CMPU 101 § 53 · Computer Science I

Trees

15 February 2024

VASSAR COLLEGE

A·D·1861

VCCS ASPREY LECTURE SERIES:

MATT FOSTER '14

FEBRUARY 16, 2024

NE 206
Talk 5:30-6:30pm
Snack and Shmooze 5-5:30pm

VASSAR CS ALUMNUS, MATTHEW FOSTER '14, IS THE ADVANCED SENIOR SYSTEMS DESIGNER AT INSOMNIAC GAMES. HE RECENTLY HELPED DESIGN MARVEL'S SPIDER-MAN 2 AND HAS SHIPPED A HANDFUL OF TITLES OVER HIS DECADE LONG TENURE IN THE VIDEO GAME INDUSTRY. HE'S WORKED AT LARGE STUDIOS LIKE 2K GAMES AND CD PROJECT RED, AS WELL AS SMALLER INDIE TEAMS AND HAS INSIGHT TO SHARE FOR WOULD BE GAME DEVELOPERS ON HOW BEST TO DESIGN A GAME'S SYSTEMS AND OPEN WORLD. HIS TALK ON FEBRUARY 16TH WILL COVER DESIGN PRINCIPLES FOR BOTH DISCIPLINES AS WELL AS A Q&A PORTION TO ANSWER ANY QUESTIONS ASPIRING DEVELOPERS MIGHT WANT THE ANSWER TO.

ColorStack GB Meeting!

Chicago LL 102
February 20th
5:00 - 6:00 PM

See you there!

Where are we?

We've seen how lists are defined:

```
data List:
  | empty
  | link(first :: Any, rest :: List)
end
```

Self-reference

And, given this data definition, we can write functions that recursively process a list:

```
fun list-fun(lst :: List) -> ...:
 doc: "Template for a function that takes a List"
 cases (List) lst:
  | empty => ...
  | link(f, r) =>
   ... f ...
   ... list-fun(r) ...
 end
where:
  list-fun(...) is ...
end
```

Recursive call

Every data definition has a corresponding template.

The more complex the data definition is – lots of variants, recursion, etc. – the more helpful it is to use the template!

Given a (recursive) data definition, you write a template by:

1. Creating a function header
2. Using **cases** to break the data input into its variants
3. In each case, listing each of the fields in the answer
4. Calling the function itself on any recursive fields

Warm-up practice

```
fun list-len(lst :: List) -> Number:
  doc: "Compute the length of a list"
  cases (List) lst:
    | empty => 0
    | link(f, r) => 1 + list-len(____)
  end
end
```

```
fun list-len(lst :: List) -> Number:
  doc: "Compute the length of a list"
  cases (List) lst:
    | empty => 0
    | link(f, r) => 1 + list-len(r)
  end
end
```

```
fun list-product(lst :: List<Number>) -> Number:
  doc: "Compute the product of all the numbers in lst"
  cases (List) lst:
    | empty => 1
    | link(f, r) => ____ * list-product(r)
  end
end
```

```
fun list-product(lst :: List<Number>) -> Number:
  doc: "Compute the product of all the numbers in lst"
  cases (List) lst:
    | empty => 1
    | link(f, r) => f * list-product(r)
  end
end
```

```
fun is-member(item, lst :: List) -> Boolean:
  doc: "Return true if item is a member of lst"
  cases (List) lst:
    | empty => ______
    | link(f, r) =>
      (f == ______) or is-member(______, ______)
  end
end
```

```
fun is-member(item, lst :: List) -> Boolean:
  doc: "Return true if item is a member of lst"
  cases (List) lst:
    | empty => false
    | link(f, r) =>
      (f == item) or is-member(item, r)
  end
end
```

Rumor mills

EMMA:

A NOVEL.

IN THREE VOLUMES.

BY THE

AUTHOR OF "PRIDE AND PREJUDICE,"
&c. &c.

VOL. I.

LONDON:
PRINTED FOR JOHN MURRAY.
1816.

The news [*of Emma and Mr. Knightley's engagement*] was universally a surprize wherever it spread; and Mr. Weston had his five minutes share of it…

"It is to be a secret, I conclude," said he. "***These matters are always a secret, till it is found out that every body knows them.*** Only let me be told when I may speak out.—I wonder whether Jane has any suspicion."

Jane Austen, *Emma*, 1815

He went to Highbury the next morning, and satisfied himself on that point. He told her the news… and Miss Bates being present, it passed, of course, to Mrs. Cole, Mrs. Perry, and Mrs. Elton, immediately afterwards. It was no more than the principals were prepared for; *they had calculated from the time of its being known at Randalls, how soon it be over Highbury*; and were thinking of themselves, as the evening wonder in many a family circle…

Jane Austen, *Emma*, 1815

Tracking rumors

Suppose we want to track gossip in this rumor mill.

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Emma

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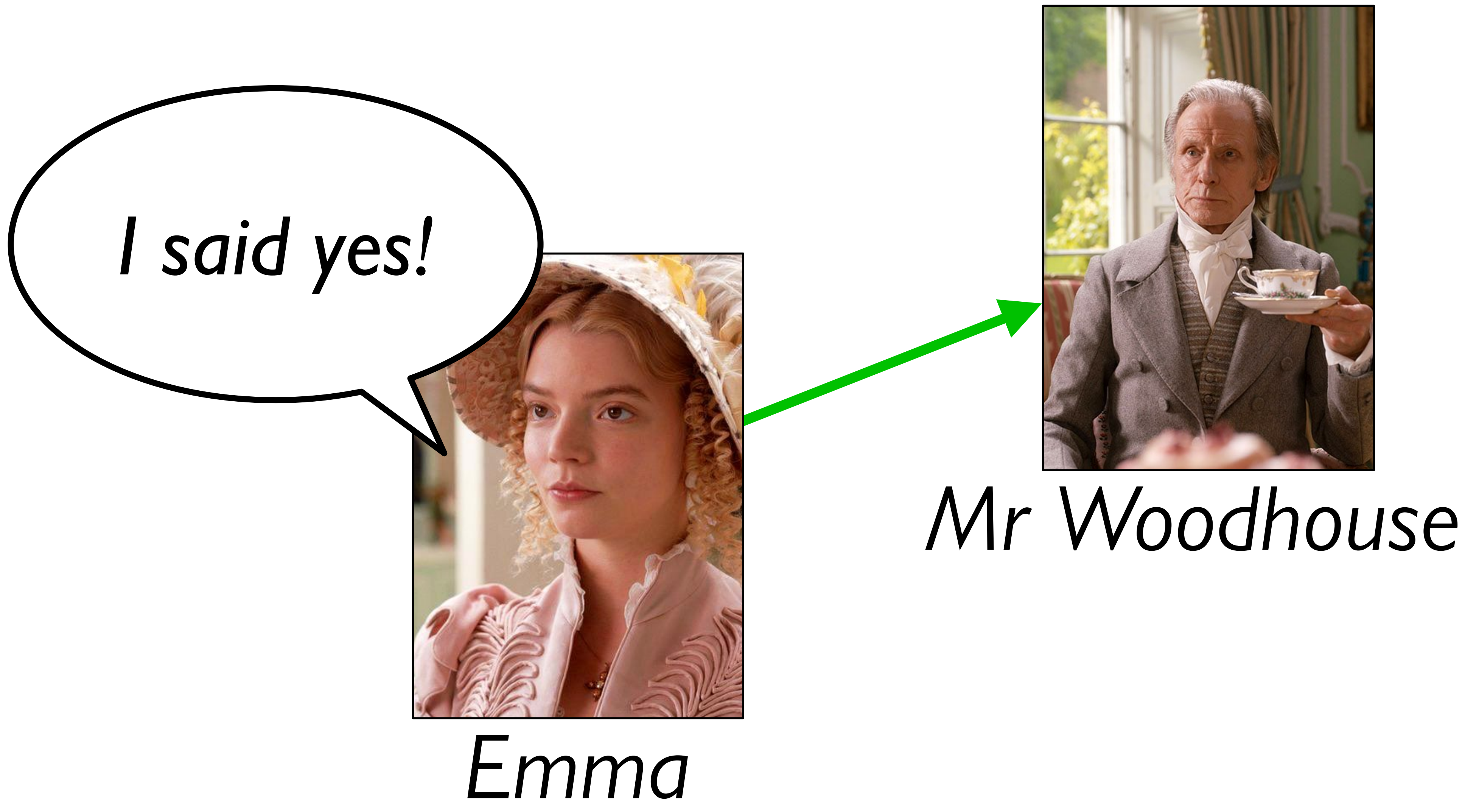
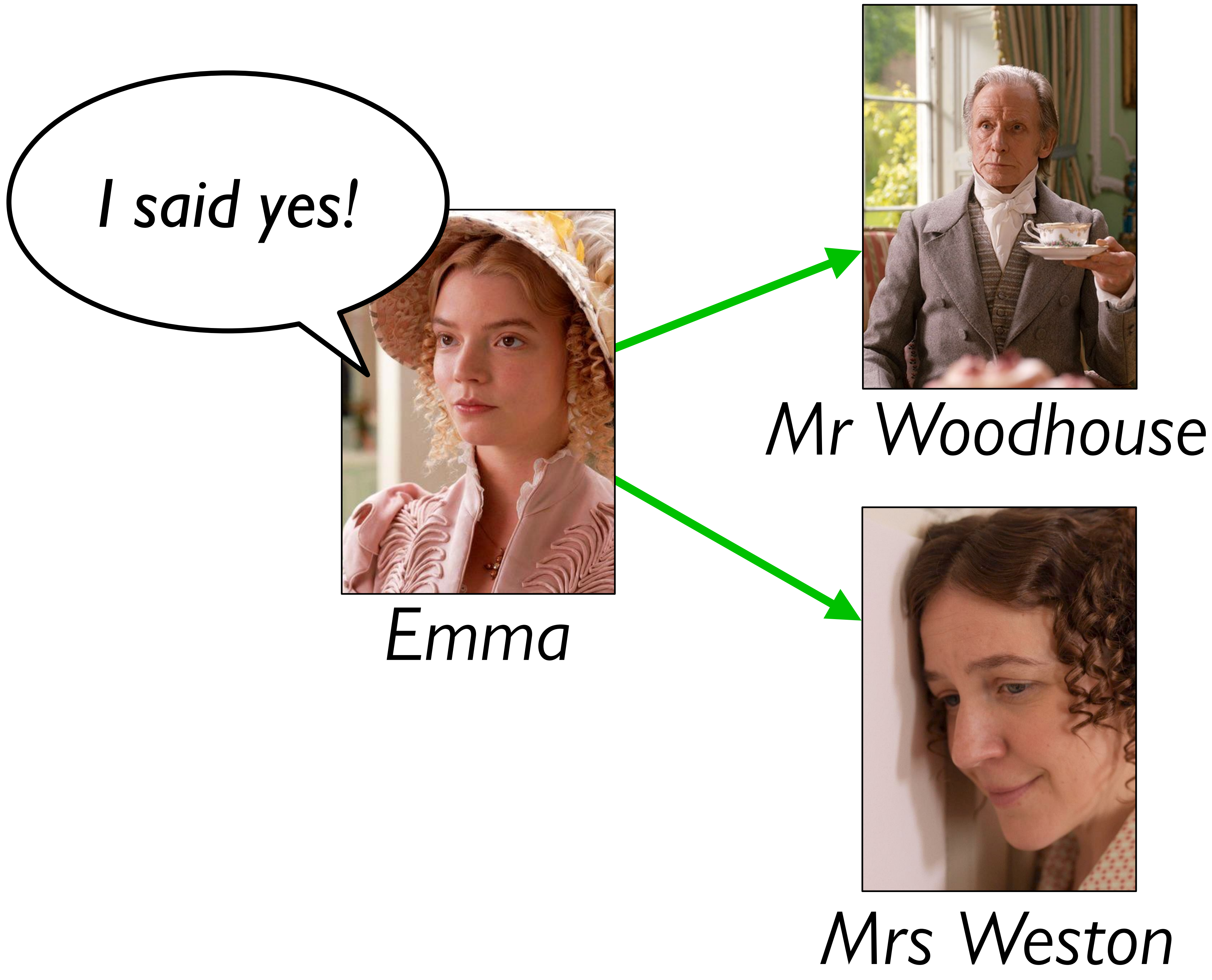


Tracking rumors

Suppose we want to track gossip in this rumor mill.



Emma

Mr Woodhouse

Mrs Weston

Tracking rumors

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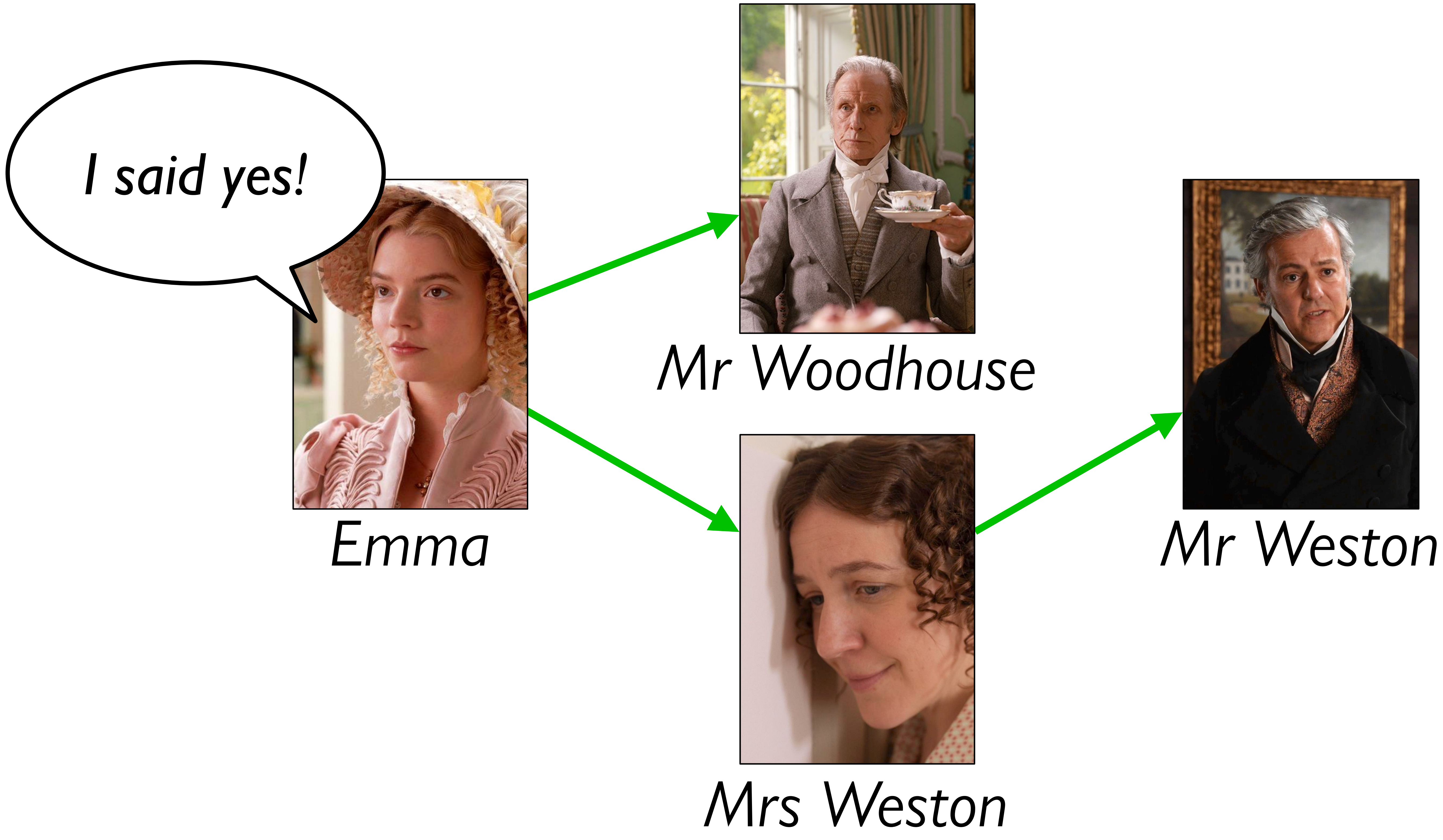


Emma

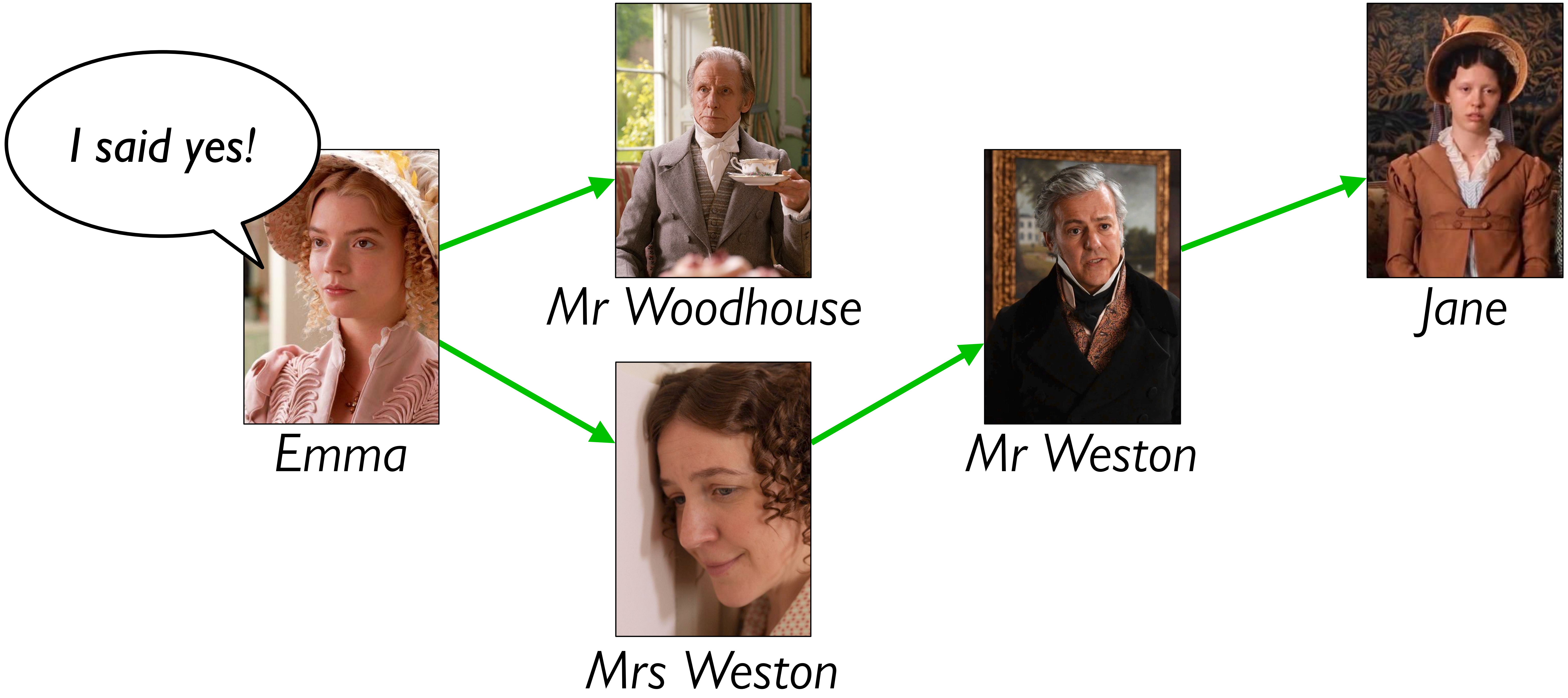
Mr Woodhouse

Mrs Weston

Mr Weston

Tracking rumors

Suppose we want to track gossip in this rumor mill.



I said yes!

Emma

Mr Woodhouse

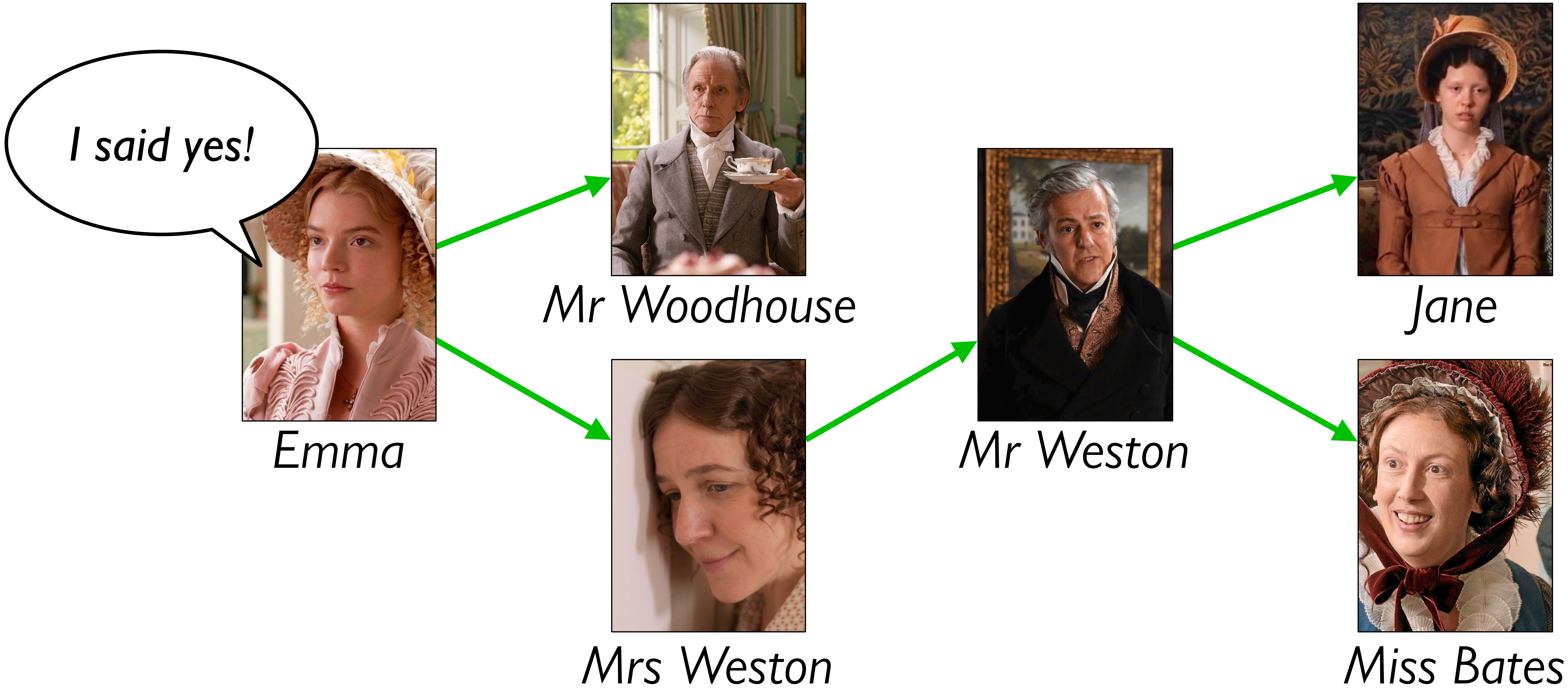
Mrs Weston

Mr Weston

Jane

Tracking rumors

Suppose we want to track gossip in this rumor mill.



I said yes!

Emma

Mr Woodhouse

Mrs Weston

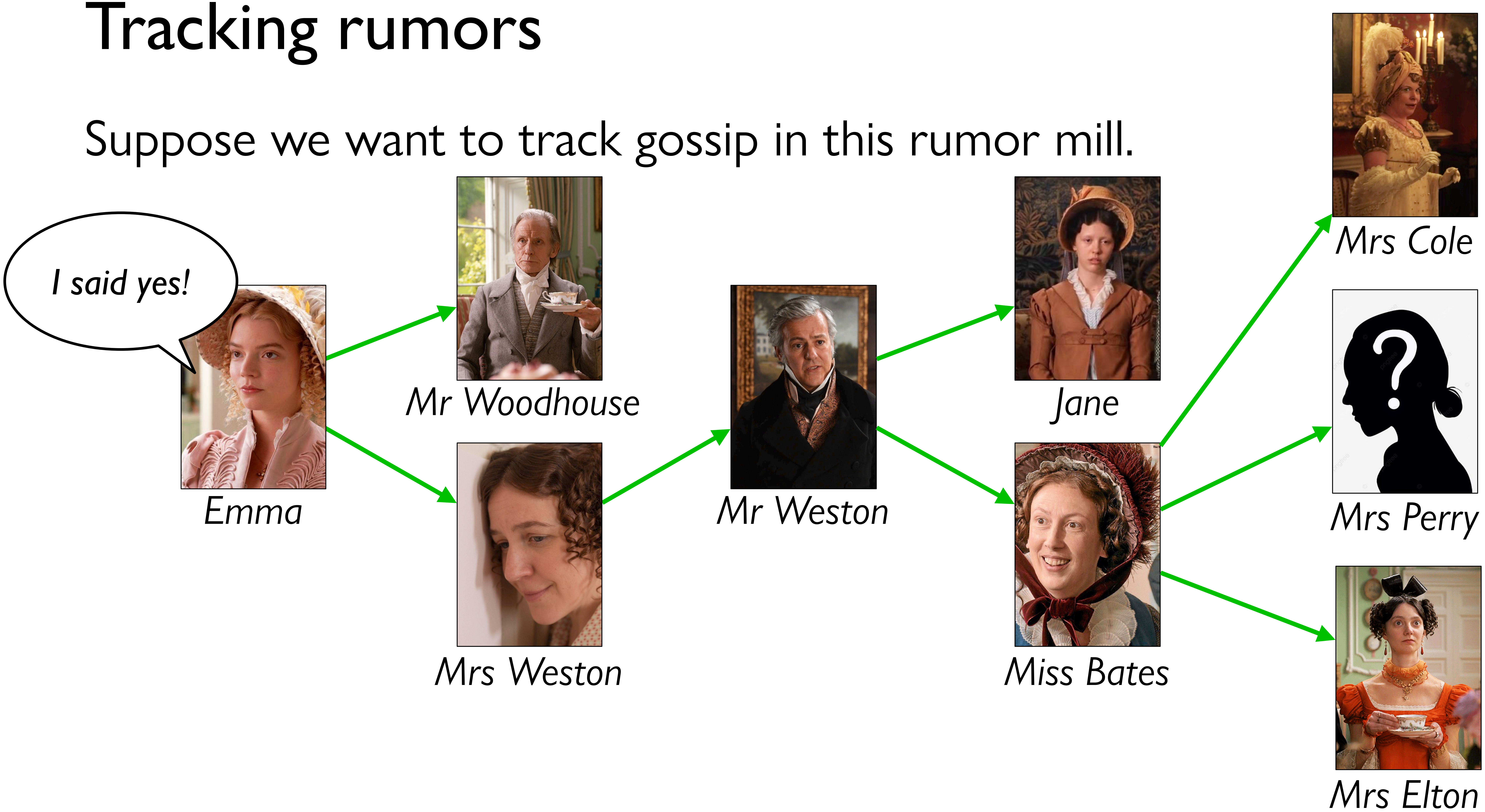
Mr Weston

Jane

Miss Bates

Tracking rumors

Suppose we want to track gossip in this rumor mill.



I said yes!

Emma

Mr Woodhouse

Mrs Weston

Mr Weston

Jane

Miss Bates

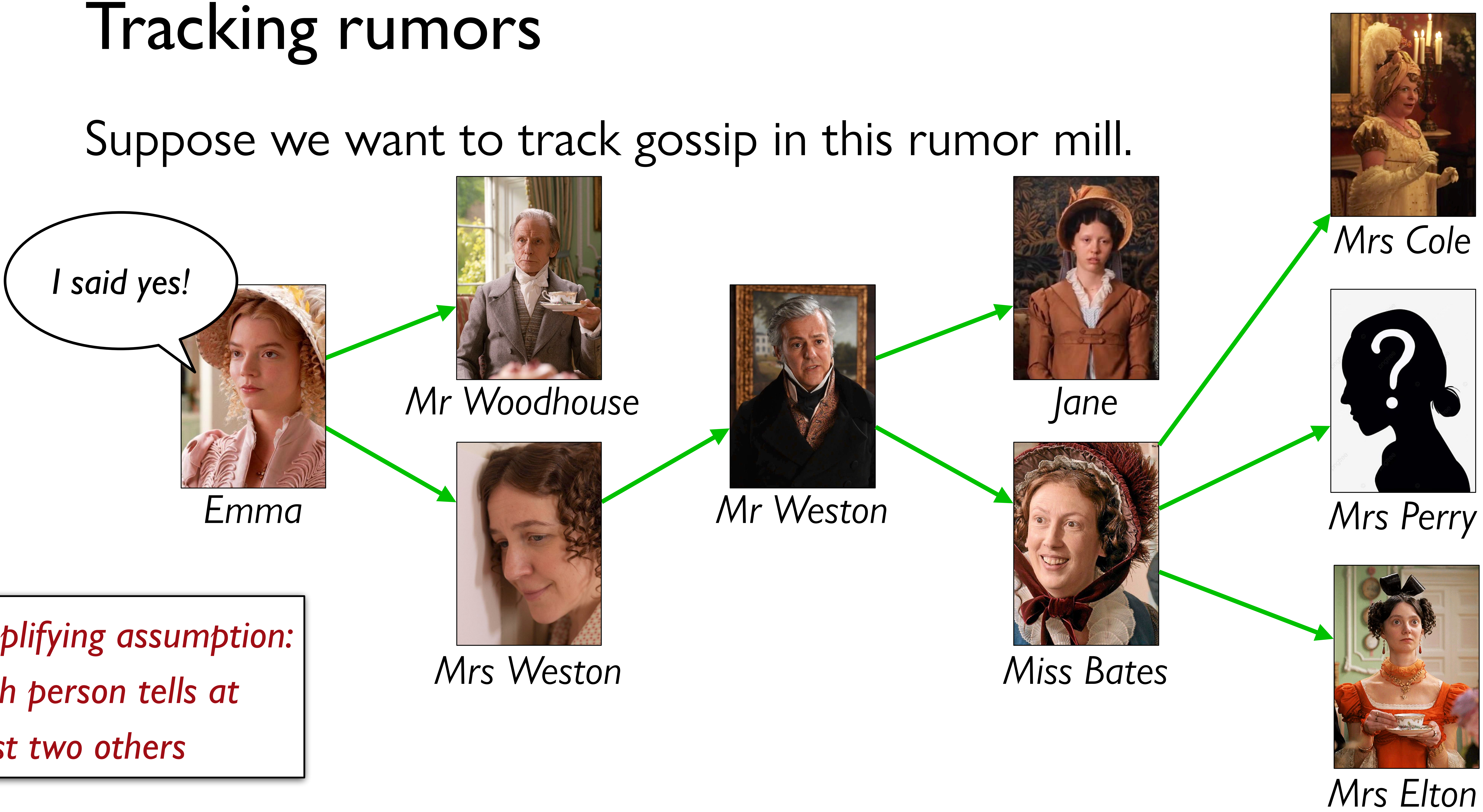
Mrs Cole

Mrs Perry

Mrs Elton

Tracking rumors

Suppose we want to track gossip in this rumor mill.



Simplifying assumption: Each person tells at most two others

Tracking rumors

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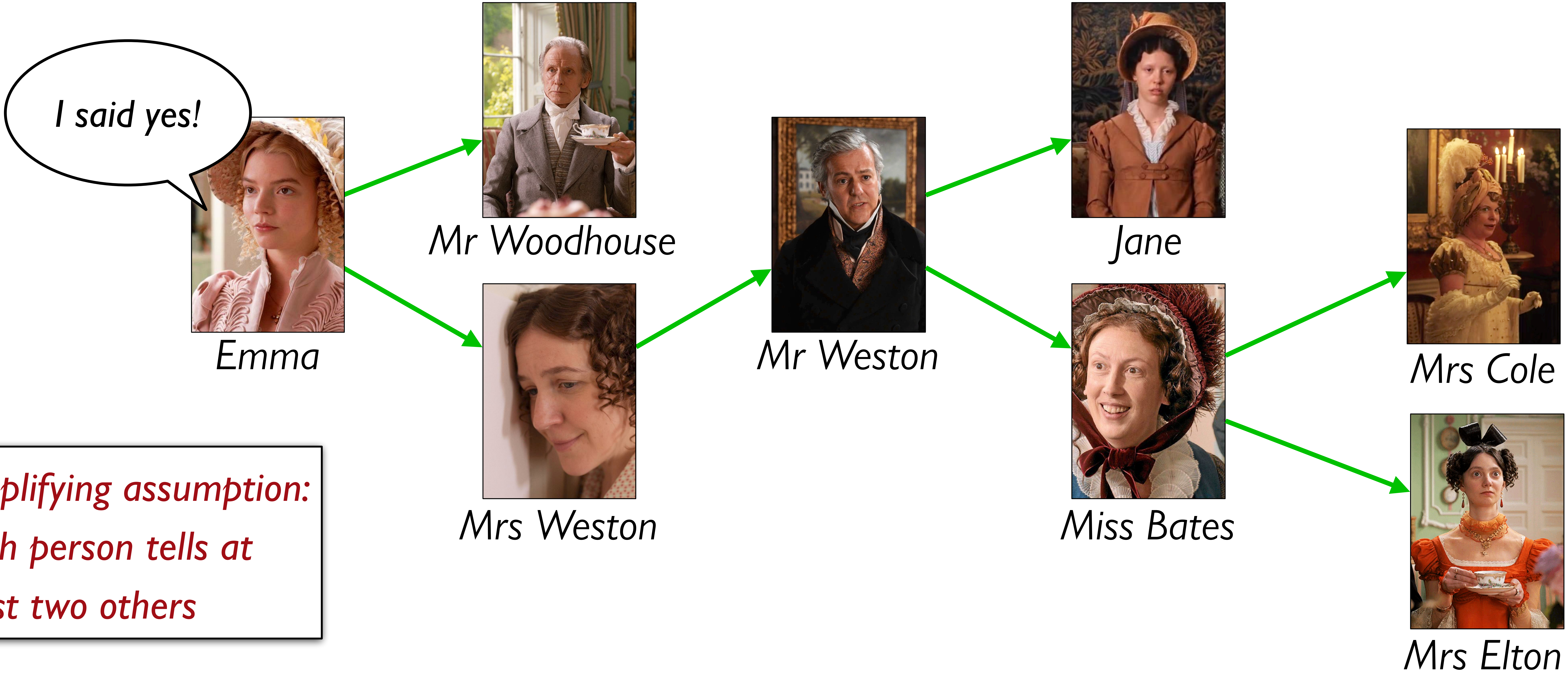

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Tracking rumors

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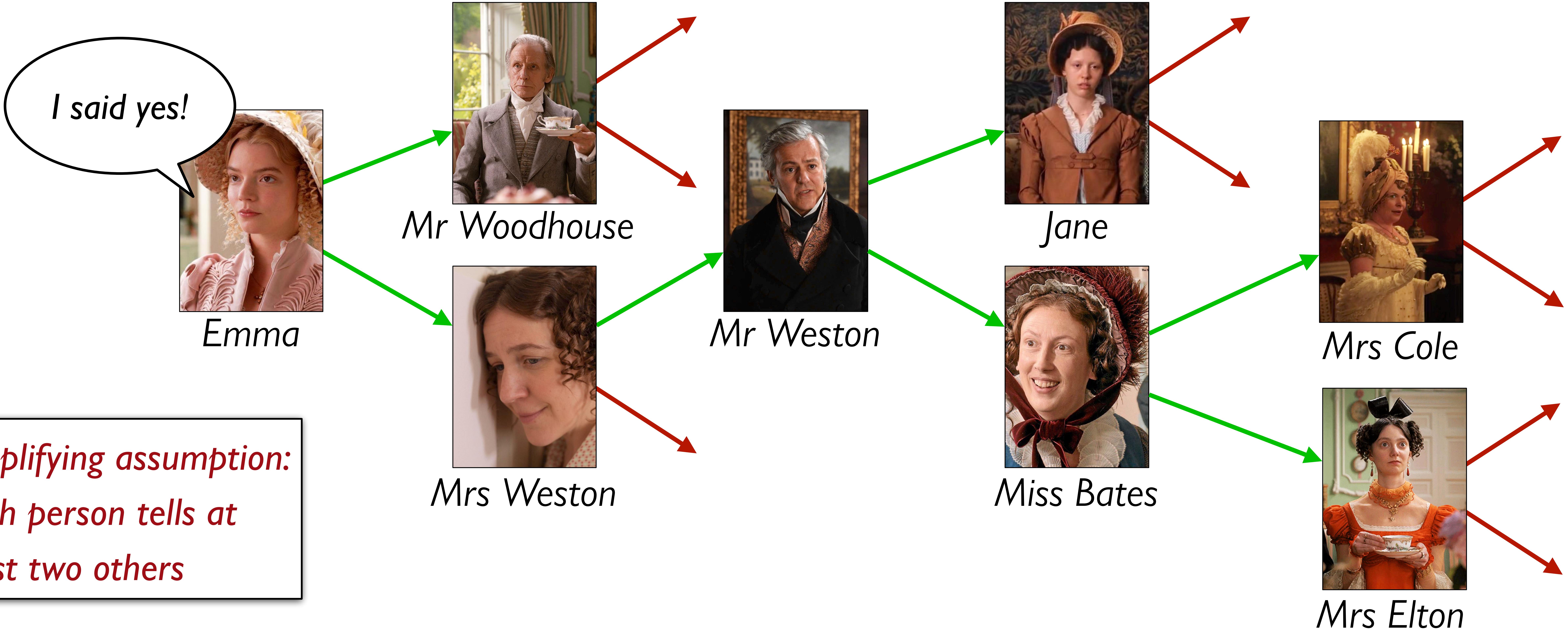


I said yes!

Emma

Mr Woodhouse

Mrs Weston

Mr Weston

Jane

Miss Bates

Mrs Cole

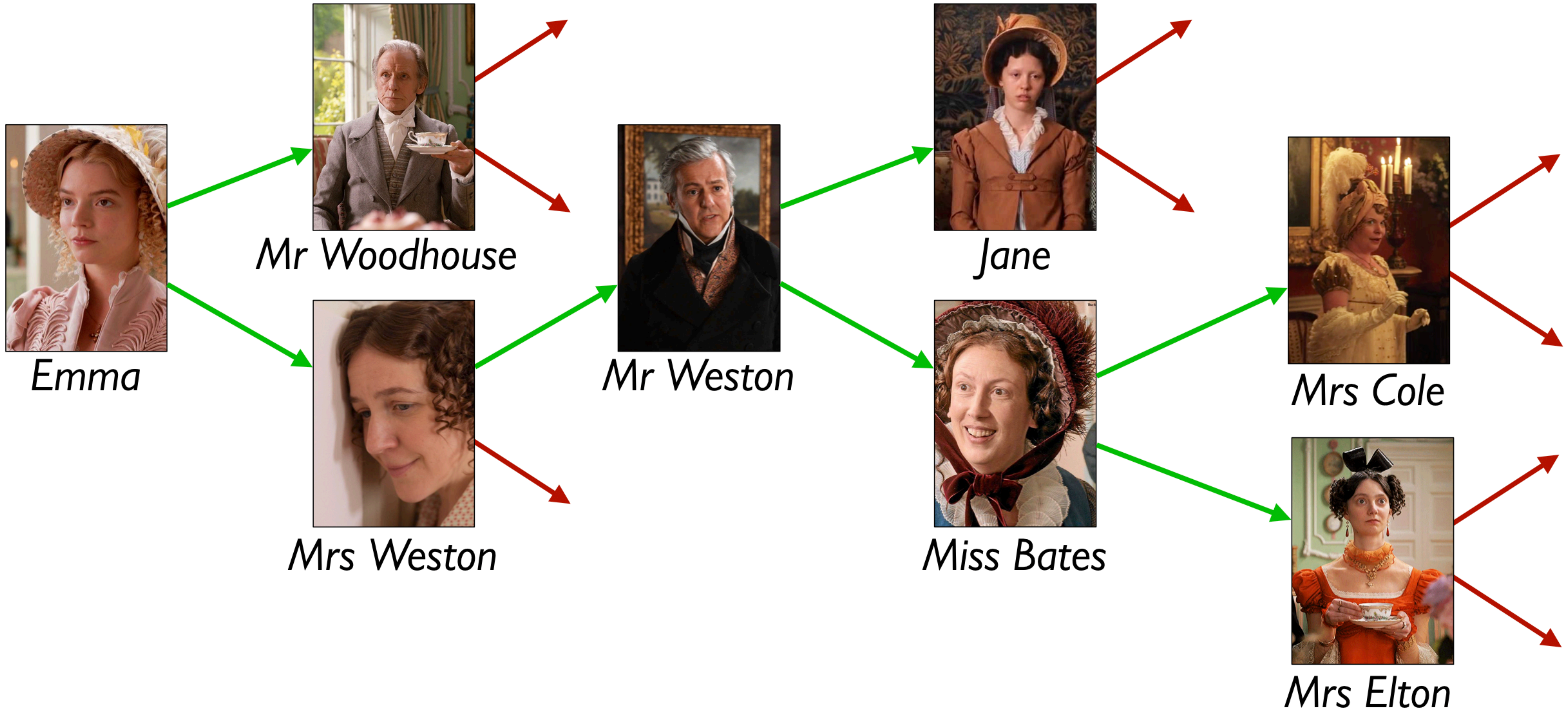
Mrs Elton

Simplifying assumption: Each person tells at most two others

The Jane Austen example is a bit frivolous, but otherwise this is an important problem.

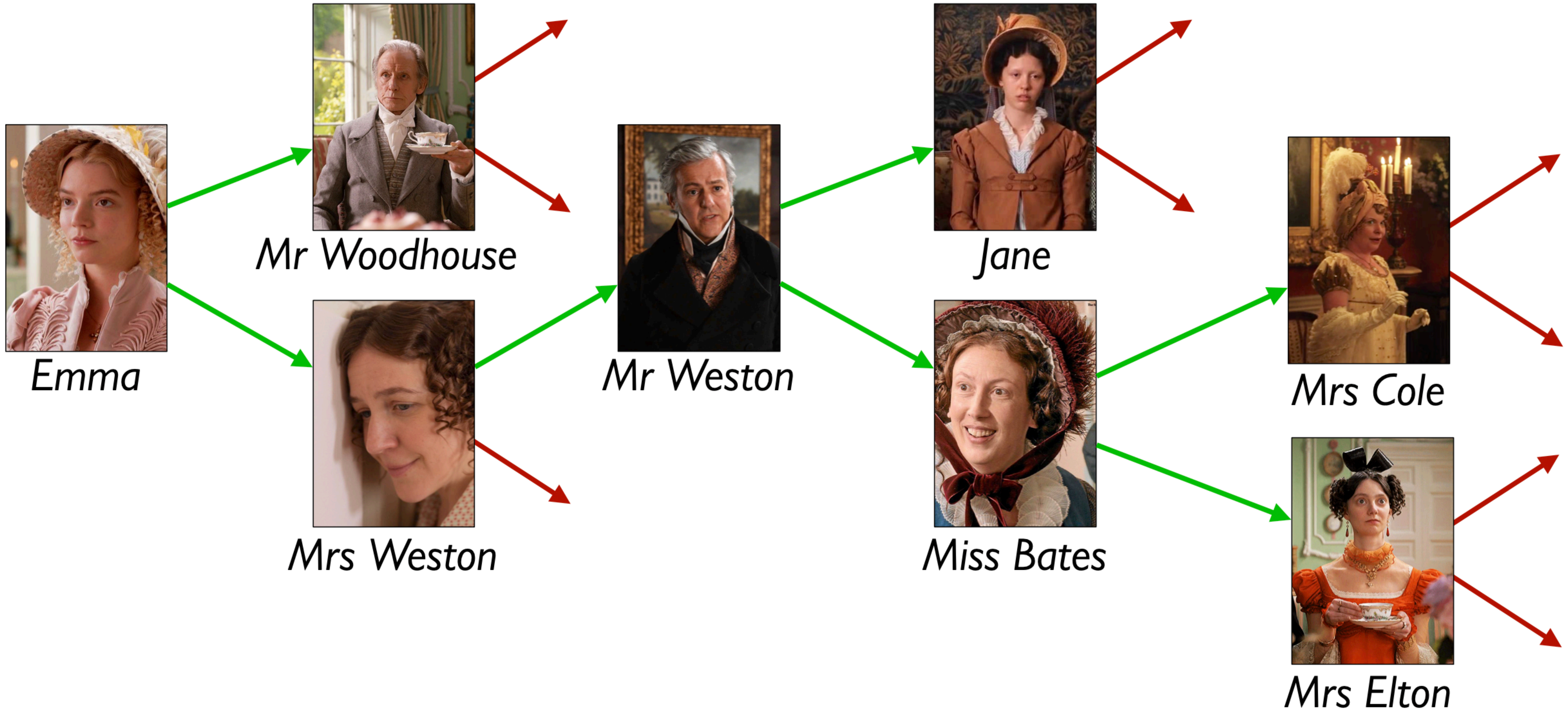
A lot of research right now is focused on building models of how information – and misinformation! – spreads through social networks, both in person and online.

Representing rumor mills



Is a rumor mill simply a list of people?

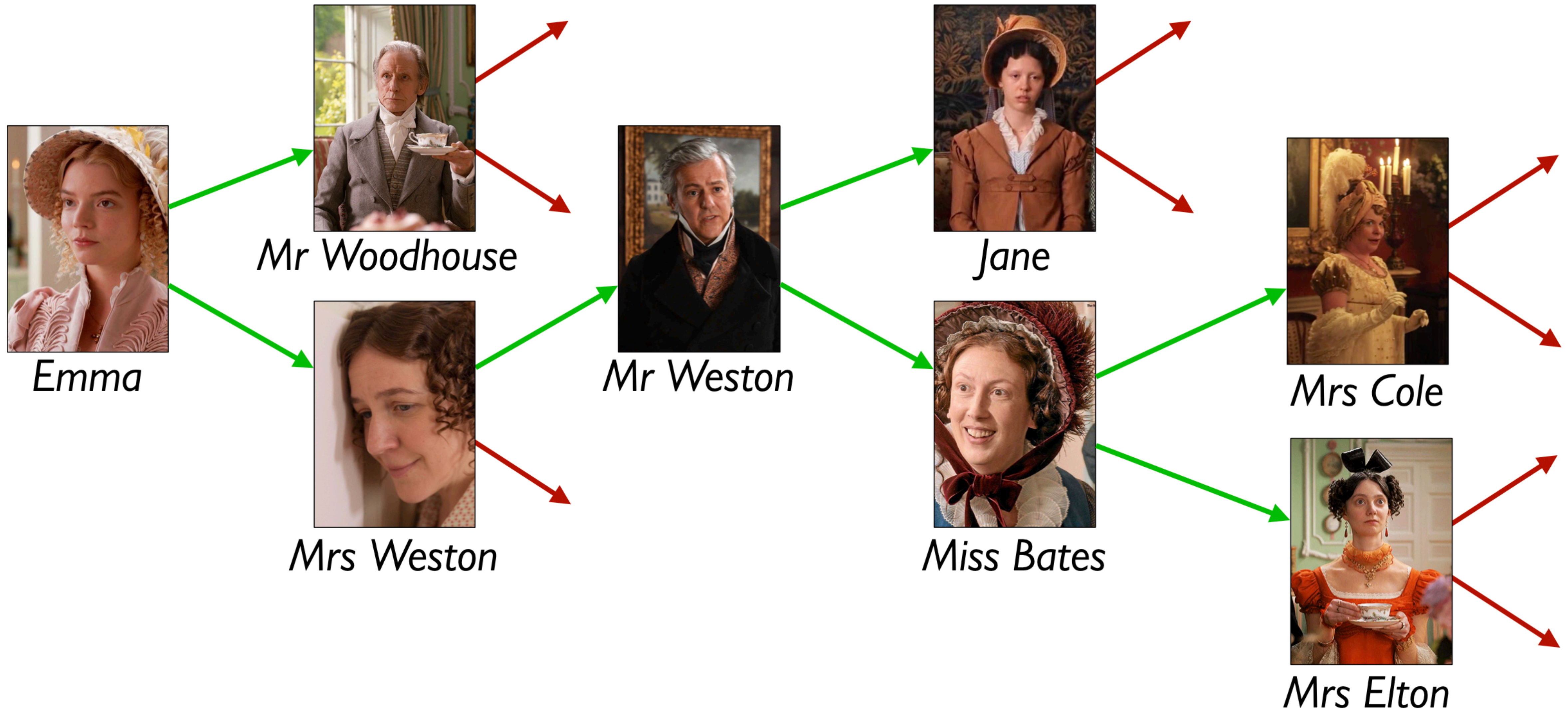
Representing rumor mills



Is a rumor mill simply a list of people?

No, because there are relationships among the people.

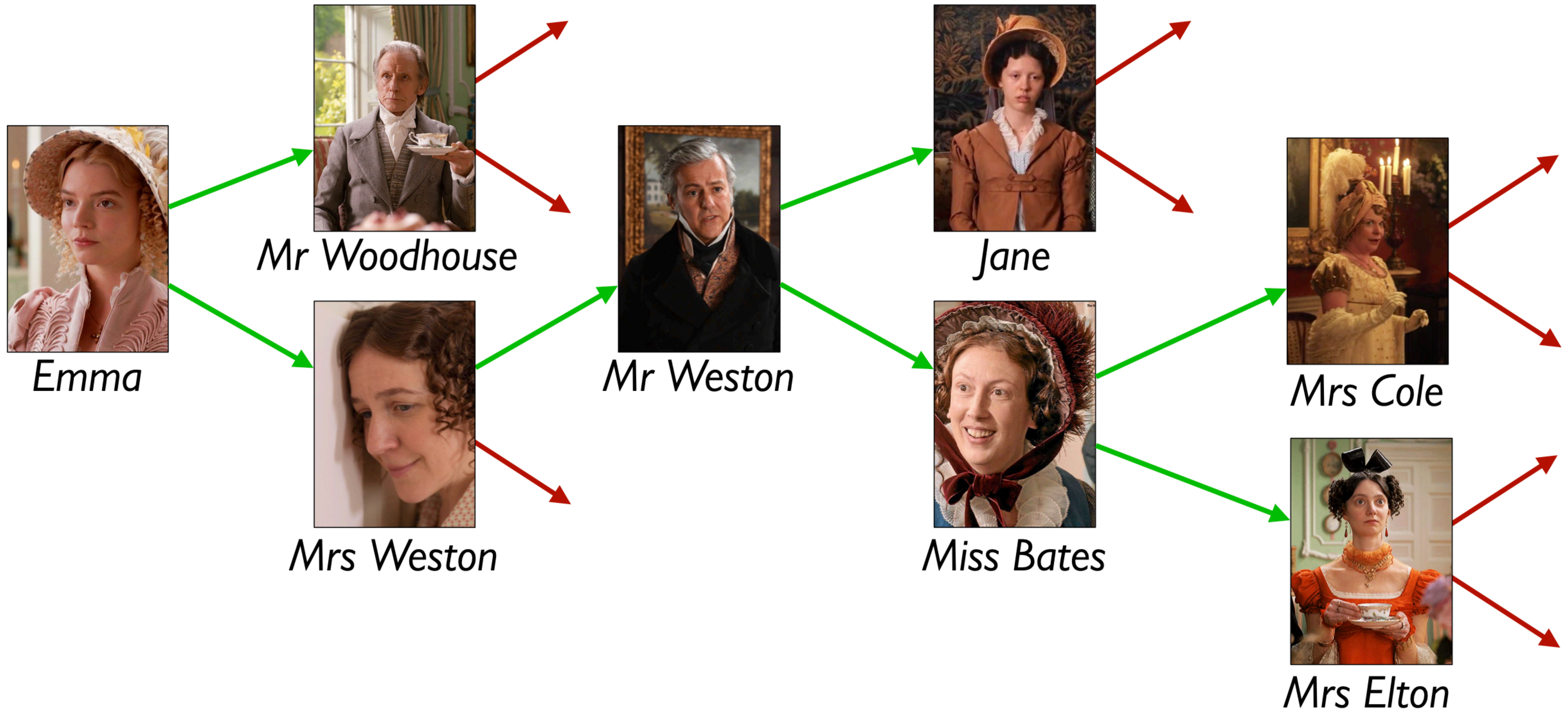
Representing rumor mills



We could represent these relations with a table, e.g.,

name :: String	*next1 :: String*	*next2 :: String*
`"Emma"`	`"Mr Woodhouse"`	`"Mrs Weston"`
`"Mr Woodhouse"`		
…	…	…

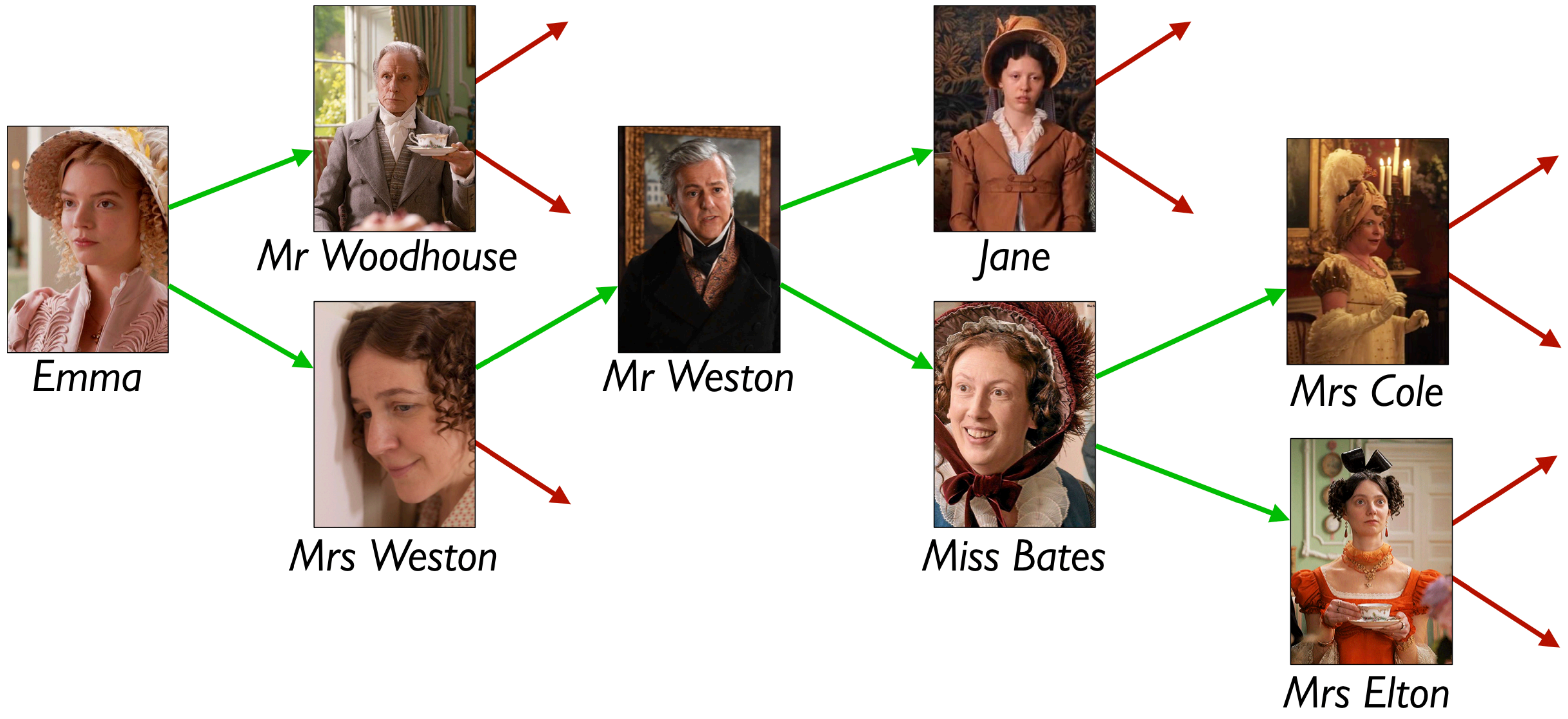
Representing rumor mills



Using a table doesn’t give us any straightforward way to process the rumor mill.

Could we use something *like* a list but representing the relations?

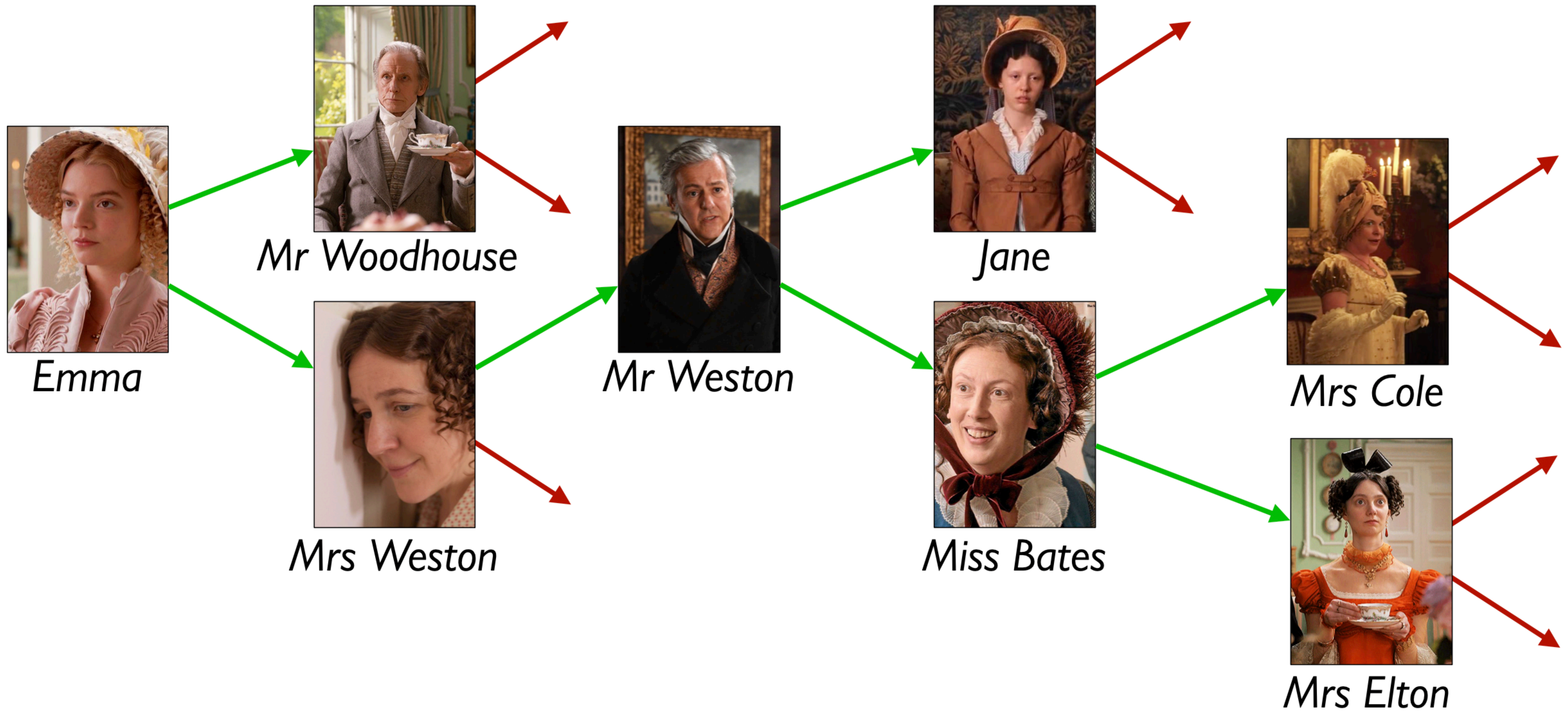
Representing rumor mills



```
data Person:
  | person(name :: String, next1 :: Person, next2 :: Person)
end
```

How about this?

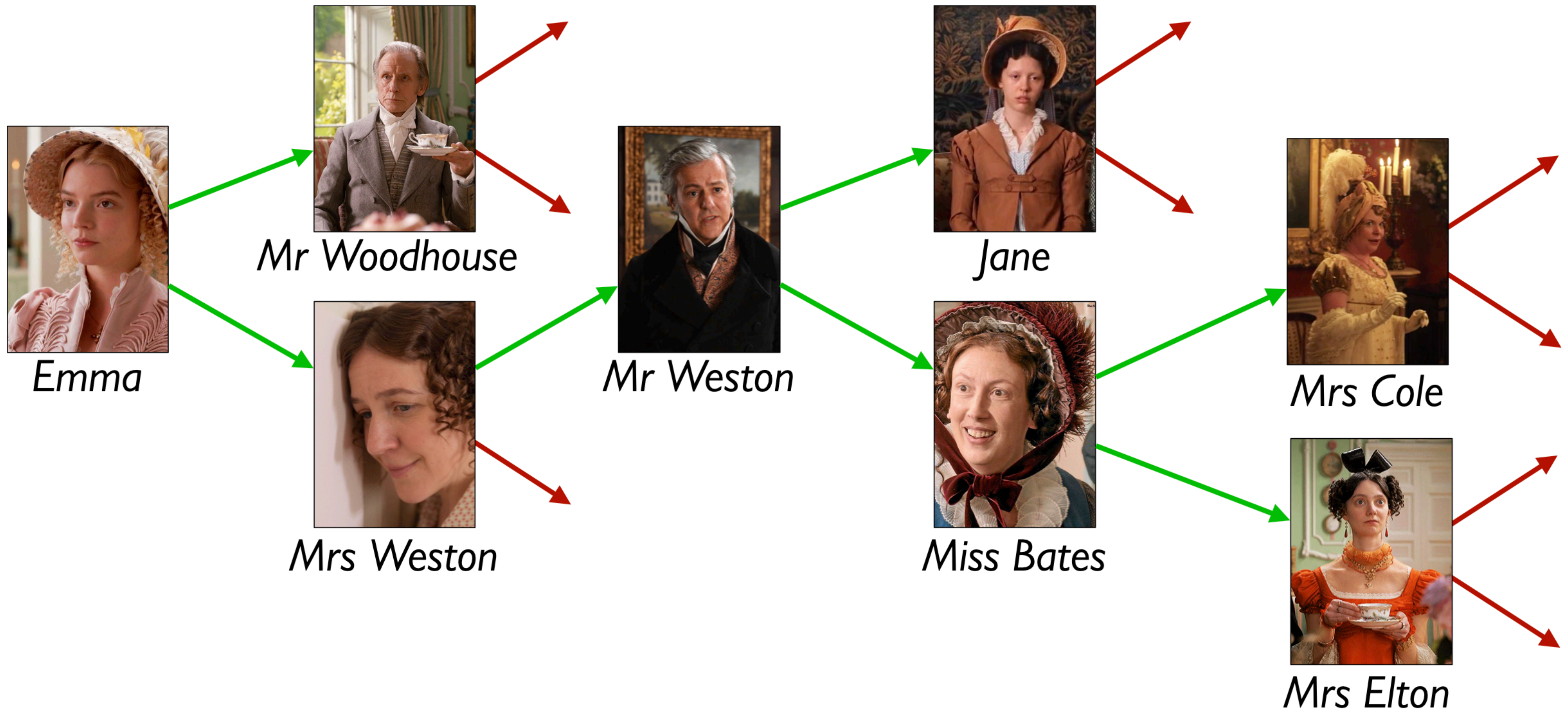
Representing rumor mills



```
data Person:
  | person(name :: String, next1 :: Person, next2 :: Person)
end
```

Some people don't gossip to anyone else – the red arrows above.

Representing rumor mills



```
data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
end
```

How about this?

Example rumor mills

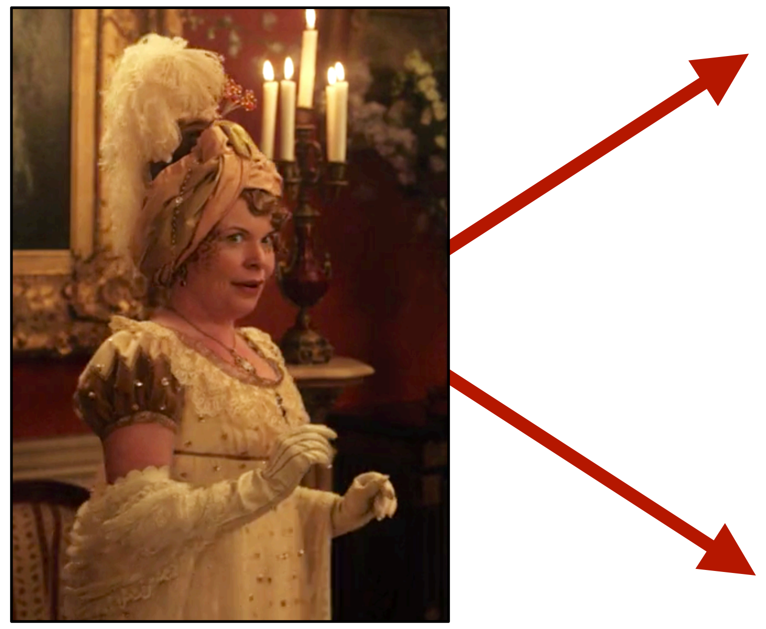
```
data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
end
```

```
no-one
```

Example rumor mills

```
data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
end
```

```
gossip("Mrs Cole", no-one, no-one)
```

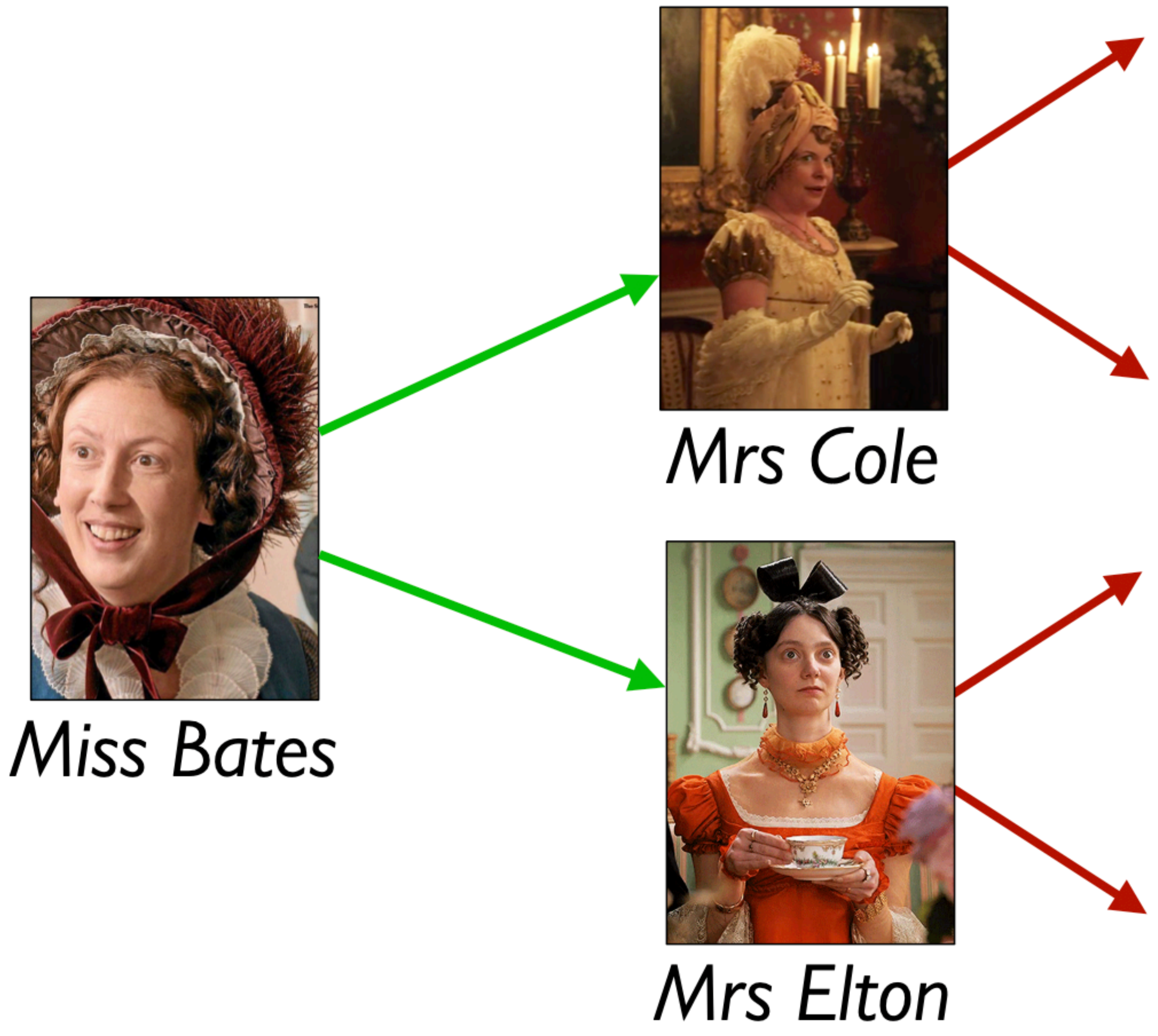


Mrs Cole

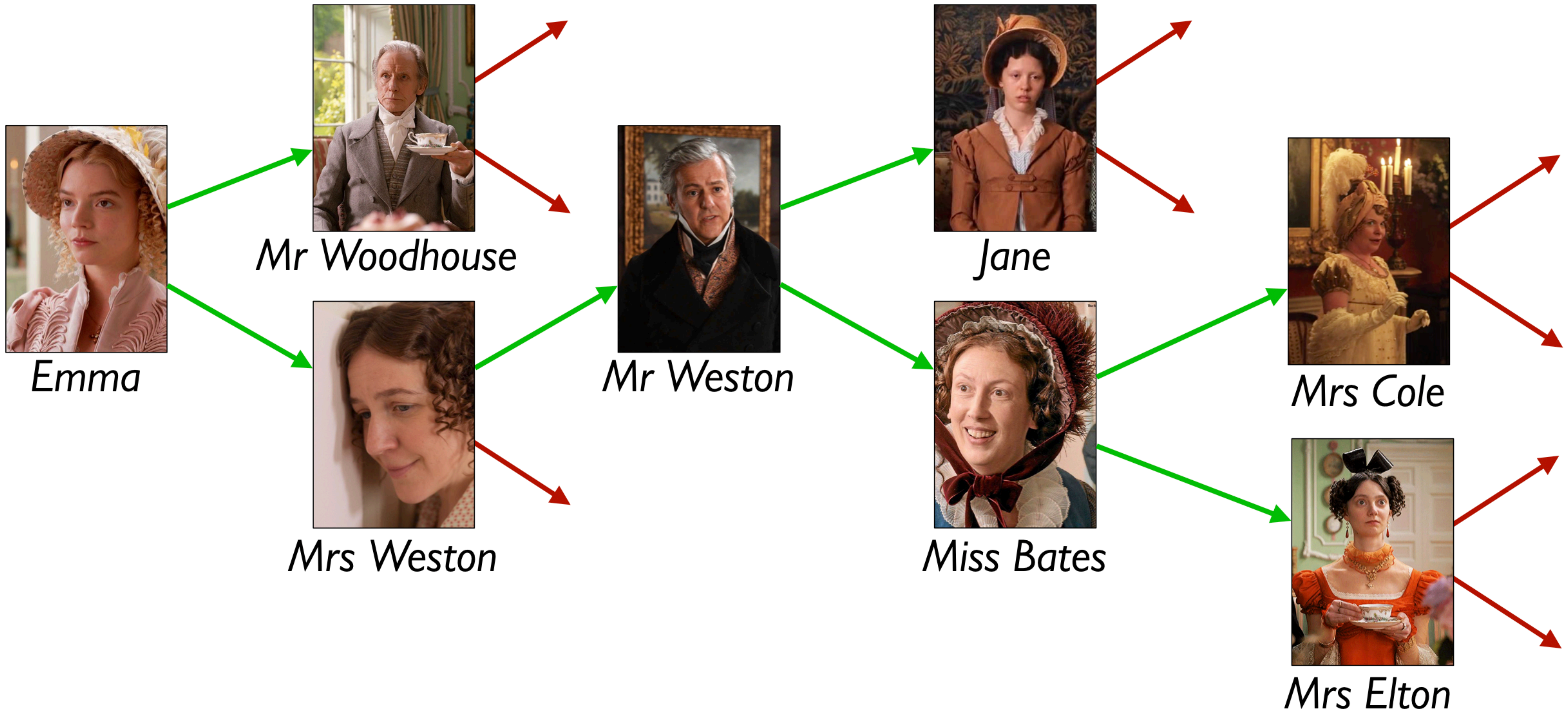
Example rumor mills

```
data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
end
```

```
gossip("Miss Bates",
  gossip("Mrs Cole", no-one, no-one)
  gossip("Mrs Elton", no-one, no-one))
```



```
gossip("Emma",
  gossip("Mr Woodhouse", no-one, no-one),
  gossip("Mrs Weston",
    gossip("Mr Weston",
      gossip("Jane", no-one, no-one),
      gossip("Miss Bates",
        gossip("Mrs Cole", no-one, no-one),
        gossip("Mrs Elton", no-one, no-one))),
    no-one))
```



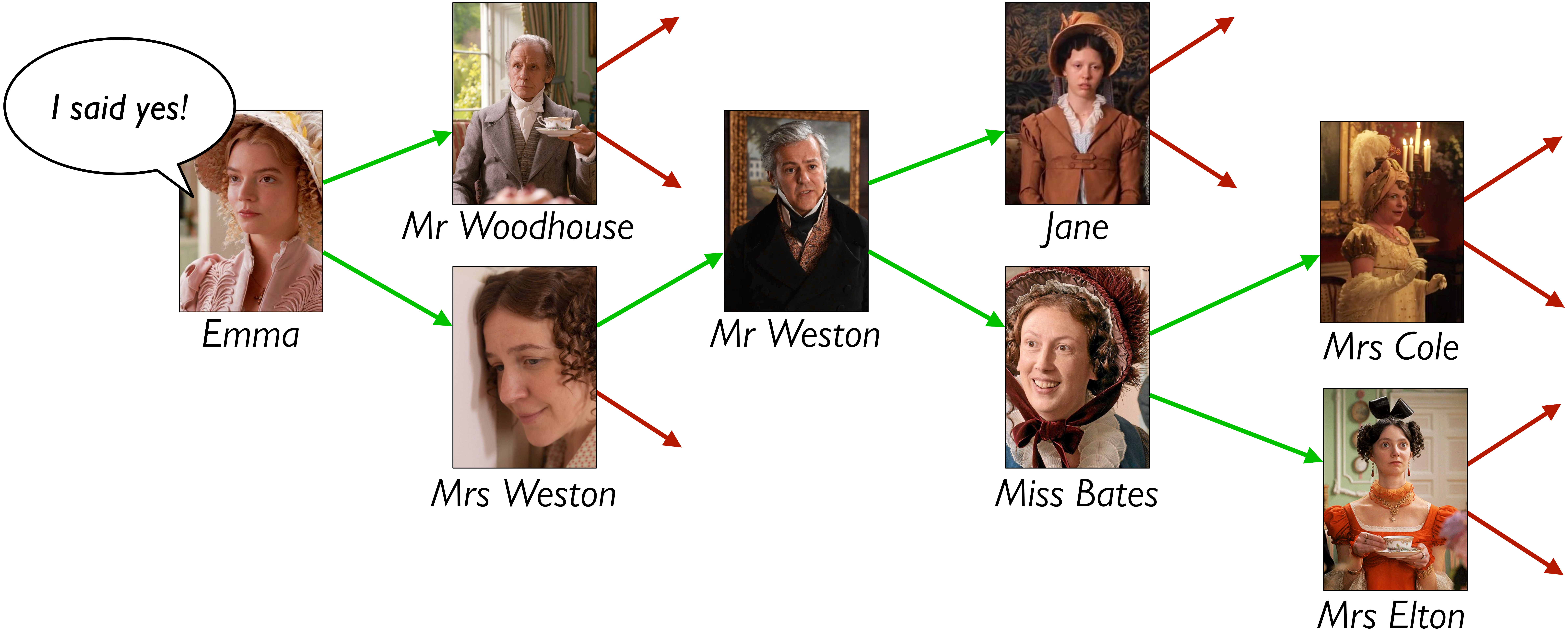
Example using names for parts:

```
MRS-COLE-MILL = gossip("Mrs Cole", no-one, no-one)

MRS-ELTON-MILL = gossip("Mrs Elton", no-one, no-one)

MISS-BATES-MILL = gossip("Miss Bates", MRS-COLE-MILL, MRS-ELTON-MILL)

JANE-MILL = gossip("Jane", no-one, no-one)

MR-WESTON-MILL = gossip("Mr Weston", JANE-MILL, MISS-BATES-MILL)

MRS-WESTON-MILL = gossip("Mrs Weston", MR-WESTON-MILL, no-one)

MR-WOODHOUSE-MILL = gossip("Mr Woodhouse", no-one, no-one)

EMMA-MILL = gossip("Emma", MR-WOODHOUSE-MILL, MRS-WESTON-MILL)
```

A *RumorMill* is a type of structure called a ***tree***.

- Each element in the tree is called a ***node***.
- The first node in the tree is called the ***root***.
- A node with no children is called a *leaf*.

Like a list, a tree is recursive: Every subtree is a tree.



Emma

Mr Woodhouse

Mrs Weston

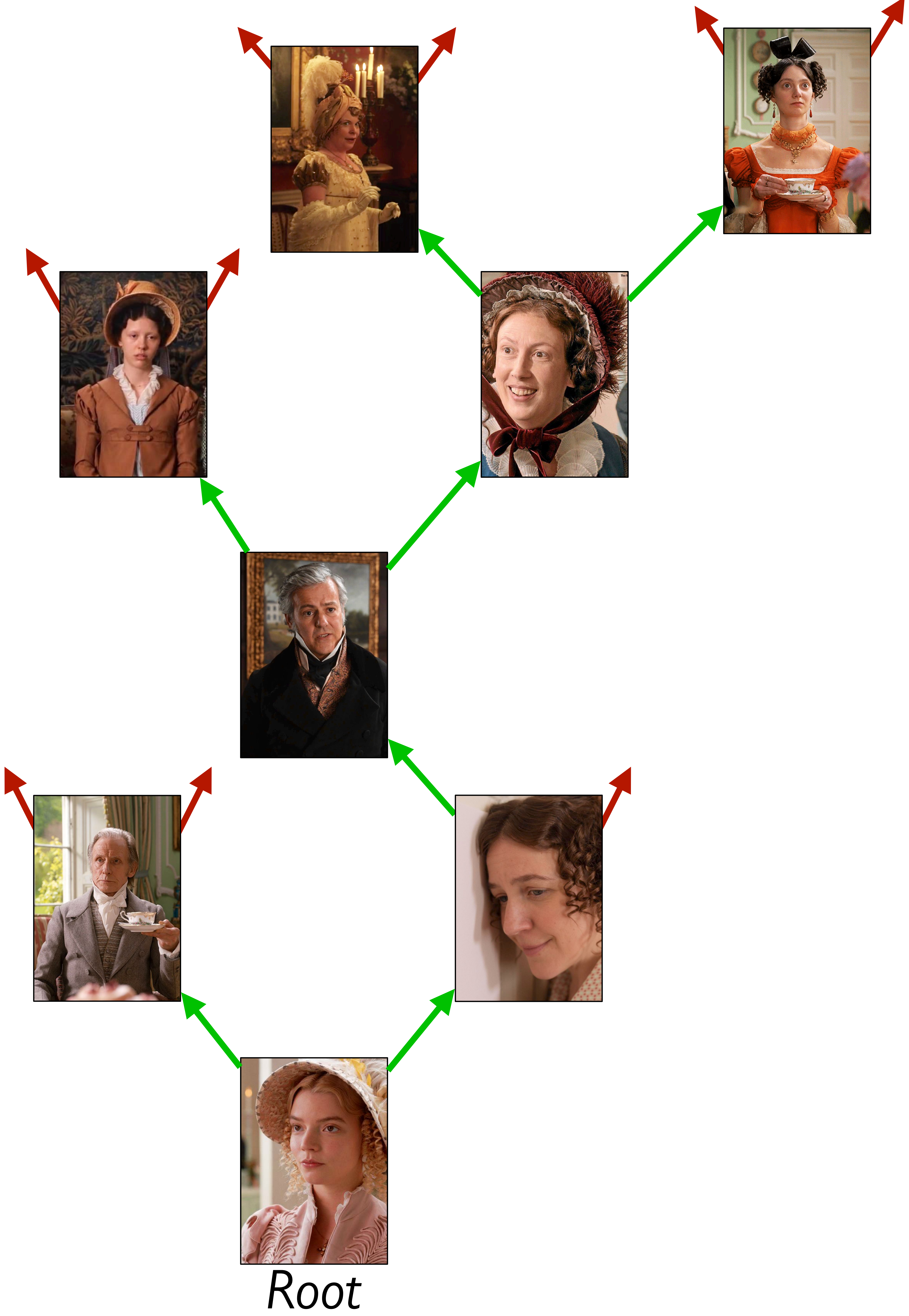
Mr Weston

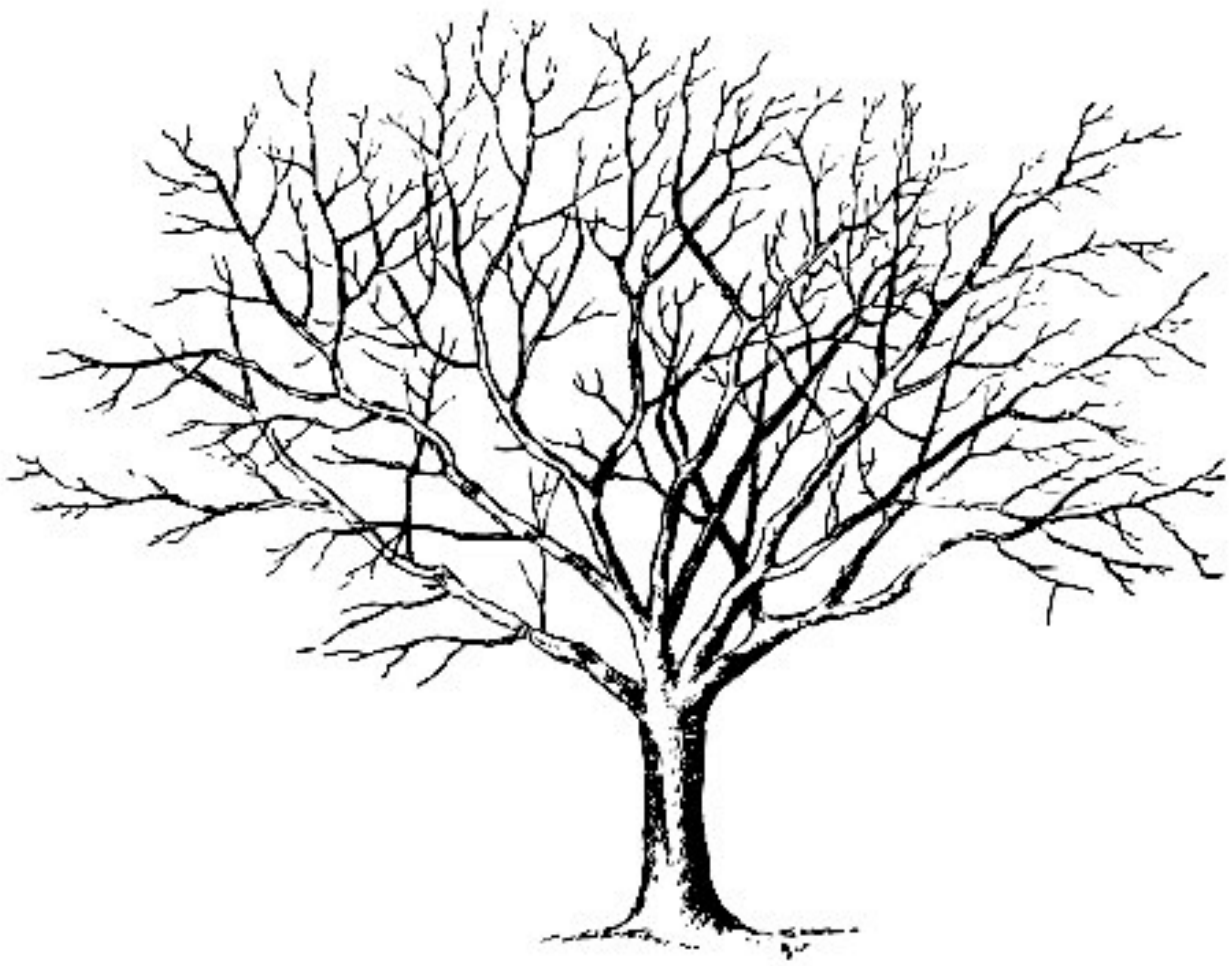
Jane

Miss Bates

Mrs Cole

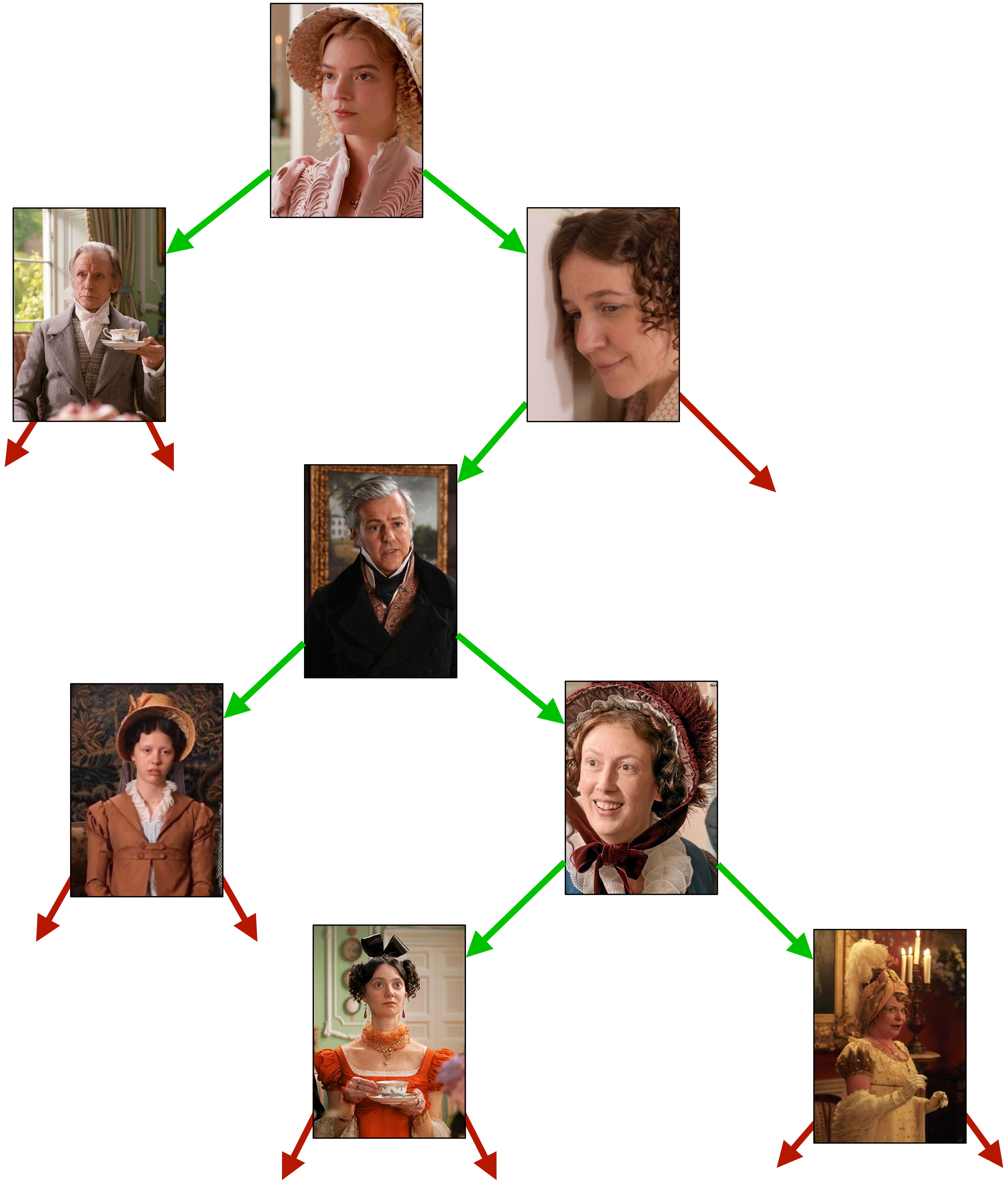
Mrs Elton

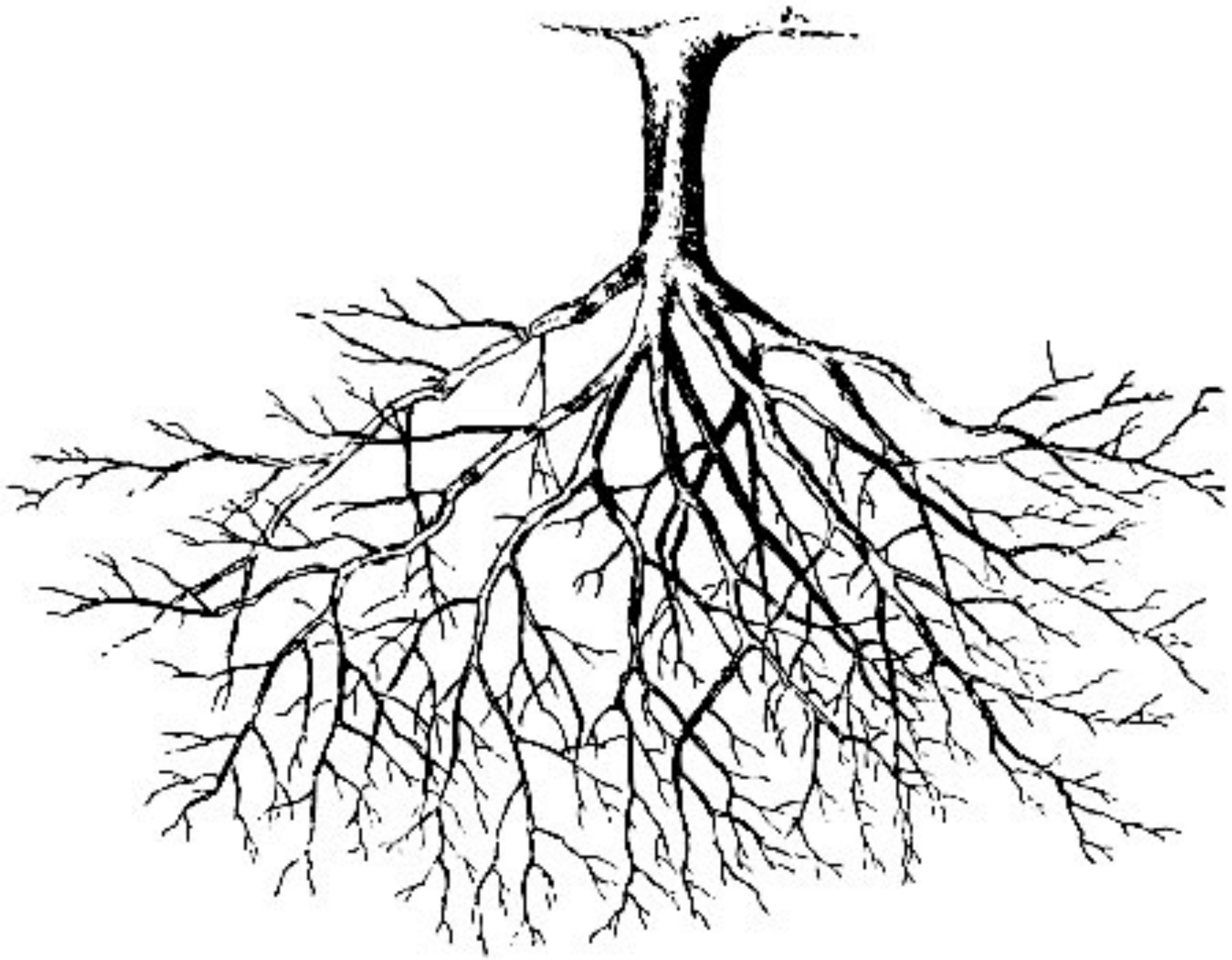




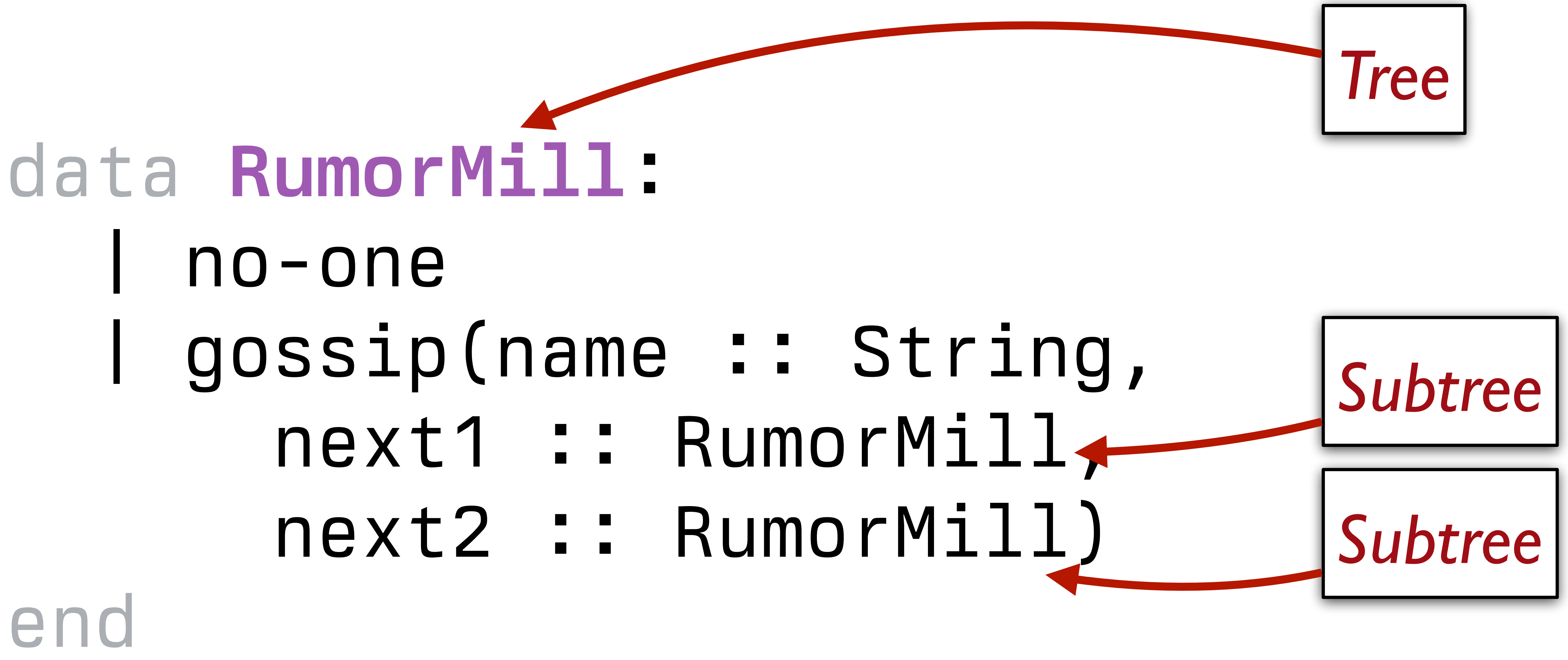
Draw it vertically and you can see it’s a tree!

Root





Computer scientists are weird.



```
data RumorMill:
  | no-one
  | gossip(name :: String,
      next1 :: RumorMill,
      next2 :: RumorMill)
end
```

Tree

Subtree

Subtree

Programming with rumors

```
data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
end
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Programming with rumors

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data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
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Self-reference × 2

Programming with rumors

```
data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
end
```

Self-reference × 2

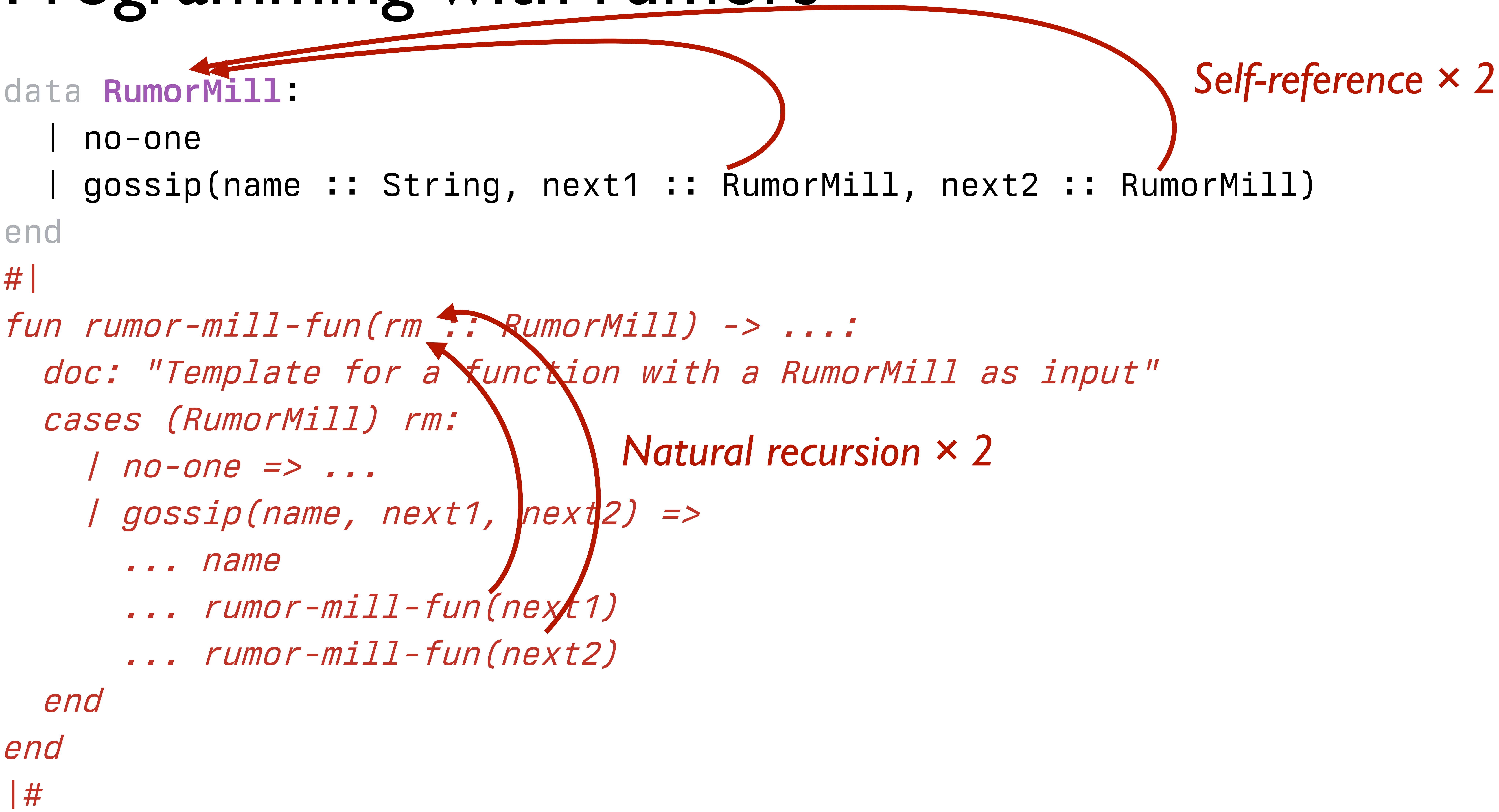
For each element, there’s not just one “next” element; there are two!

Programming with rumors

Self-reference × 2

```
data RumorMill:
  | no-one
  | gossip(name :: String, next1 :: RumorMill, next2 :: RumorMill)
end
#|
fun rumor-mill-fun(rm :: RumorMill) -> ...:
  doc: "Template for a function with a RumorMill as input"
  cases (RumorMill) rm:
    | no-one => ...
    | gossip(name, next1, next2) =>
      ... name
      ... rumor-mill-fun(next1)
      ... rumor-mill-fun(next2)
  end
end
|#
```

Programming with rumors



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#|
fun rumor-mill-fun(rm :: RumorMill) -> ...:
  doc: "Template for a function with a RumorMill as input"
  cases (RumorMill) rm:
    | no-one => ...
    | gossip(name, next1, next2) =>
      ... name
      ... rumor-mill-fun(next1)
      ... rumor-mill-fun(next2)
  end
end
|#
```

Self-reference × 2

Natural recursion × 2

Starter file:

`tinyurl.com/101-2024-02-15-starter`

Rumor program examples

Design the function **`is-informed`** that takes a person’s name and a rumor mill and determines whether the person is part of the rumor mill.

Rumor program examples

Design the function **`gossip-length`** that takes a rumor mill and determines the length of the longest sequence of people transmitting the rumor.

Rumor program examples

Design the function **`add-gossip`** that takes a rumor mill and two names – one new and one old – and adds the new person to the rumor mill, receiving rumors from the old person. (You can assume the old person does not already have two next persons!)

Solutions:

`tinyurl.com/101-2024-02-15`

Acknowledgments

This lecture incorporates material from:

Jane Austen, *Emma*

Tom Ellman, Vassar College

Marc Smith, Vassar College