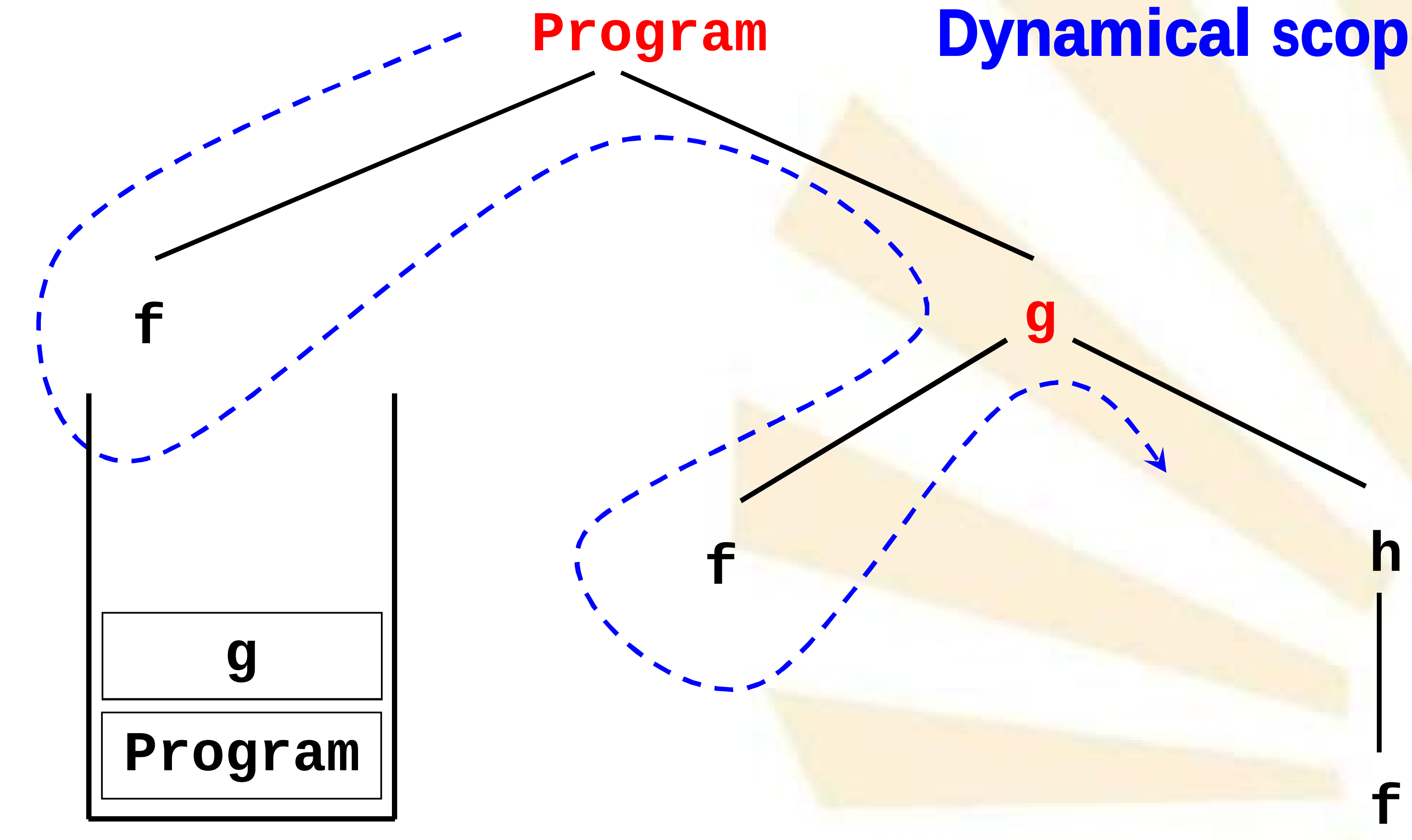
```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x2

    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x

    Use of x
    Call to f
    Call to g
```

Dynamical scope

- ***Notice*: use of *x2* of *g* in *f***



Dynamical scope



Activation Stack

Activation Tree

Run with

dynamical

scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x

     Use of x
     Call to f
     Call to g
```

Run with

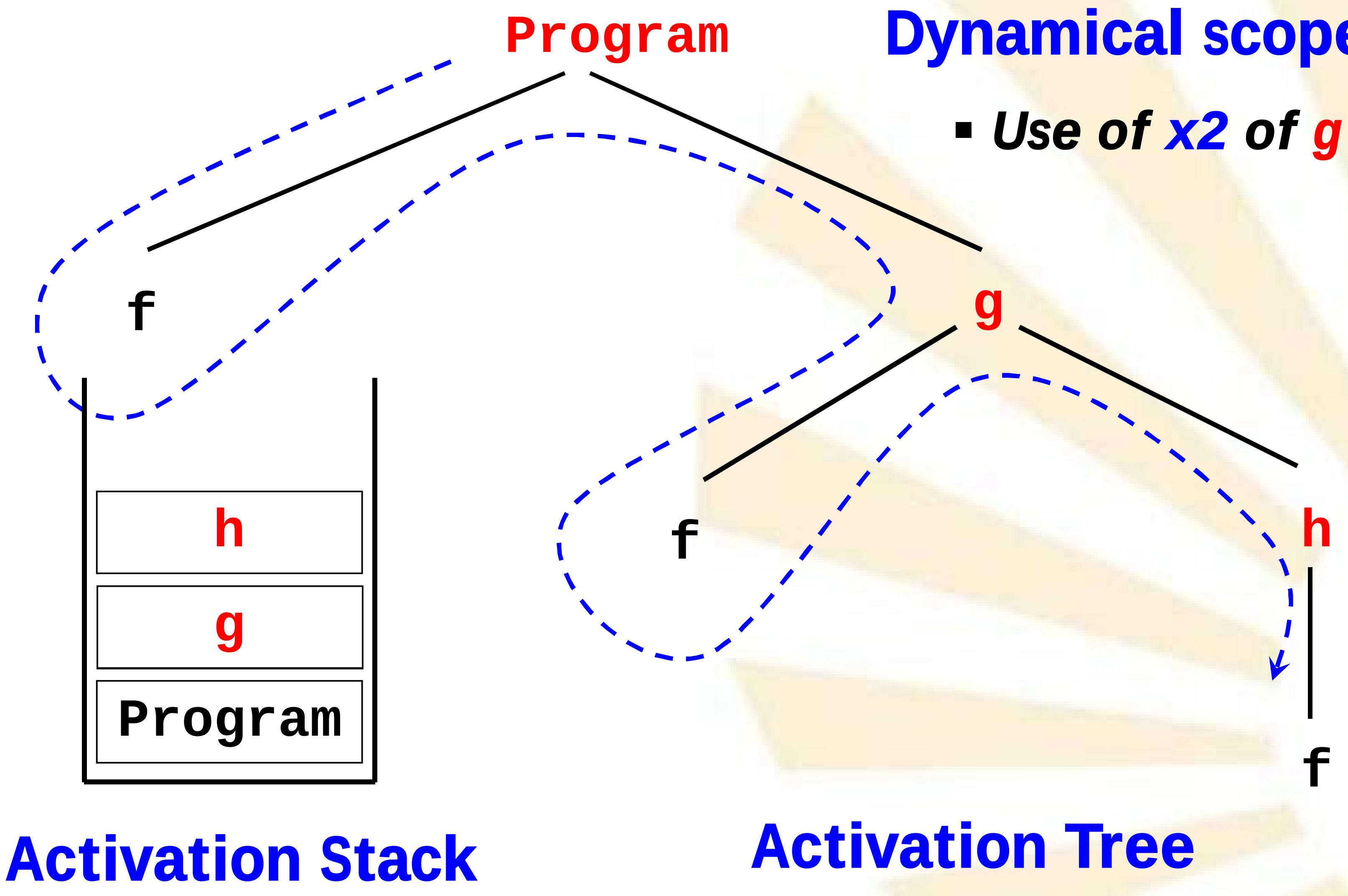
dynamical

scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x2   <=
      Call to f

      Call to f
      Call to h   <=
      if condition = true then Call to g
      else    Use of x

     Use of x
     Call to f
     Call to g   <=
```

Dynamical scope

- *Use of x2 of g in h*



Run with dynamical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x  (x2)

     Declaration of procedure h
      Use of x
      Call to f ⟸

      Call to f
      Call to h ⟸
      if condition = true then Call to g
      else   Use of x

     Use of x
     Call to f
     Call to g ⟸
```

Run with

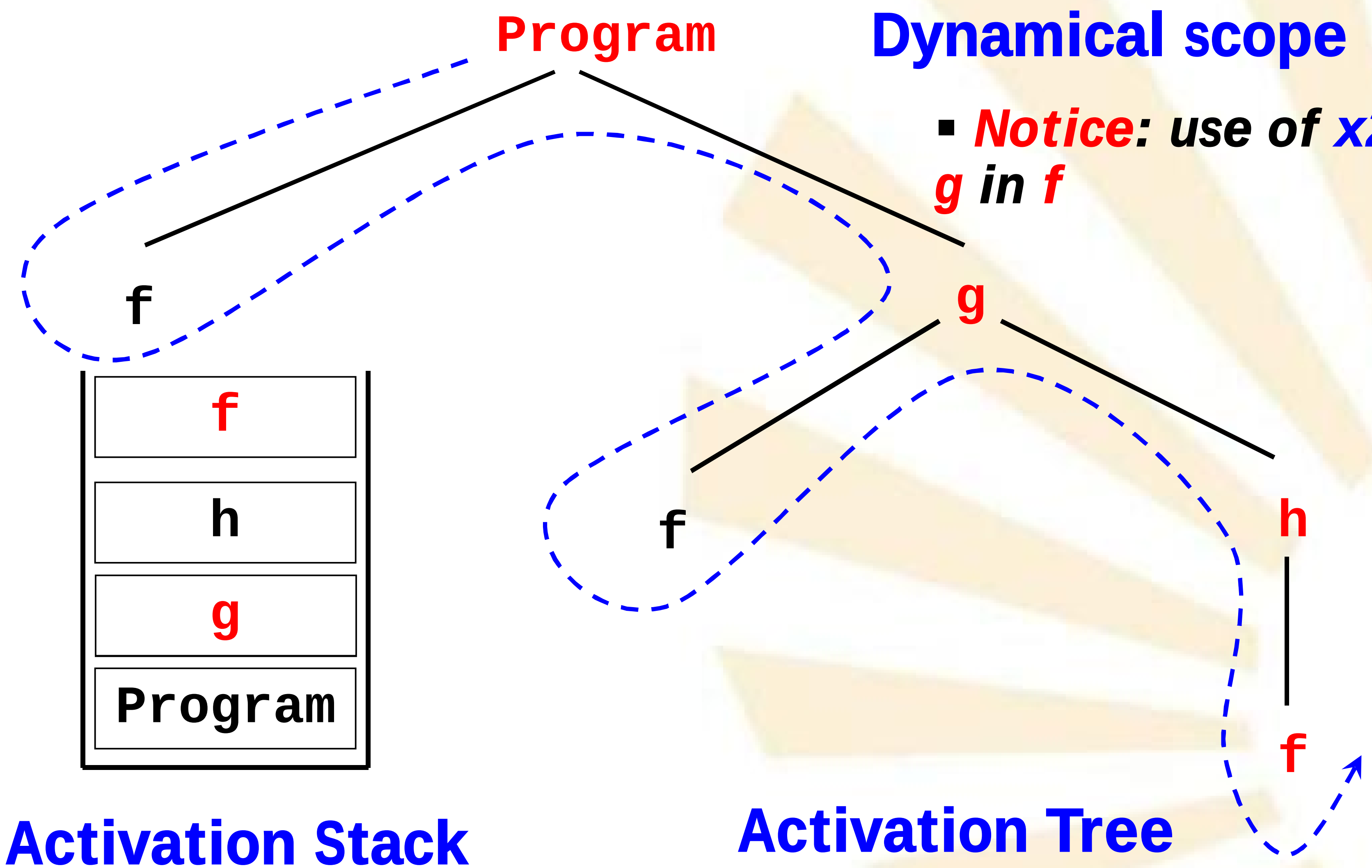
dynamical

scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x2


    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x

     Use of x
     Call to f
     Call to g
```

Dynamical scope

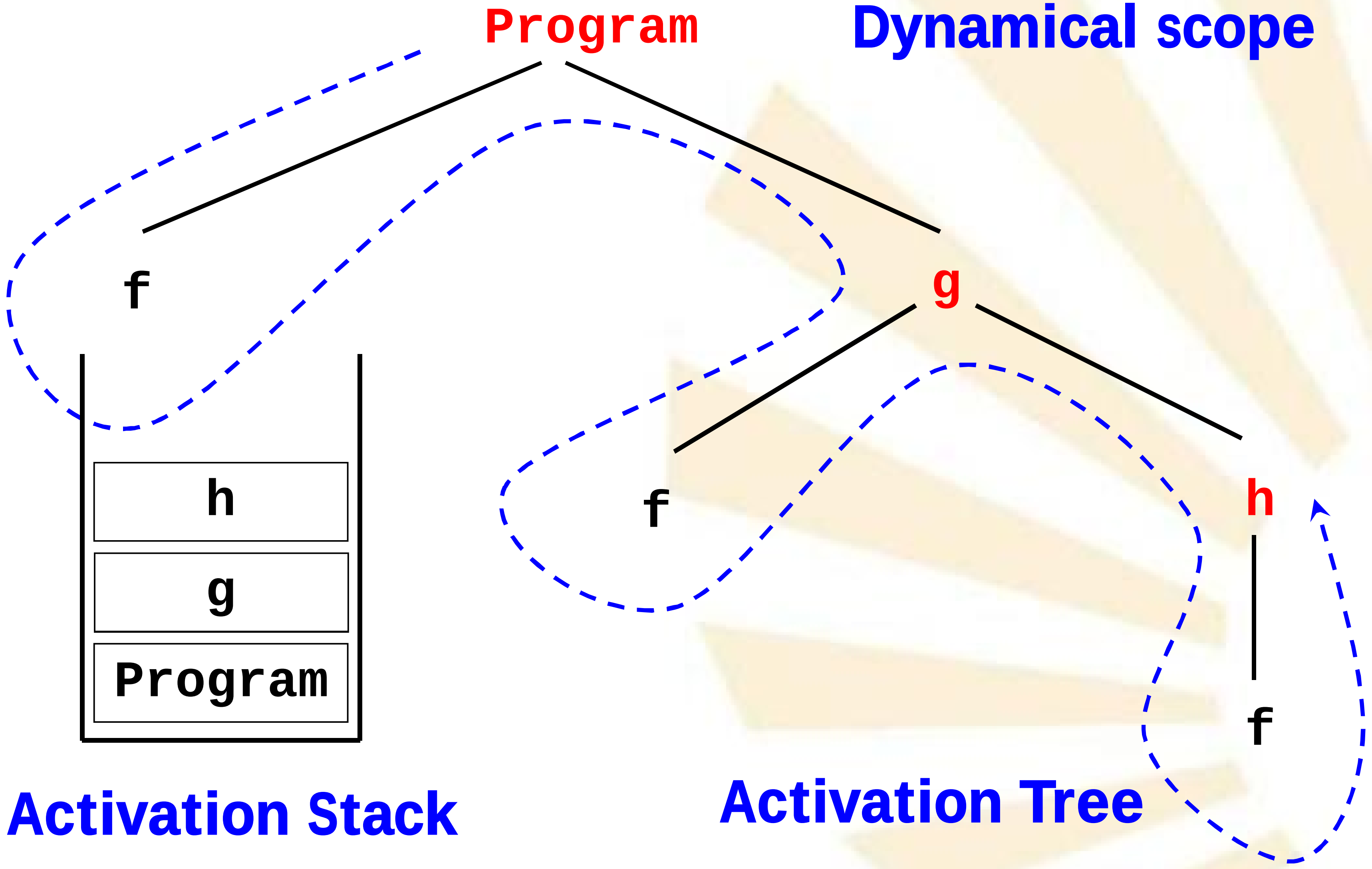
- *Notice: use of x2 of g in f*



Activation Stack

Activation Tree

Dynamical scope



Activation Stack

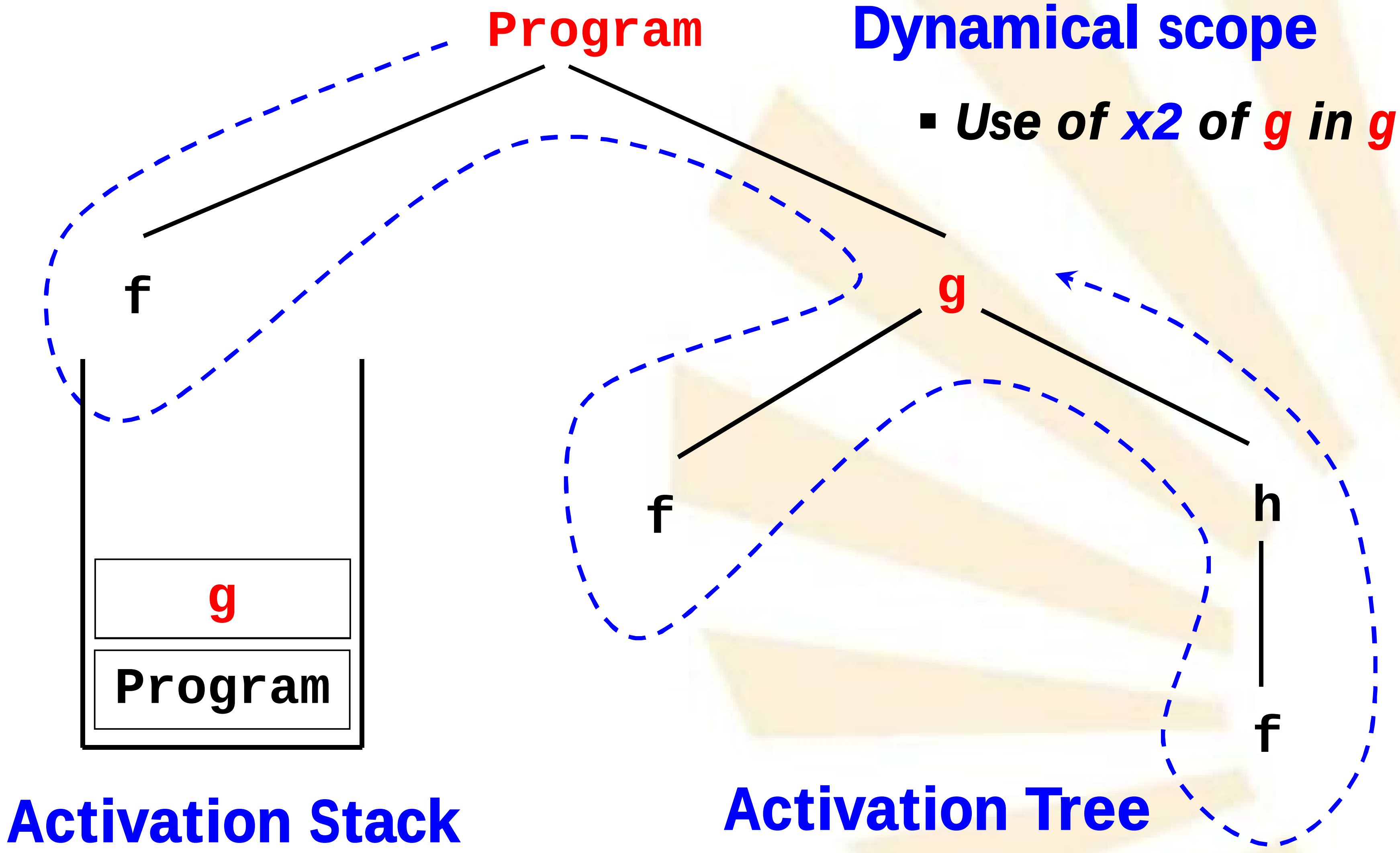
Activation Tree

Run with dynamical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x2 <=

     Use of x
     Call to f
     Call to g <=
```

Dynamical scope

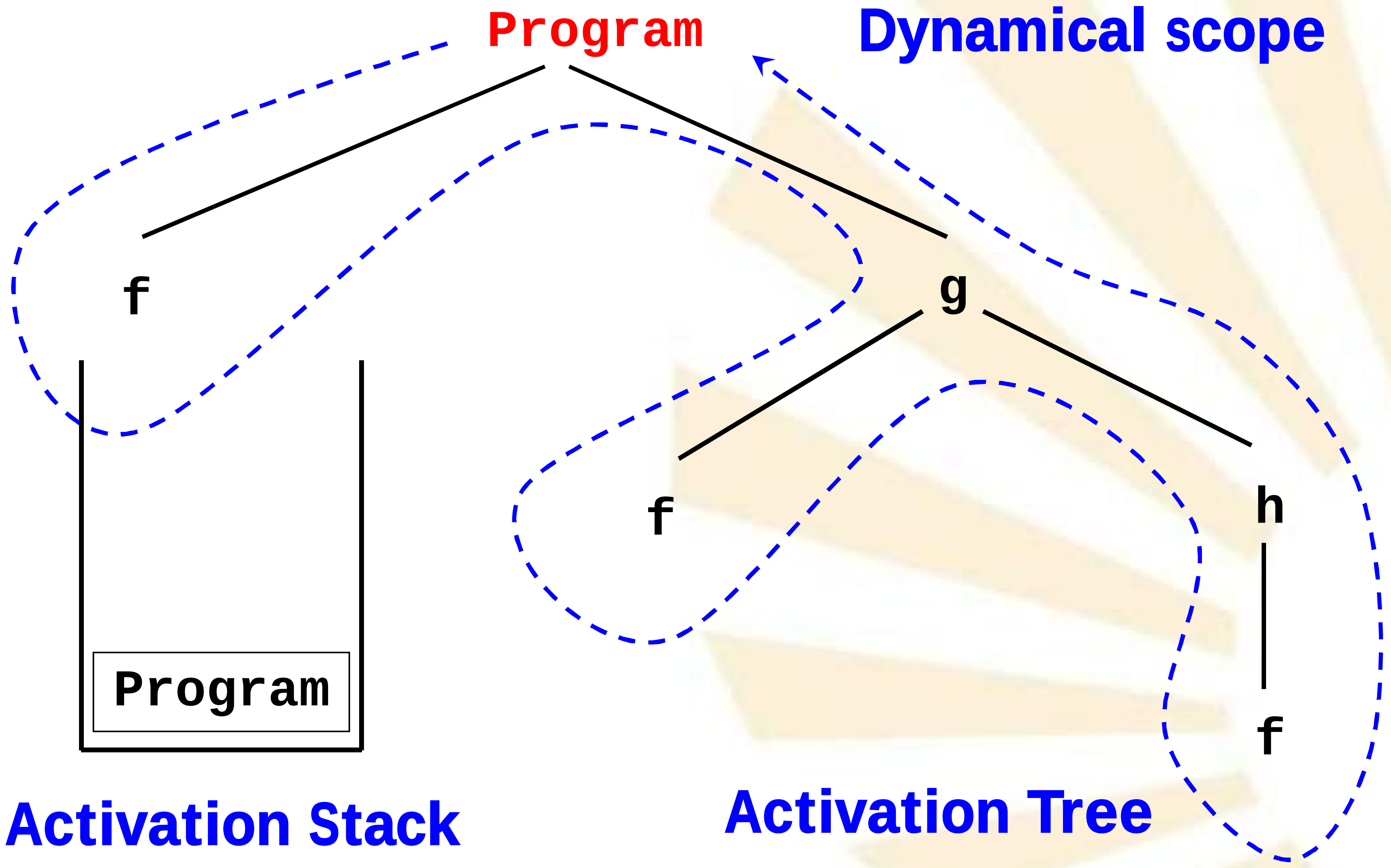
- *Use of x2 of g in g*

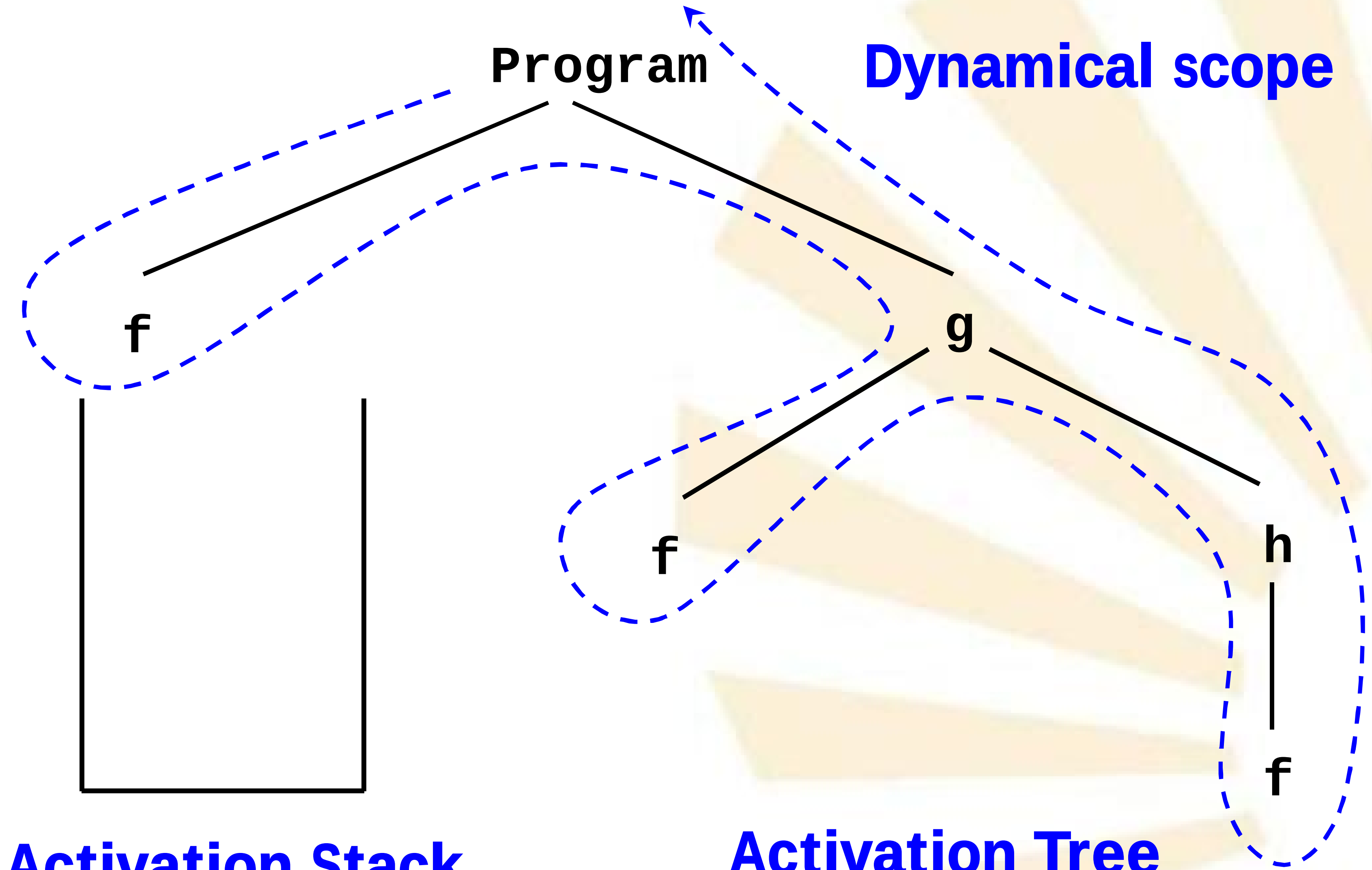


Run with dynamical scope

```
Program
    Declaration of variable x (x1)

    Declaration of procedure f
     Use of x

    Declaration of procedure g
      Declaration of variable x   (x2)

     Declaration of procedure h
      Use of x
      Call to f

      Call to f
      Call to h
      if condition = true then Call to g
      else    Use of x2

     Use of x
     Call to f
     Call to g
```

Dynamical scope




Program
f
g
f
h
f
Dynamical scope
Activation Stack
Activation Tree

2. **Historic Summary of Scheme**

- ✓ LISP
- ✓ Compilation versus Interpretation
- ✓ Dynamically versus statically scope
- ✓ **Origin of Scheme**

2. Historic Summary of Scheme

✓ Origin of Scheme:

- Gerald Jay **Sussman** (MIT) and Guy Lewis **Steele** Jr.
- **Question**:

  How would **LISP** be with **lexical** or **static scope** rules?
- **Answer**: new language → **Scheme**
  - More **efficient** implementation of **recursion**
  - **First class functions**.
  - Rigorous **semantic** rules
- **Influence** on Common LISP: lexical scope rules
- ***Revised ⁵ Report on the Algorithmic Language Scheme***

2. **Historic Summary of Scheme**

- ✓ **Scheme**:
  - ➢ **Structure of scheme programs**
    - ▪ Sequence of
      - **definitions** of functions and variables
      - and **expressions**

CÓRDOBA UNIVERSITY

SUPERIOR POLYTECHNIC SCHOOL

DEPARTMENT OF
COMPUTER SCIENCE AND NUMERICAL ANALYSIS

DECLARATIVE PROGRAMMING

COMPUTER ENGINEERING

COMPUTATION ESPECIALITY

FOURTH YEAR

FIRST FOUR-MONTH PERIOD

Subject 1.- Introduction to Scheme language