

EE542

Lecture 22: Large Language Model Part 1

Internet and Cloud Computer

Young Cho

Department of Electrical Engineering

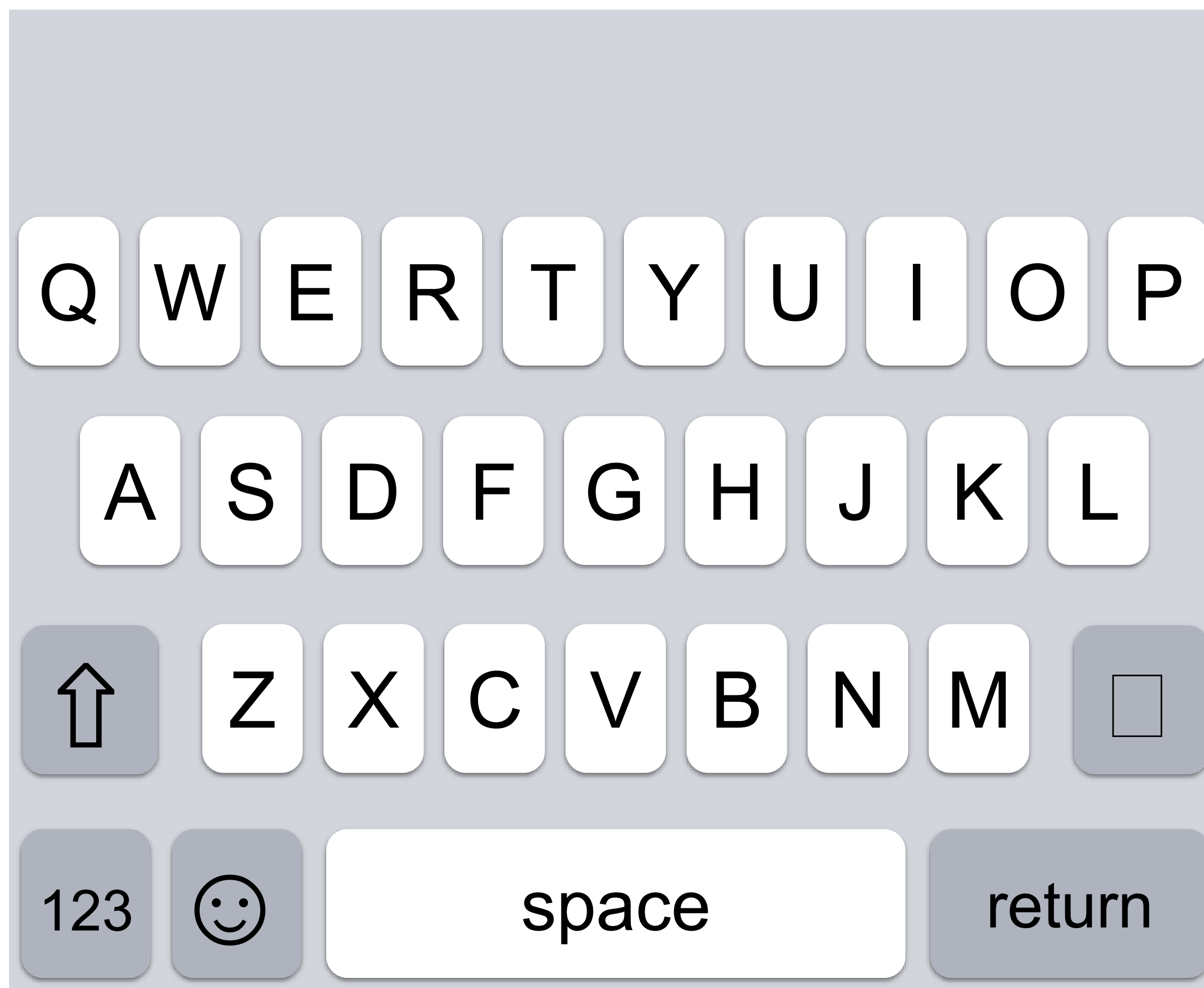
University of Southern California

Final Project Progress Demos

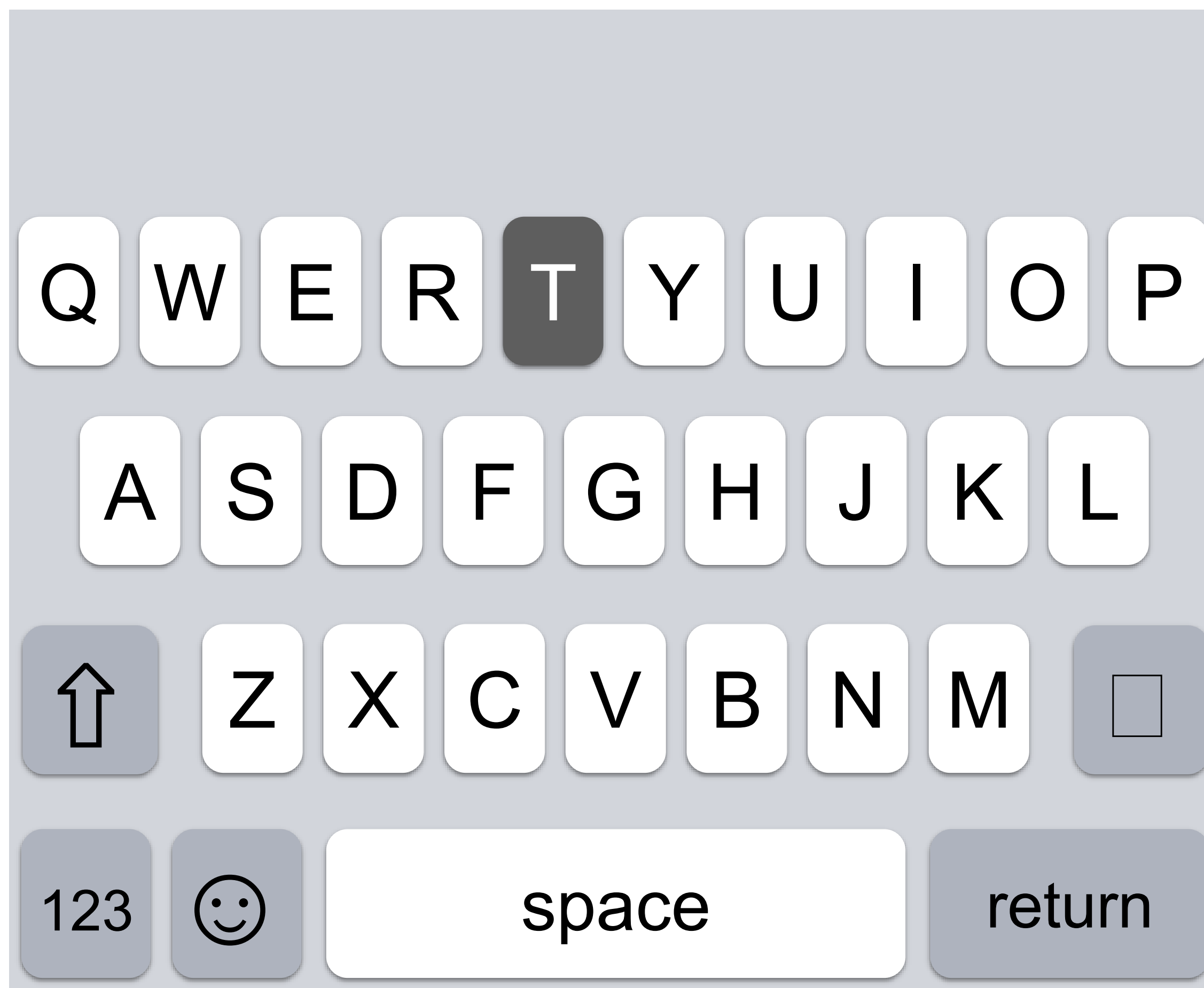
- + Due Every Mondays 11:59 PM in Nov
- + Must Demonstrate Working System
- + Incremental Functions Added with Corresponding Results
- + System Must Work Every Demo
- + Every Team Member Must Contribute in Describing the Demo

Final Project Progress Presentations

- + November 6, 8, 13
 - + Large Language Model and Word Embeddings
- + November 15
 - + Final Regular Lecture (Mandatory Attendance)
- + November 18, 20
 - + Submit Practice Presentation Slides (Blackboard on Nov 18 at 11:59PM)
 - + Go over the Practice Presentations (Mandatory Attendance)
- + November 25, 27, 29
 - + Submit Final Project Progress Presentation Slides (Blackboard on Nov 25 at 11:59PM)
 - + Final Project Progress Presentation (Mandatory Attendance)
 - + 7 teams on 27th and 6 teams on 29th
- + December 13
 - + Final Project Demo Presentation Video



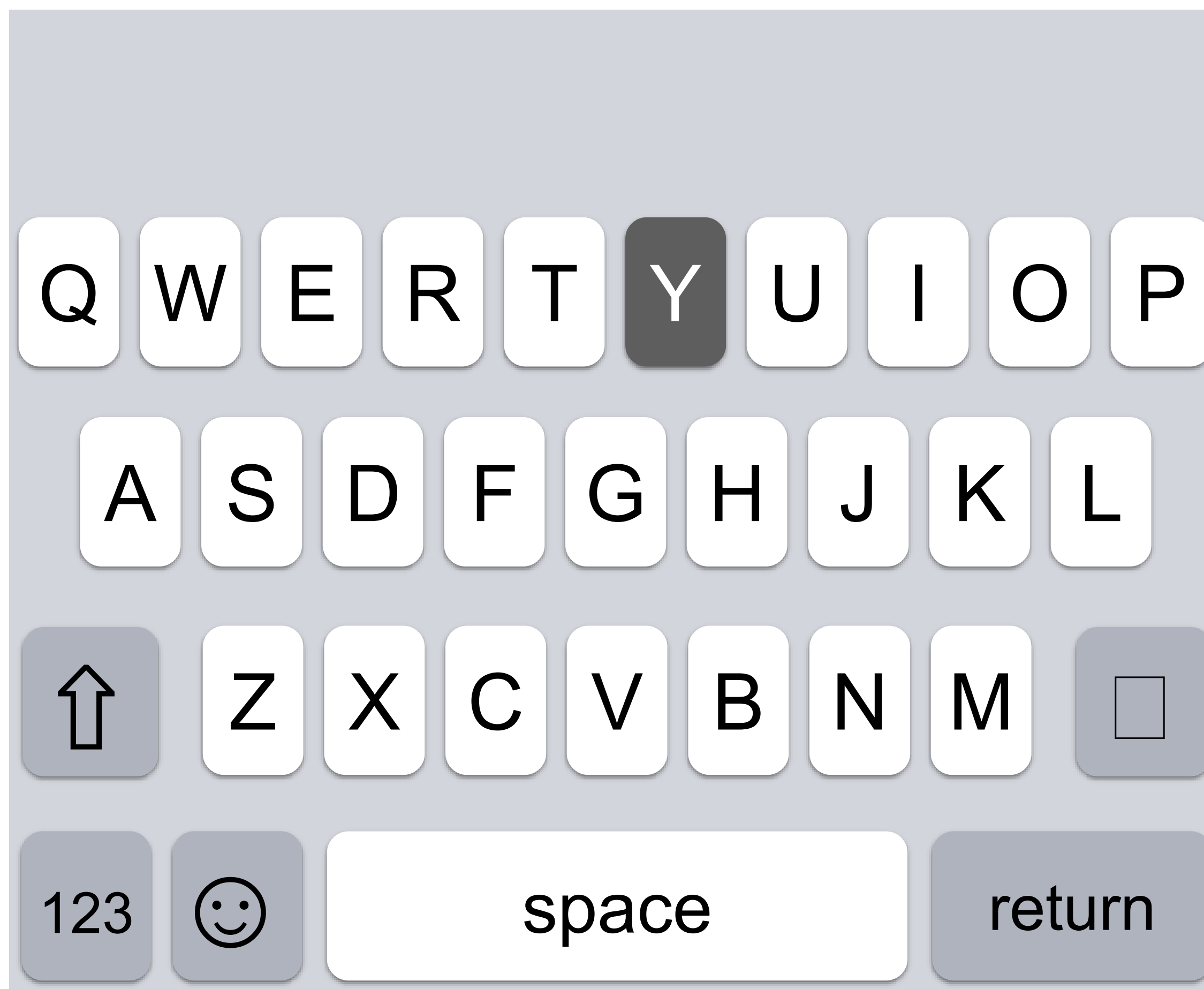
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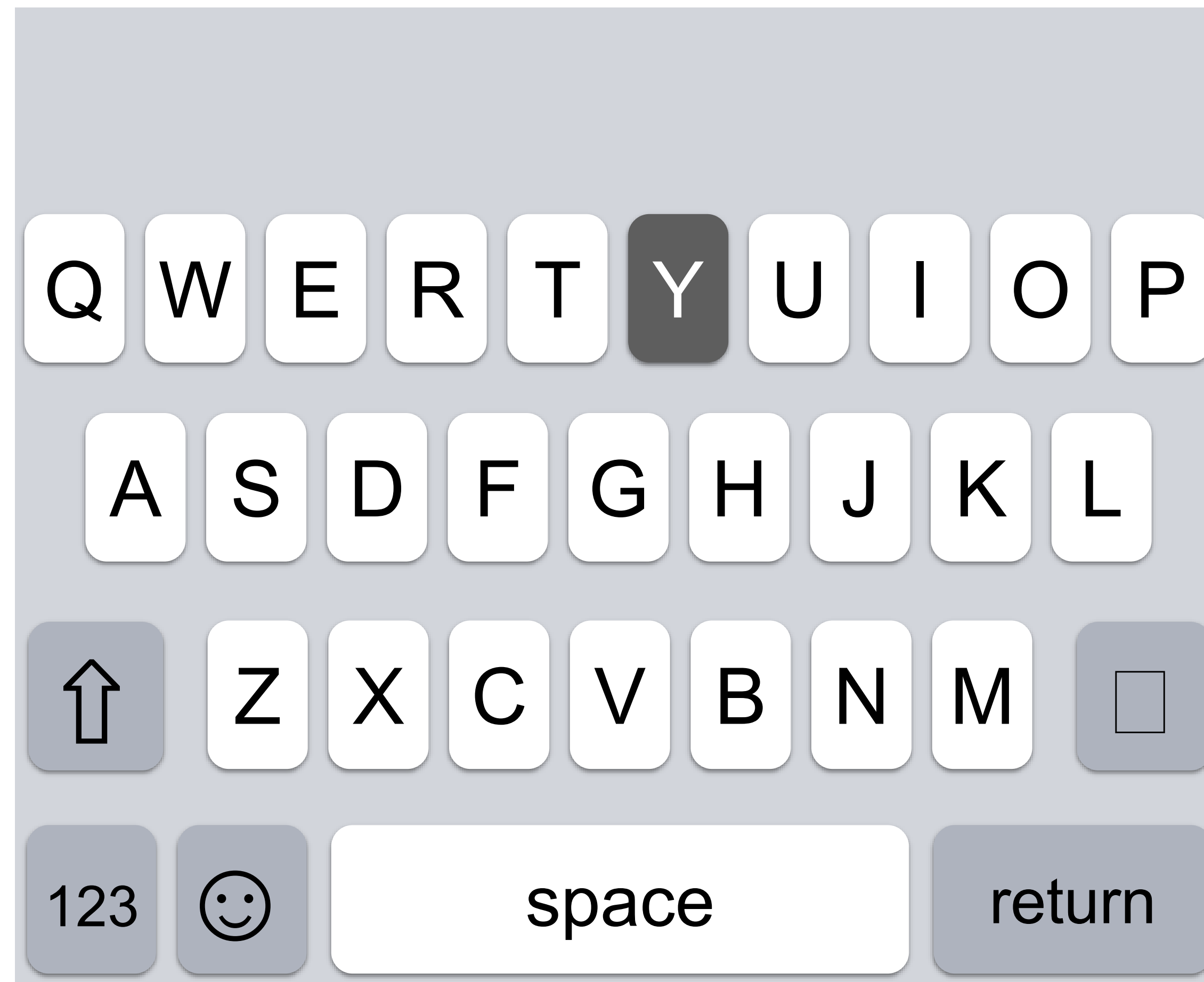
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tye

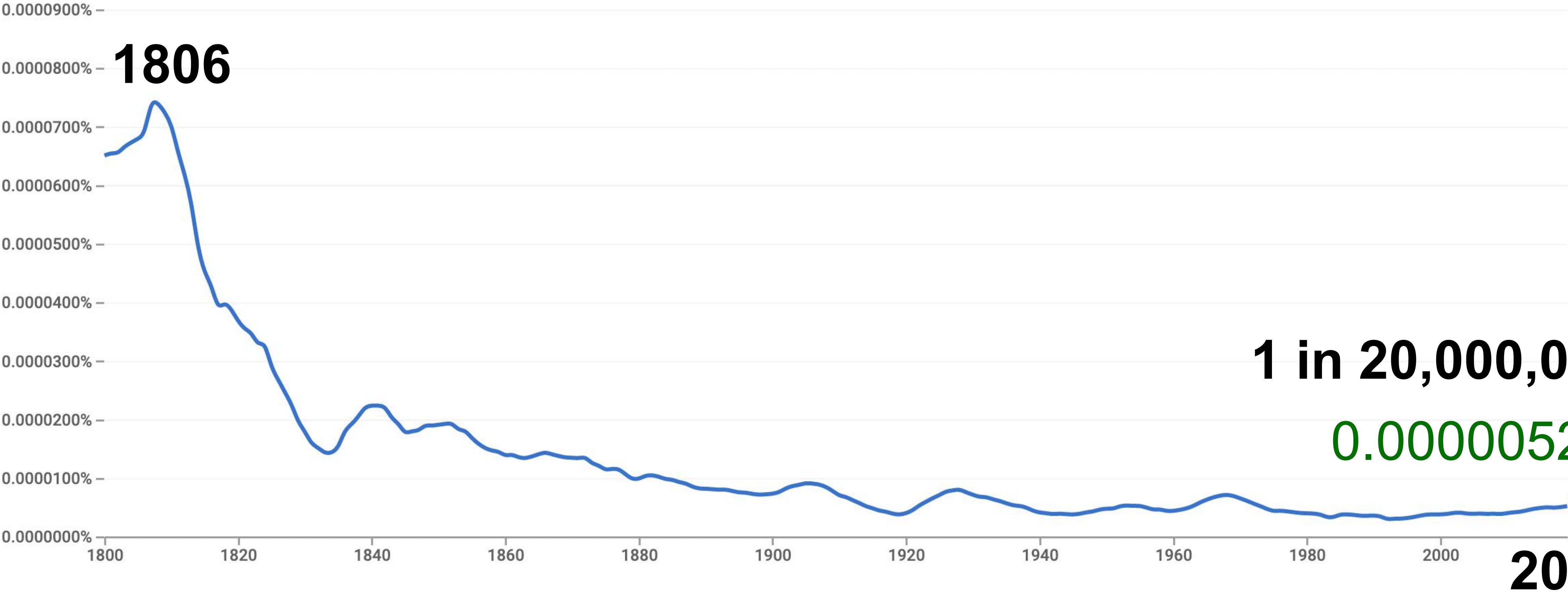
type

tycoon

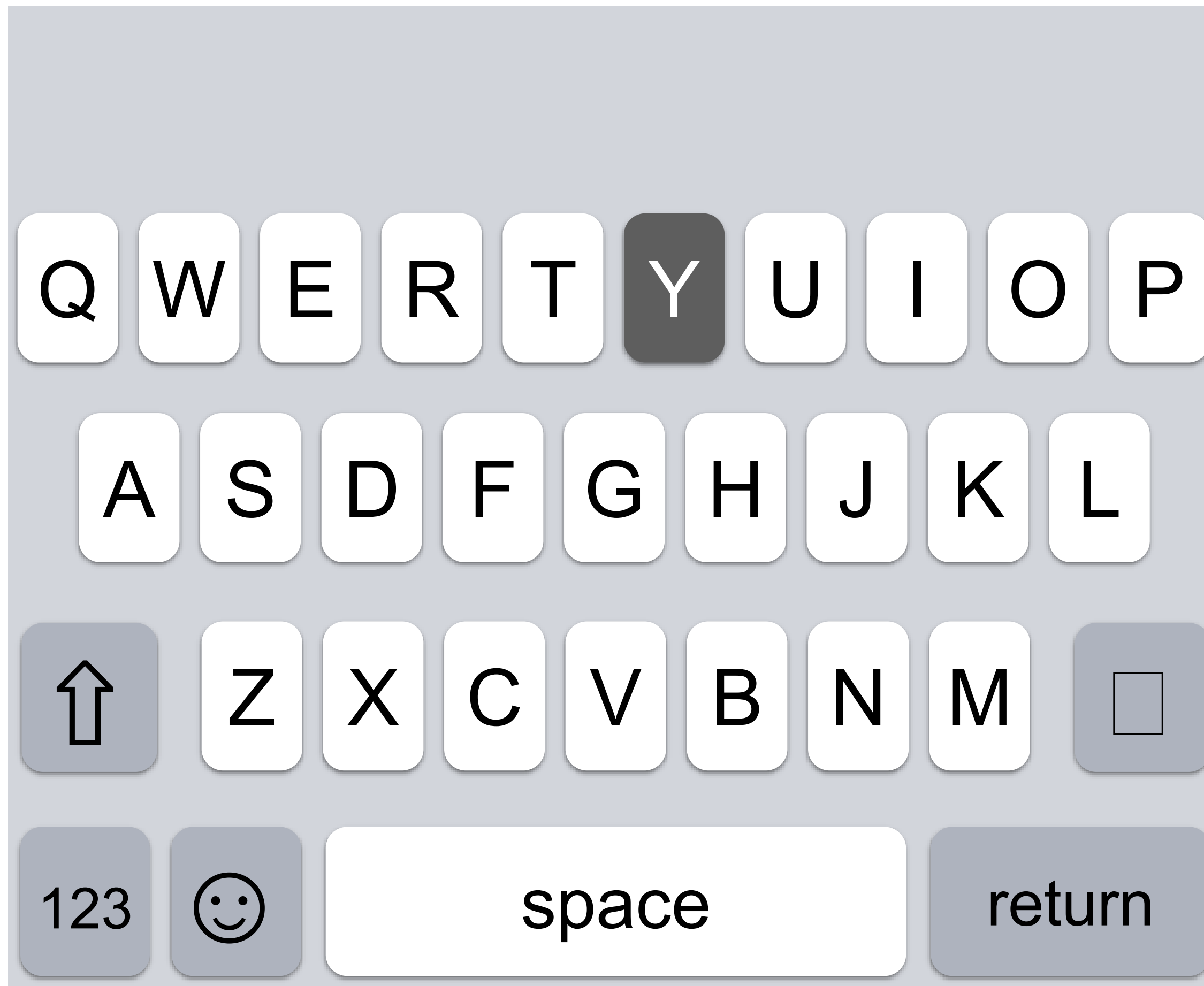
typhoon

tympanic

typography



ty|



0.0000052224% tye

0.0148257168% type

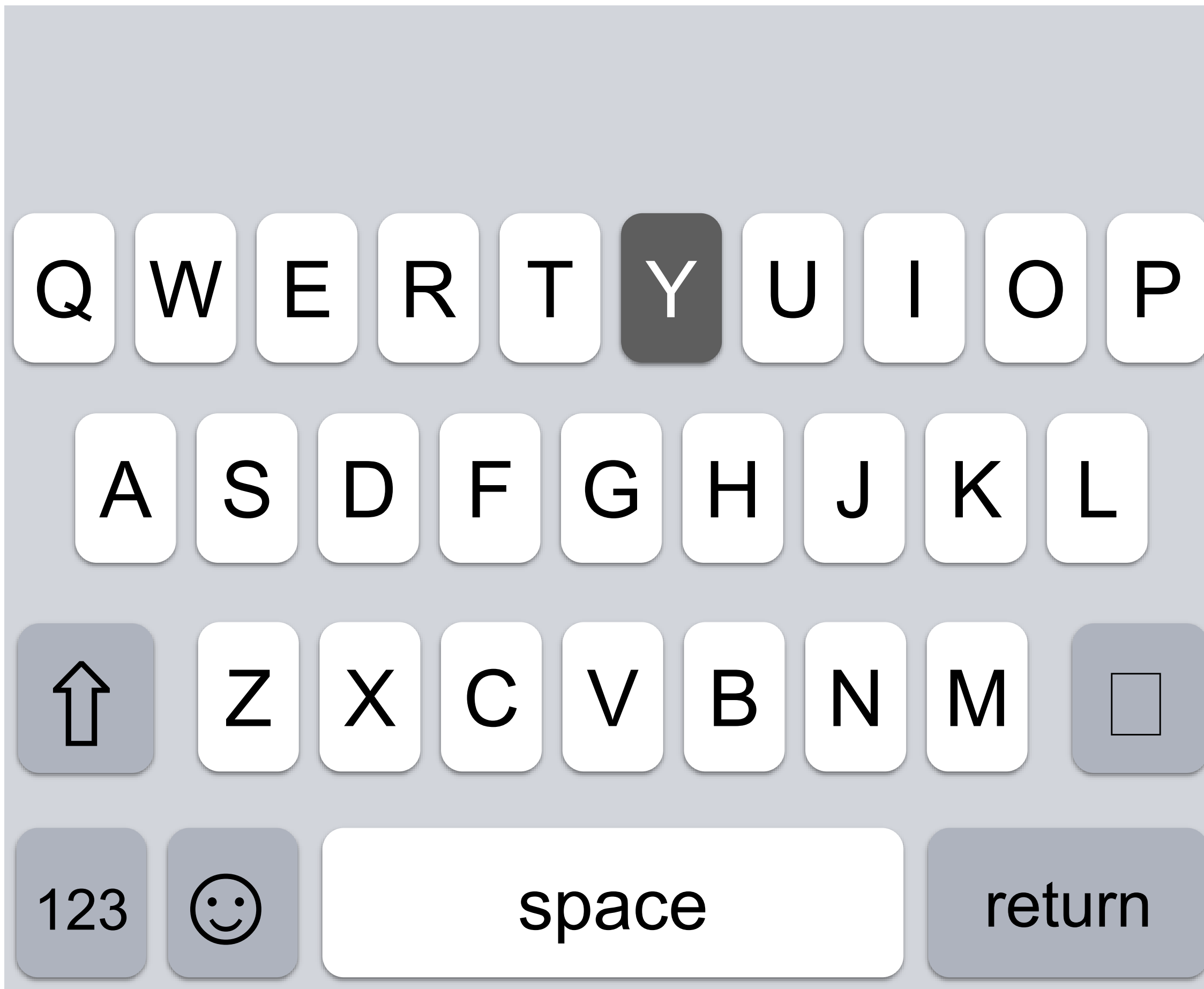
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0.0000396270% typhoon

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0.0000397285% typography

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0.0148257168% type

0.0000606981% tympanic

0.0000397285% typography

0.0000396270% typhoon

0.0000374782% tycoon

0.0000052224% tye

🔍 how



🔍 how



🔍 how many ounces in a cup

🔍 how many ounces in a gallon

🔍 how long is the new minions movie

🔍 how long does covid last

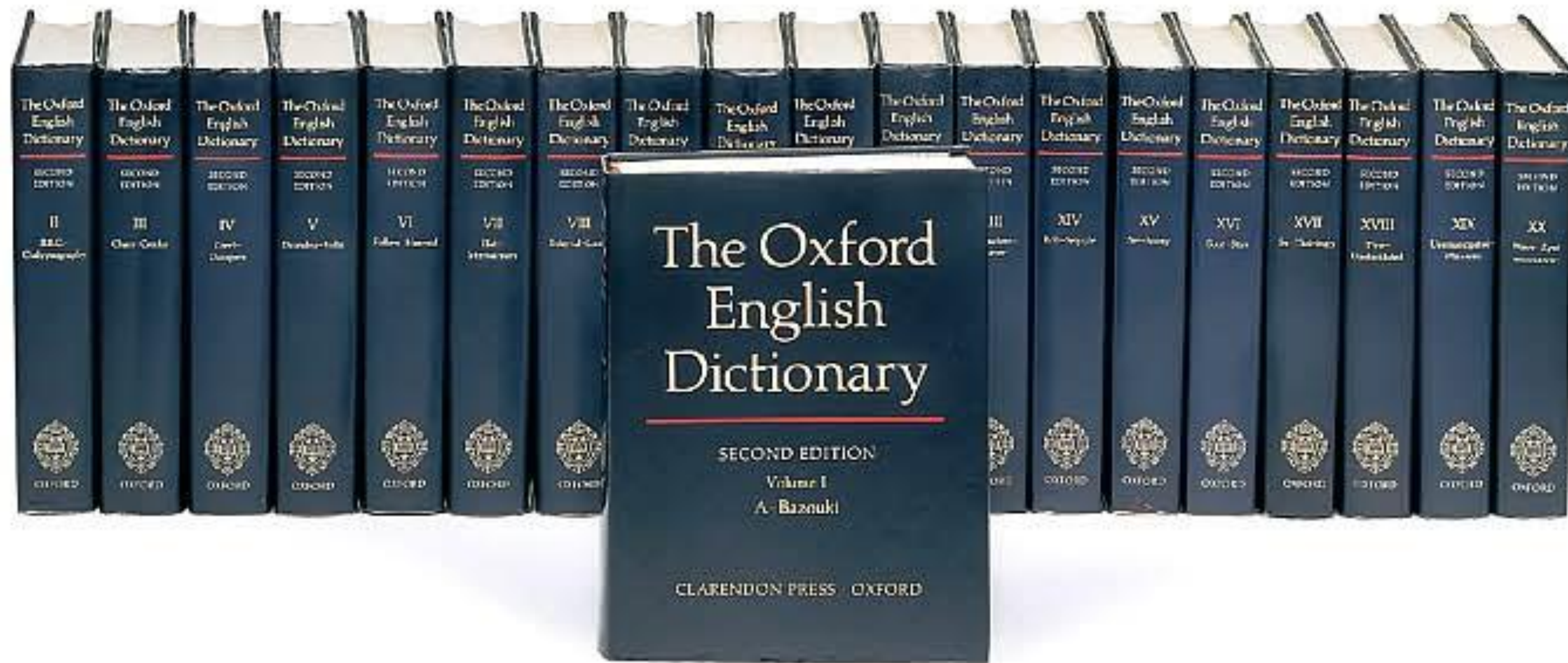
🔍 how did elvis die

🔍 how long to boil eggs

🔍 how to tie a tie

She just won the 2032 election

100,000 words



word word word word word word word word word word .

100,000 100,000 100,000 100,000 100,000 100,000 100,000 100,000 100,000 100,000

10^{50}

Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all if her hair was still red

~~Early one morning the sun was shining I was laying in bed~~

~~Wondering if she had changed at all if her hair was still red~~

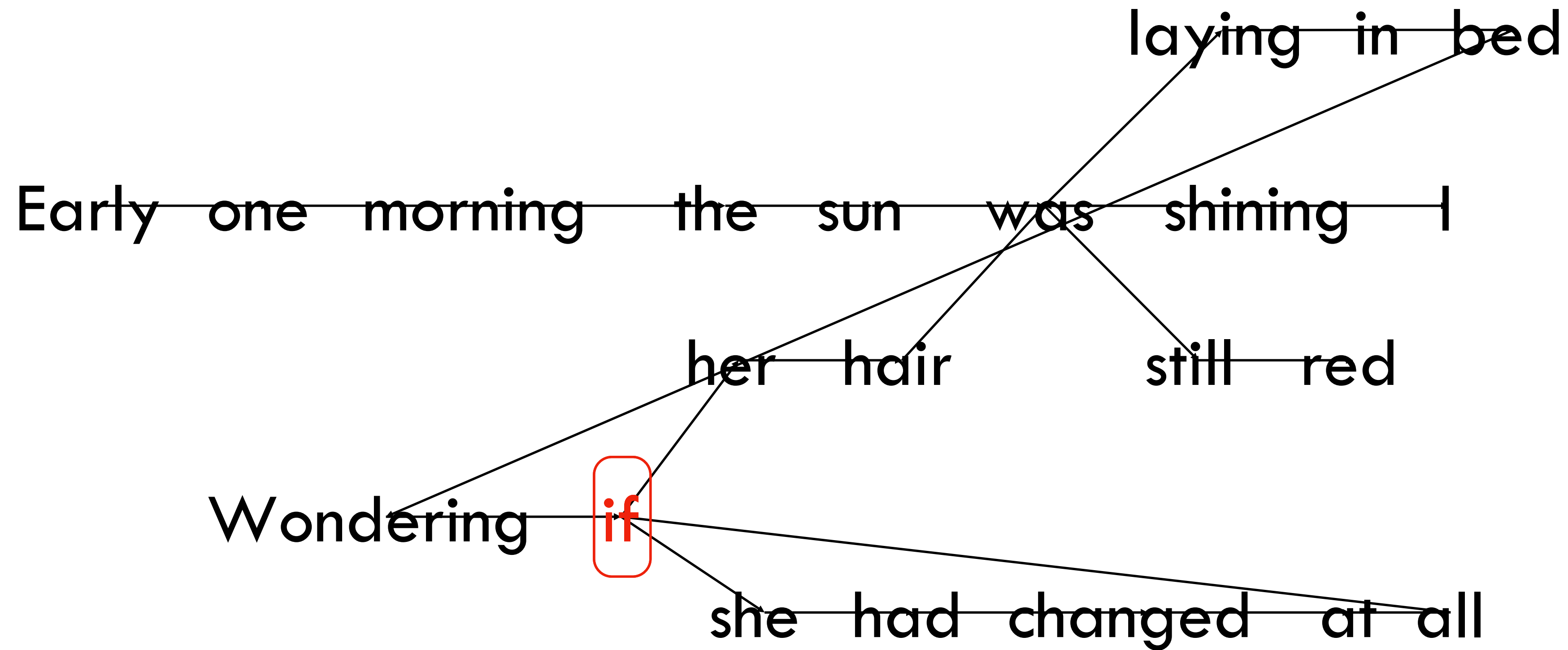
Early one morning the sun **was** shining I **was** laying in bed

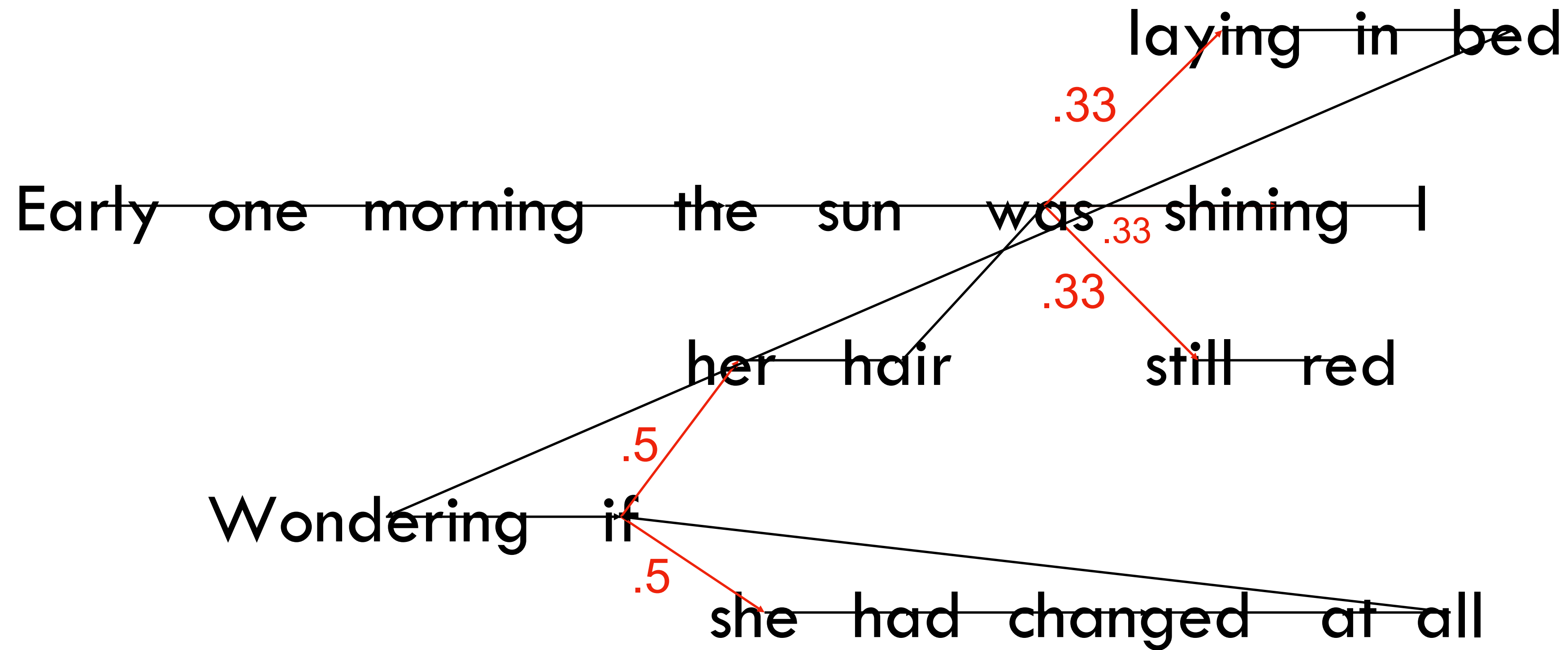
Wondering if she had changed at all if her hair **was** still red

Early one morning the sun **was** shining I
laying in bed
her hair still red
Wondering if she had changed at all if

Early one morning the sun was shining I
laying in bed
her hair still red
Wondering if she had changed at all if

```
graph TD; A[Early one morning the sun was shining I] --- B[laying in bed]; A --- C[her hair]; A --- D[still red]; A --- E[Wondering if she had changed at all if];
```





Language Model

Language Models

- + A Probabilistic Model
 - + Assigns a probability in a sequence of words
 - + $p[\text{word1}, \text{word2}, \text{word3}, \dots, \text{wordN}]$
 - + May have understanding of grammar or NOT

Sentence: “the cat sat on the mat”

$$\begin{aligned} P(\text{the cat sat on the mat}) = & P(\text{the}) * P(\text{cat}|\text{the}) * P(\text{sat}|\text{the cat}) \\ & * P(\text{on}|\text{the cat sat}) * P(\text{the}|\text{the cat sat on}) \\ & * P(\text{mat}|\text{the cat sat on the}) \end{aligned}$$

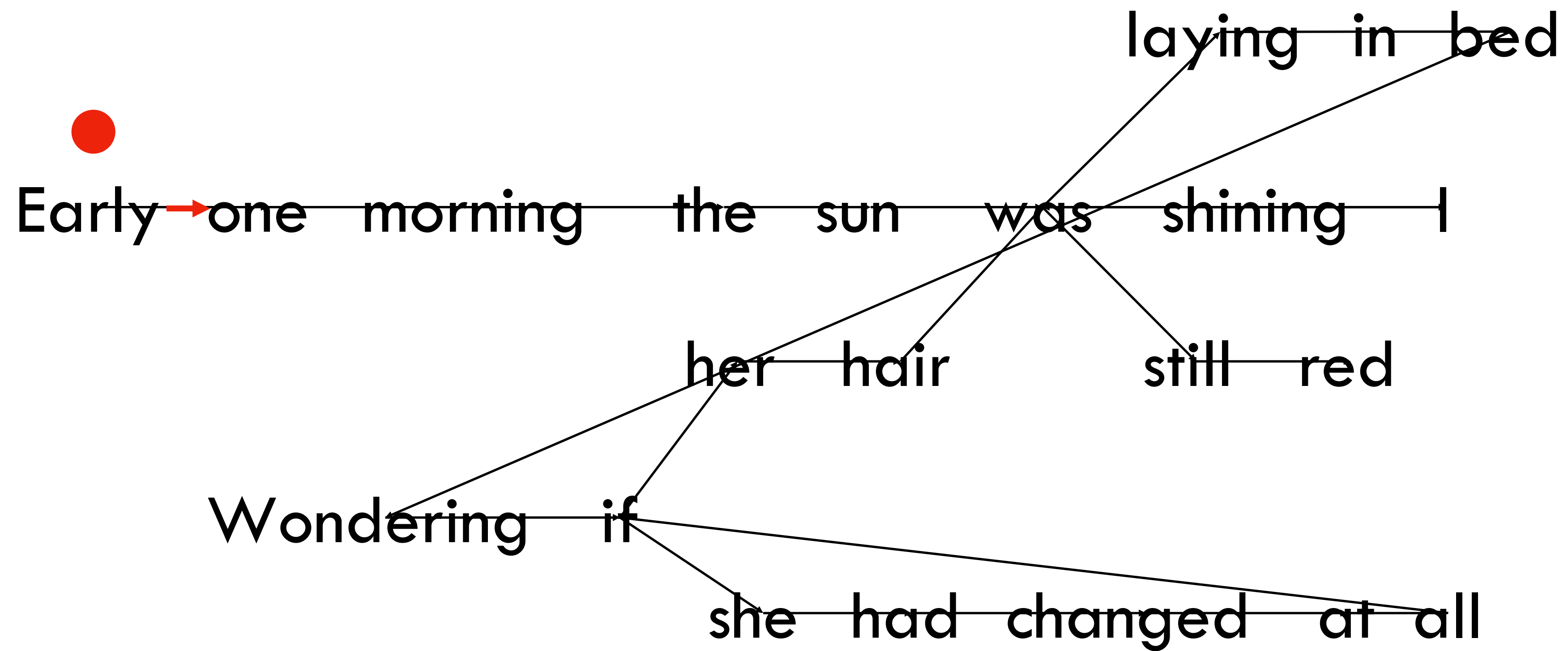
Implicit order



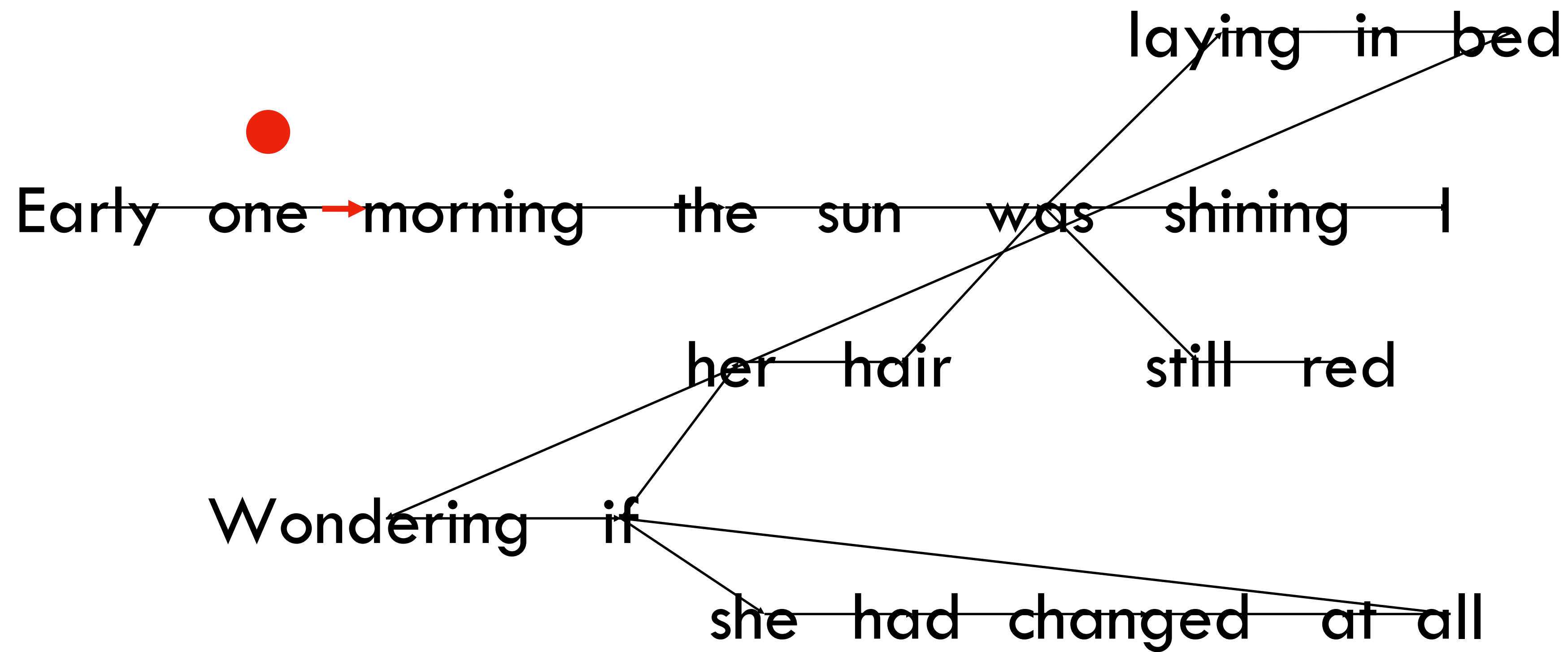
Early one morning the sun was shining I
laying in bed
her hair still red
Wondering if
she had changed at all

```
graph TD; A[Early one morning the sun was shining I] --- B[laying in bed]; A --- C[her hair]; A --- D[still red]; C --- E[Wondering if]; E --- F[she had changed at all];
```

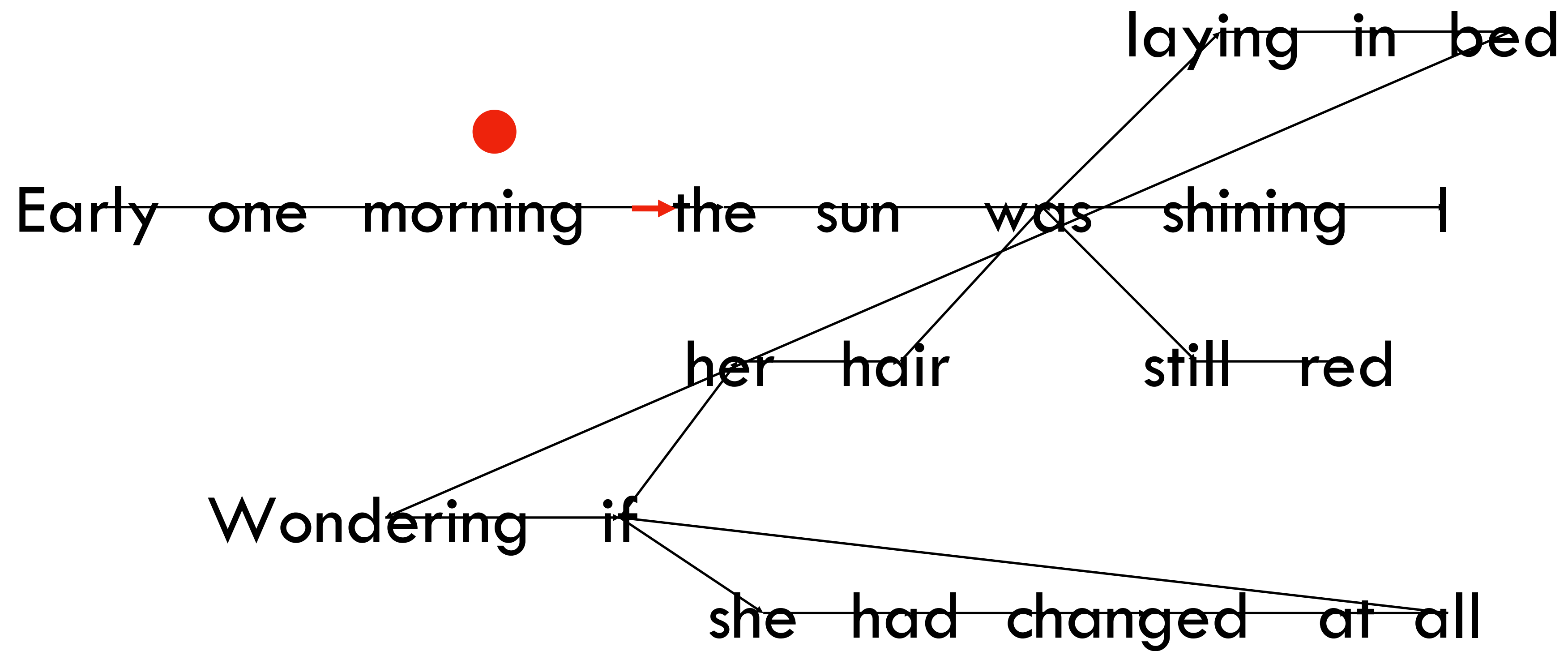
Early



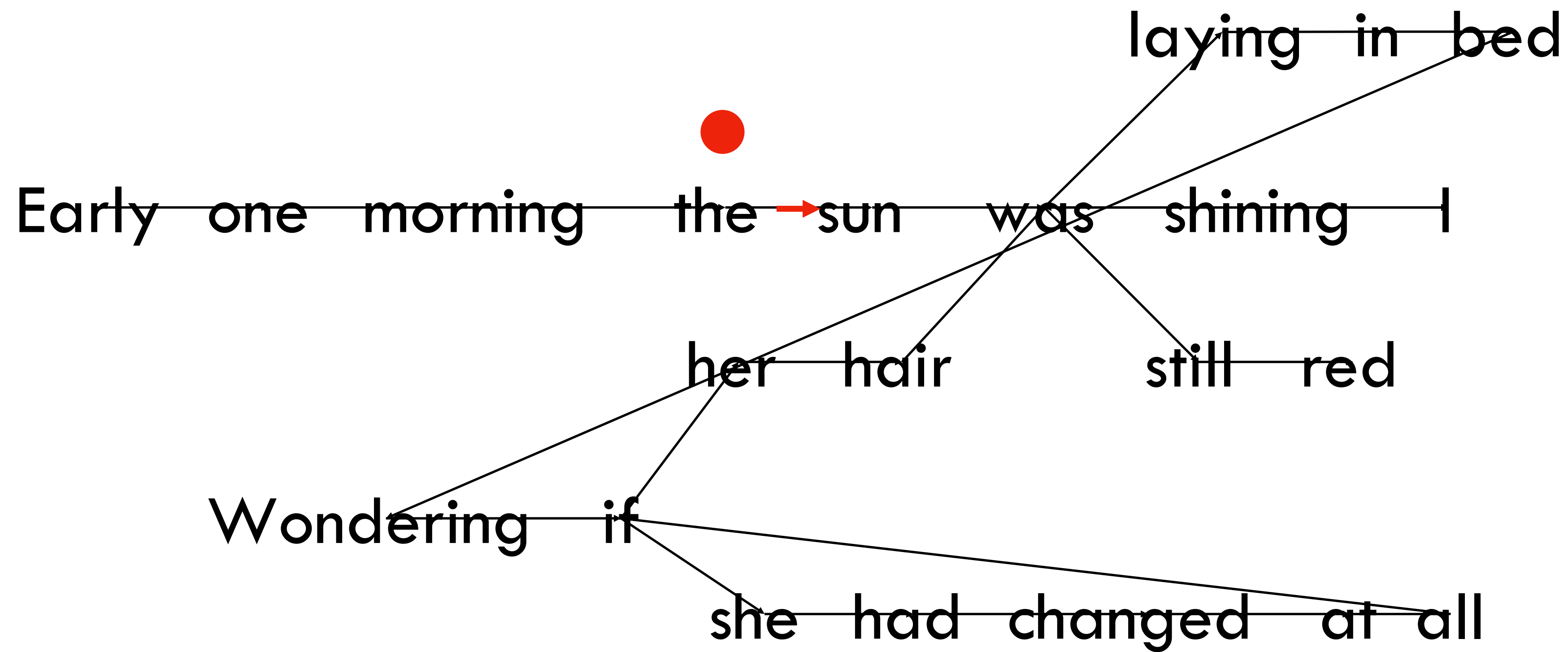
Early one



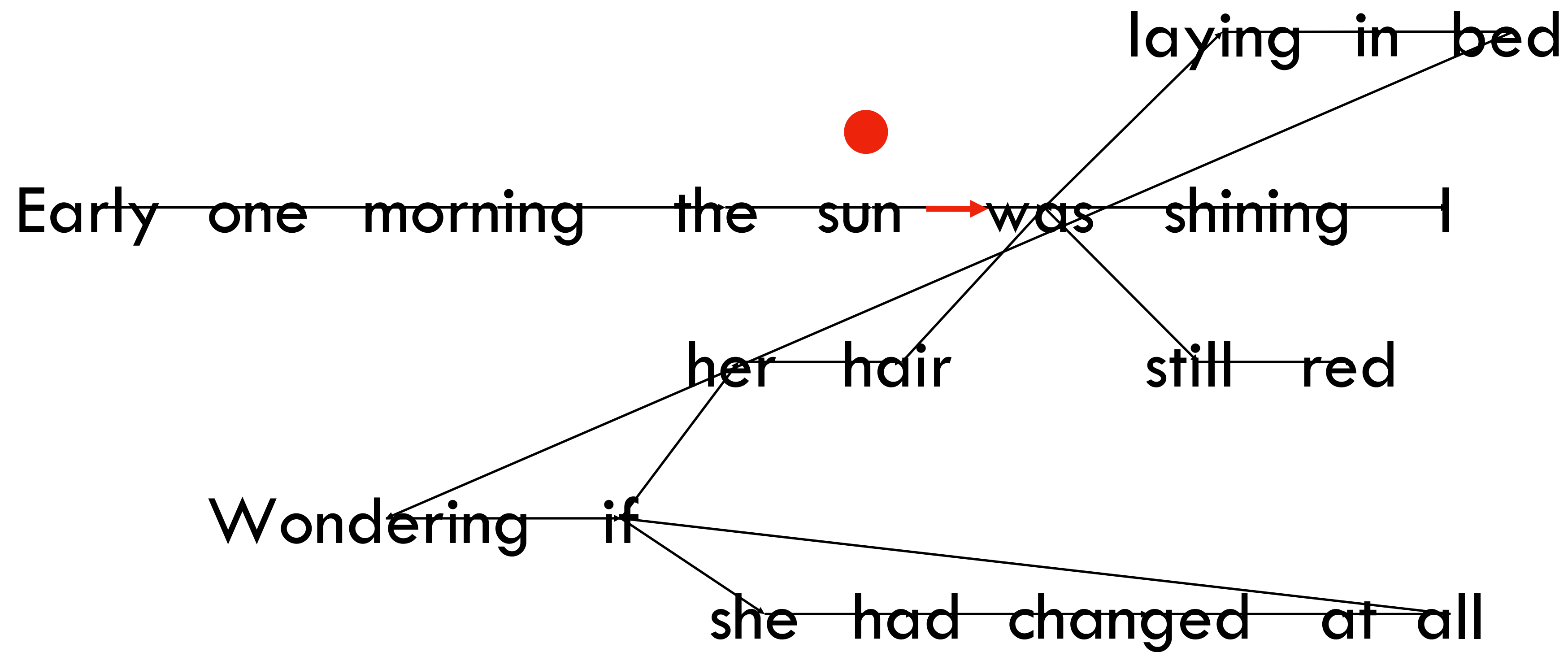
Early one morning



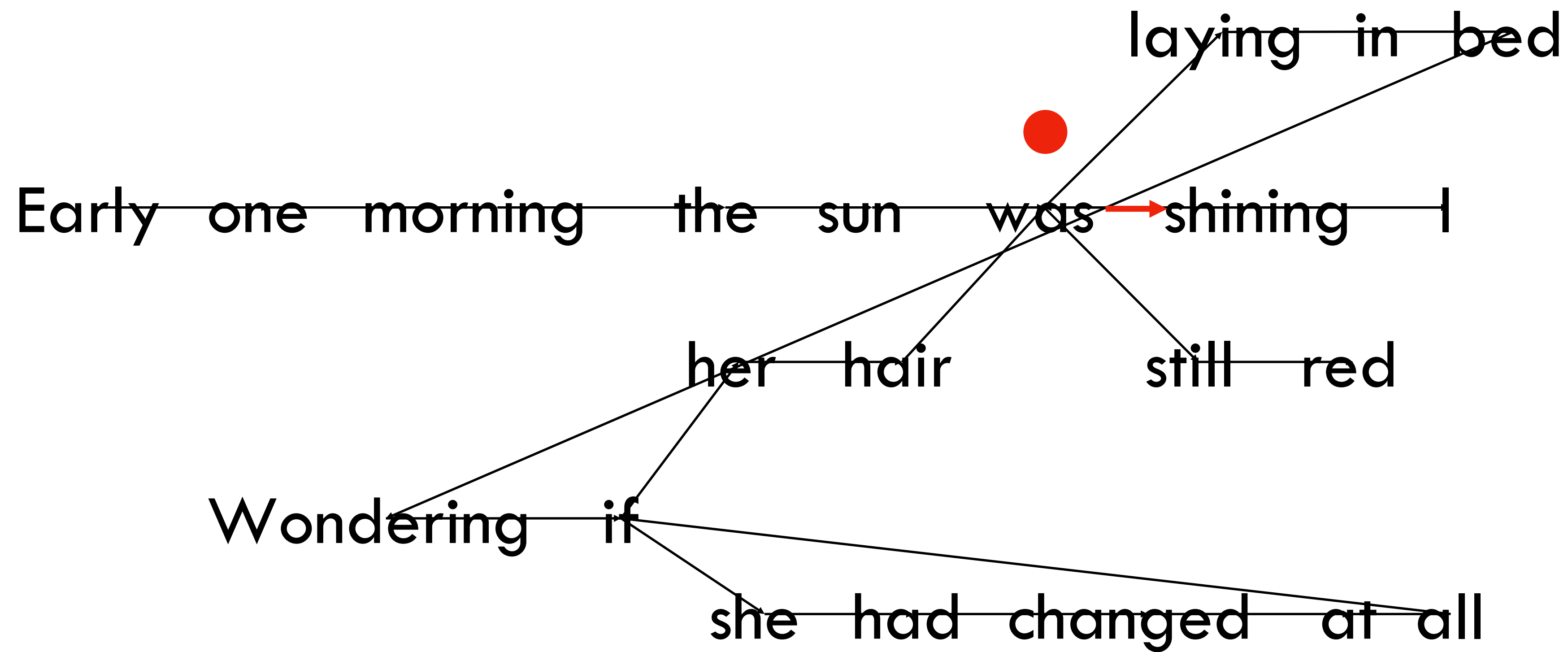
Early one morning the



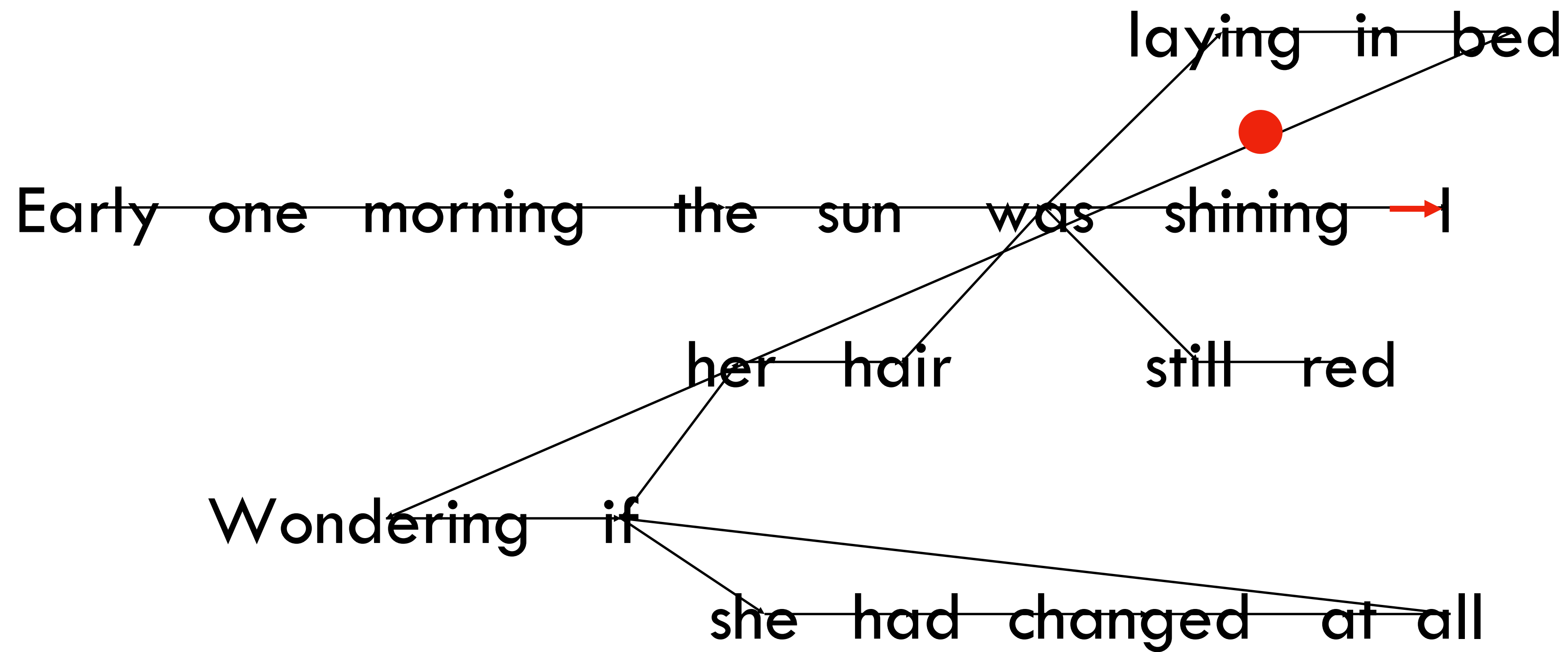
Early one morning the sun



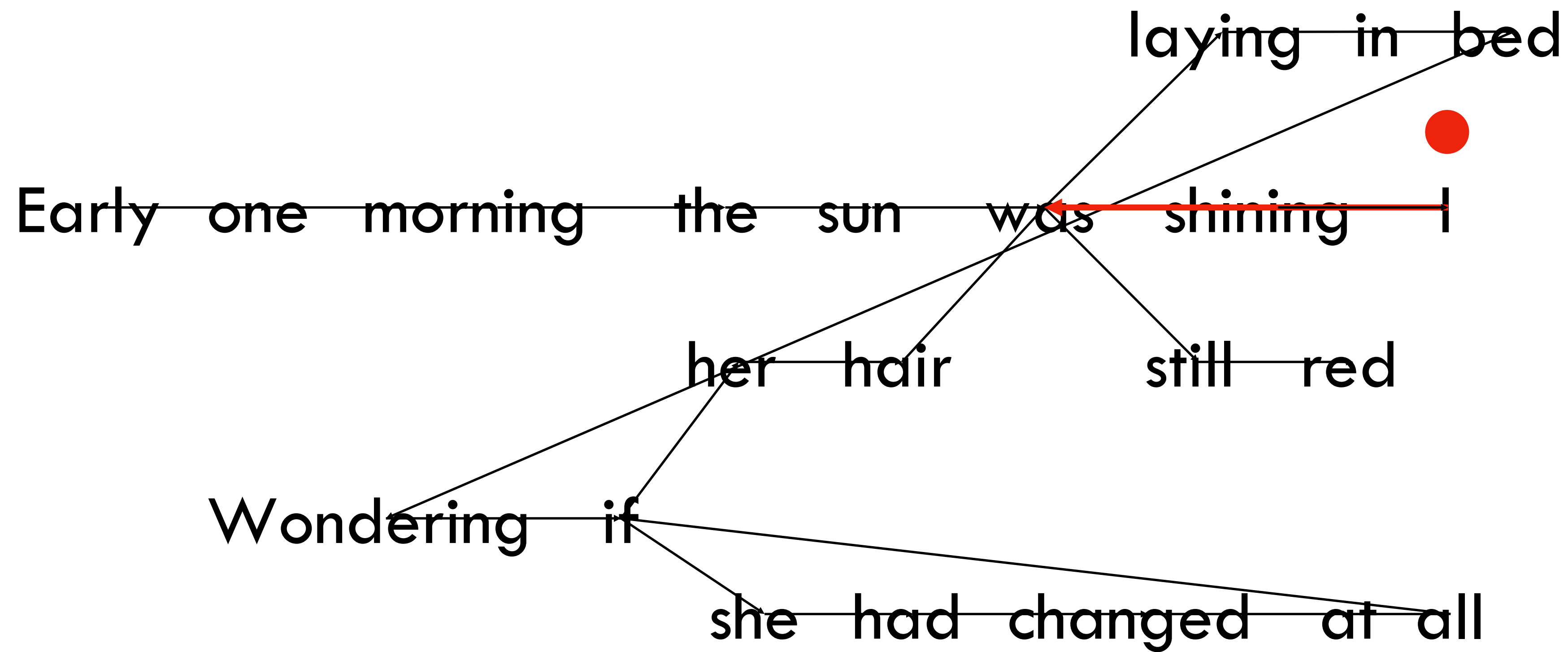
Early one morning the sun was



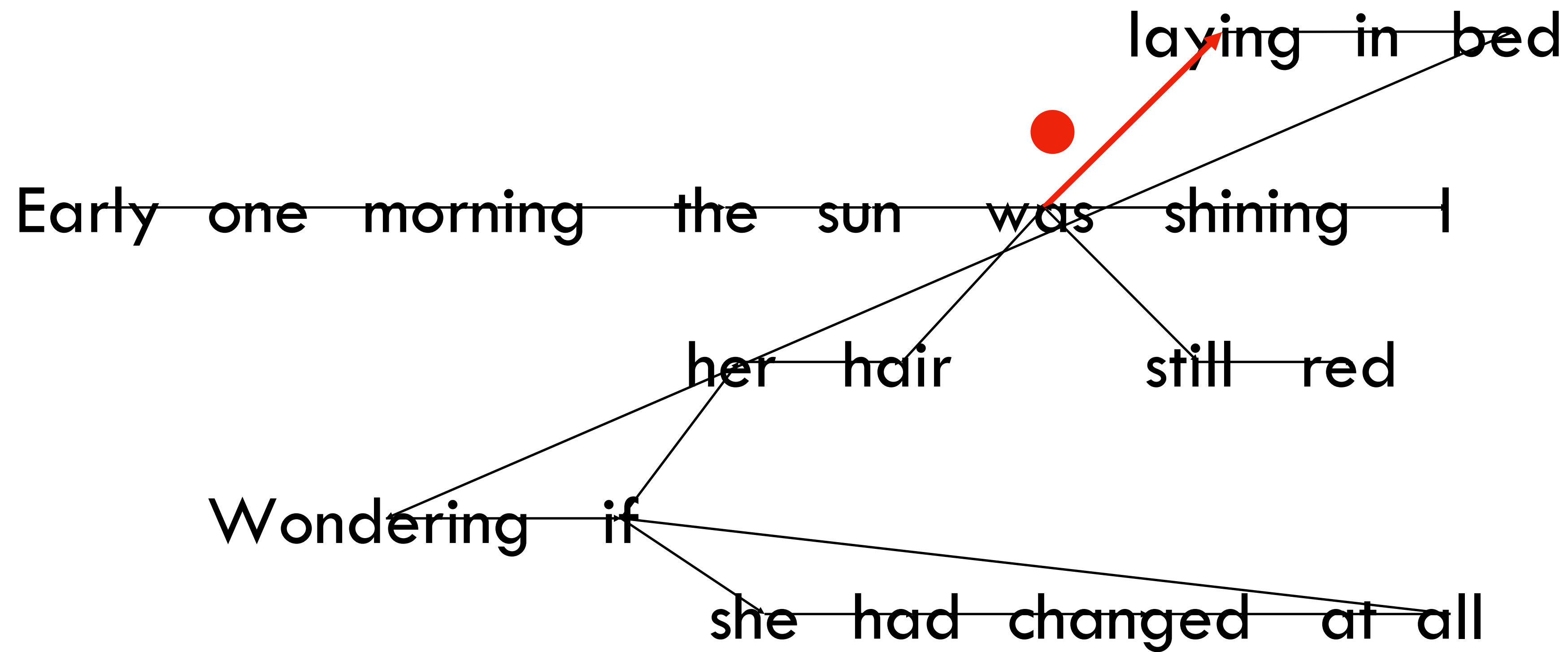
Early one morning the sun was shining



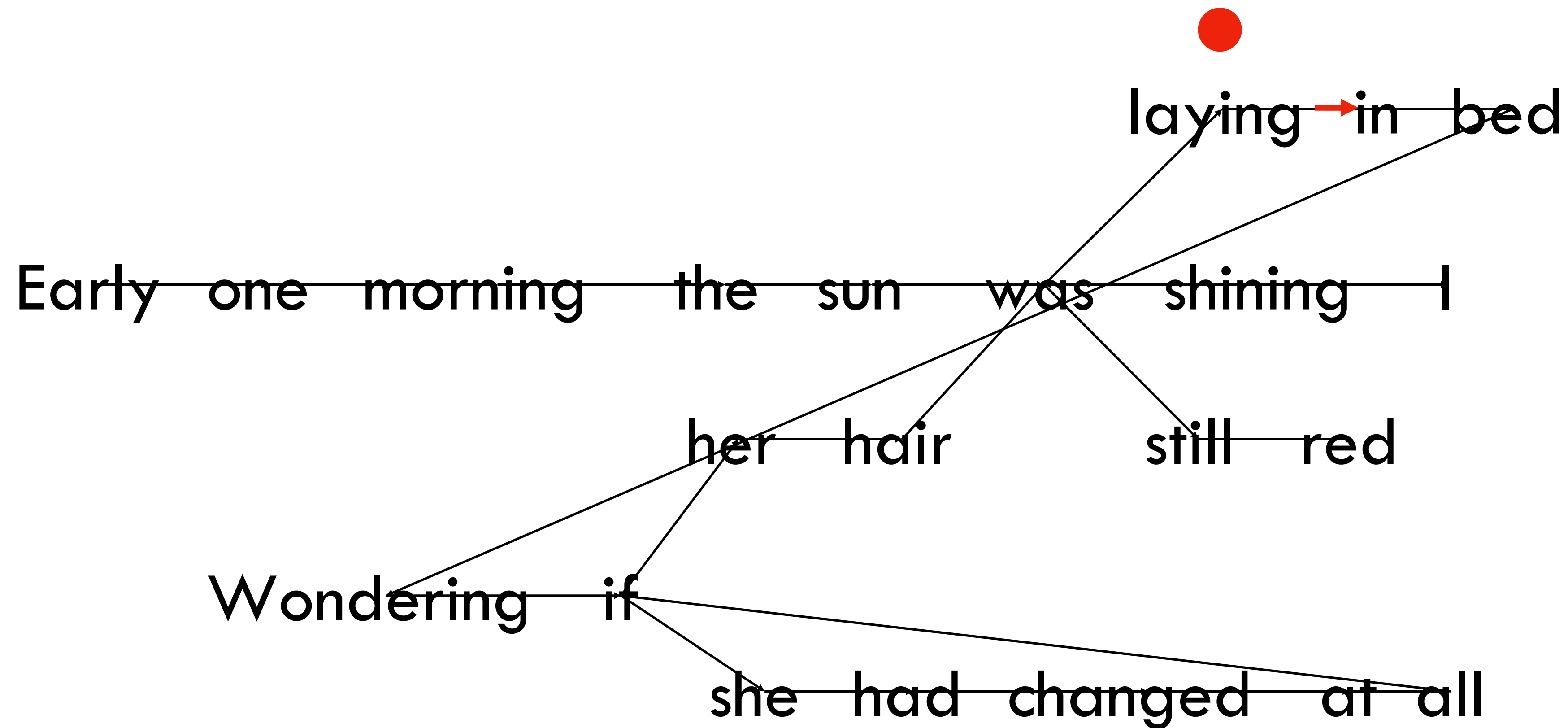
Early one morning the sun was shining I



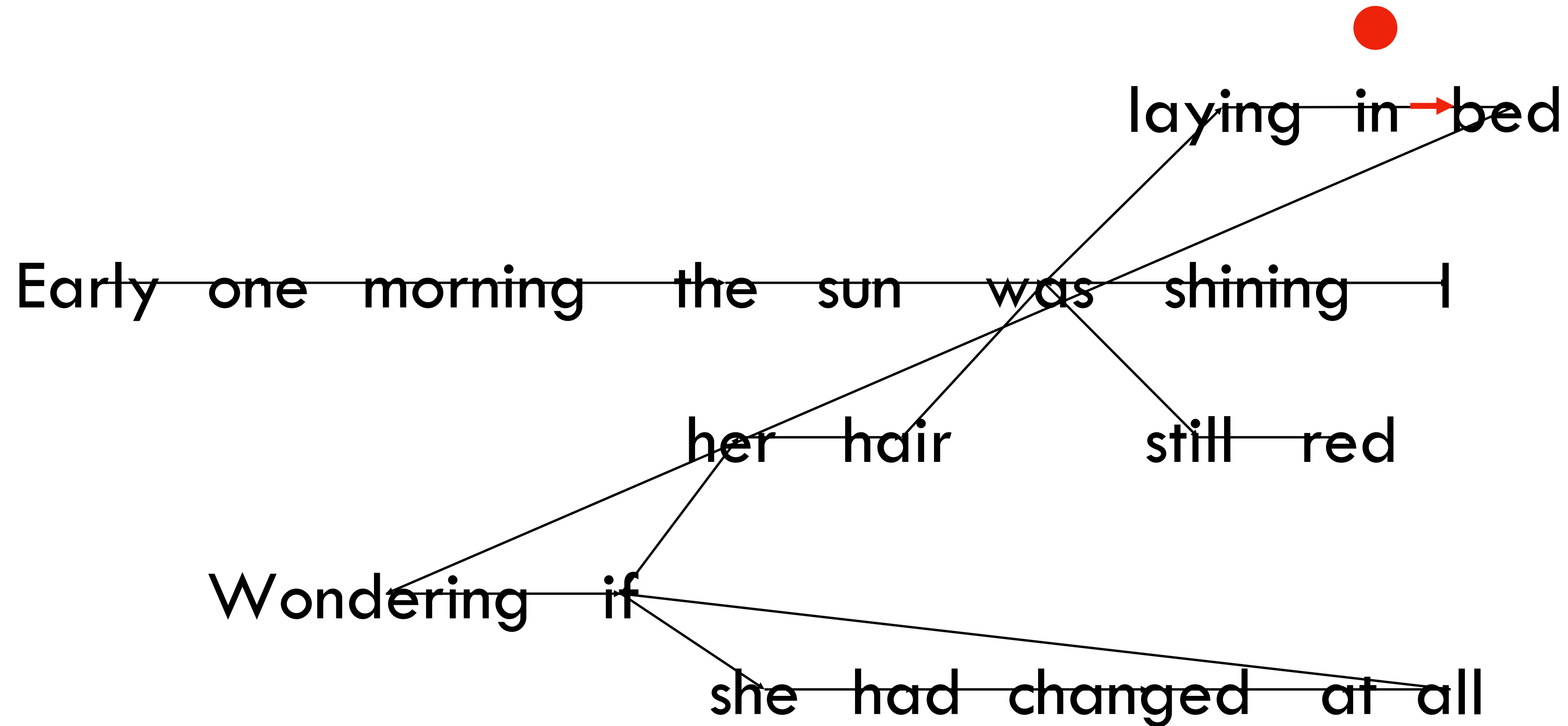
Early one morning the sun was shining I was



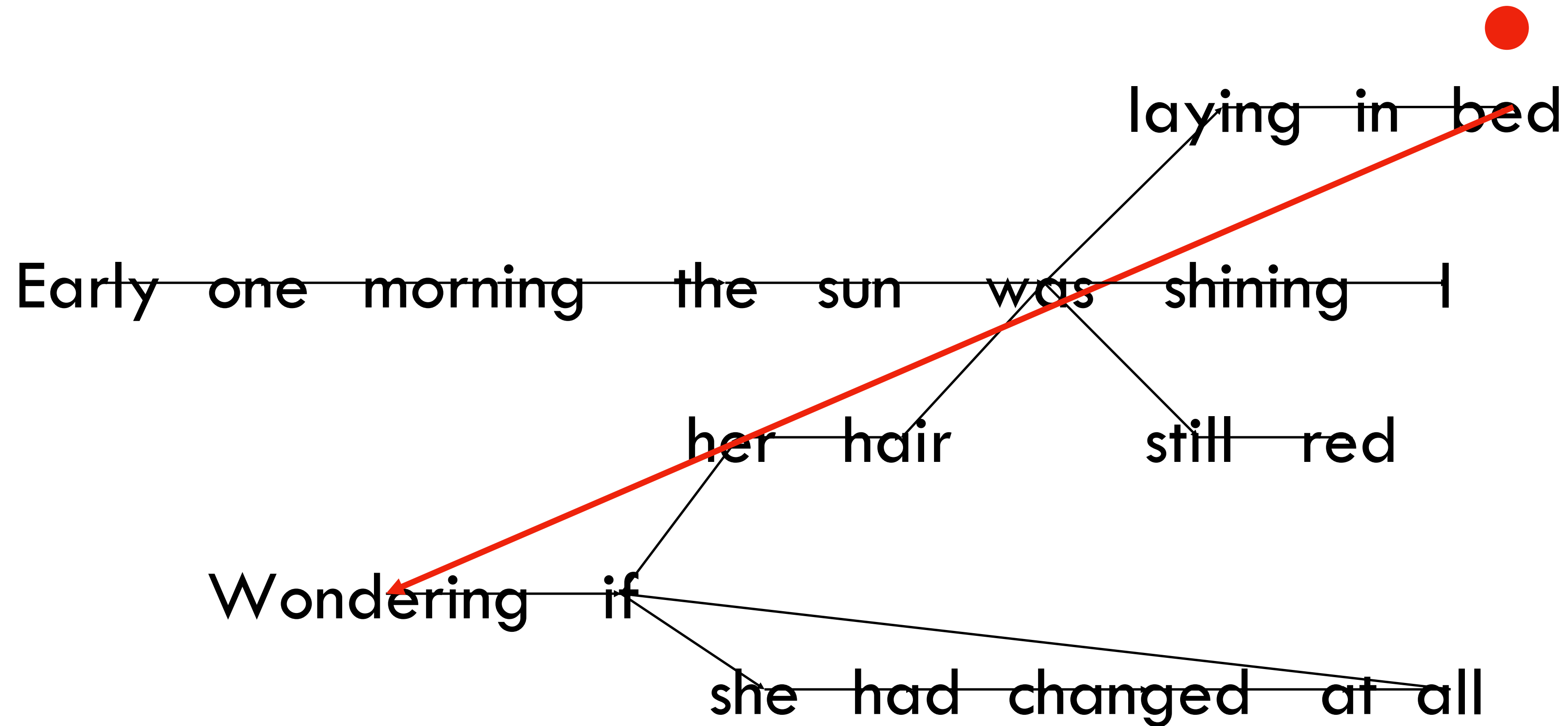
Early one morning the sun was shining I was laying



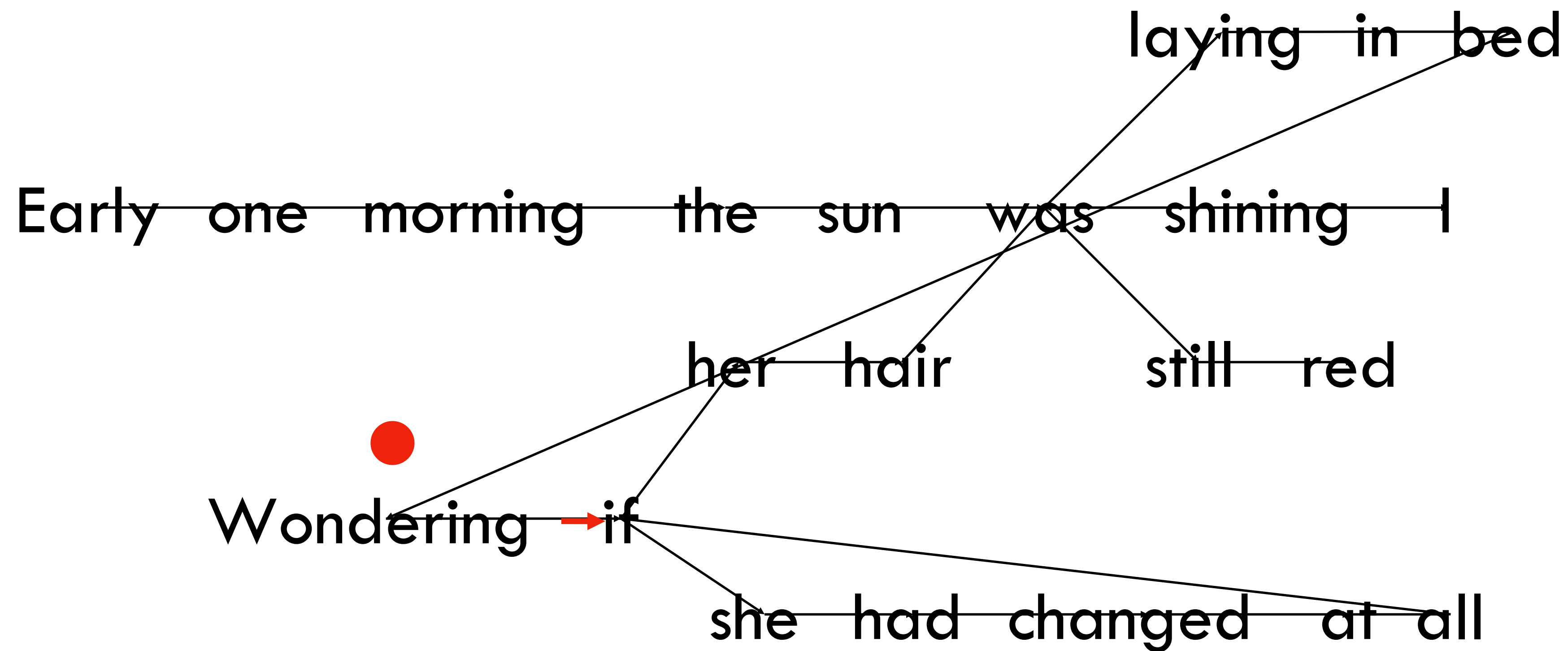
Early one morning the sun was shining I was laying in



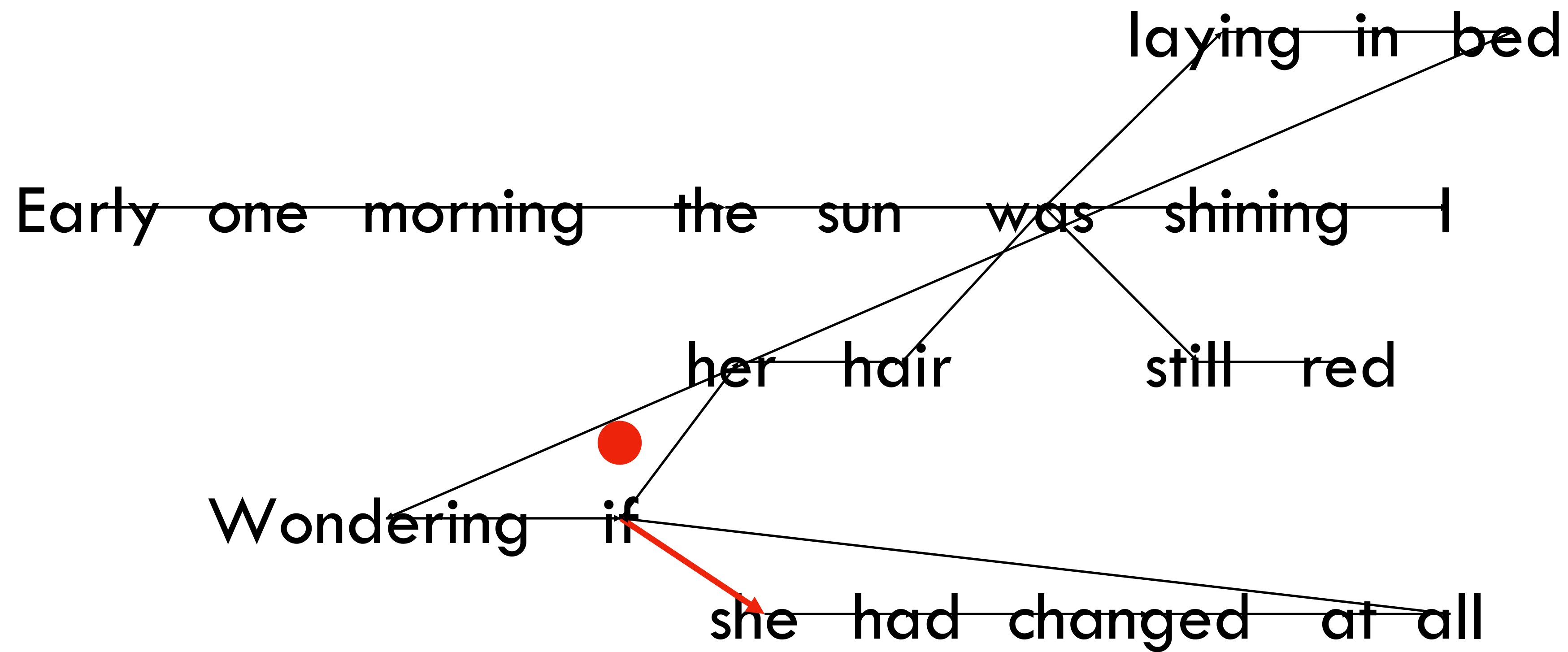
Early one morning the sun was shining I was laying in bed



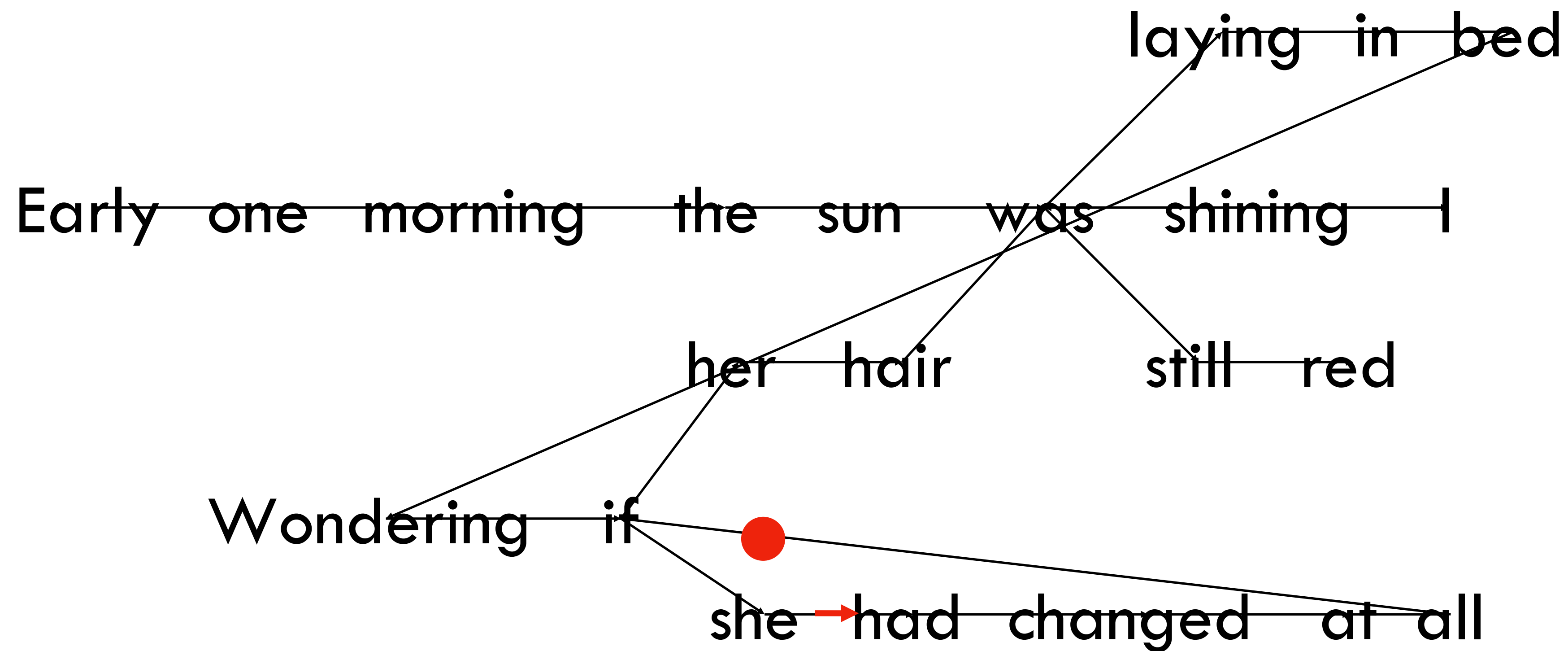
Early one morning the sun was shining I was laying in bed
Wondering



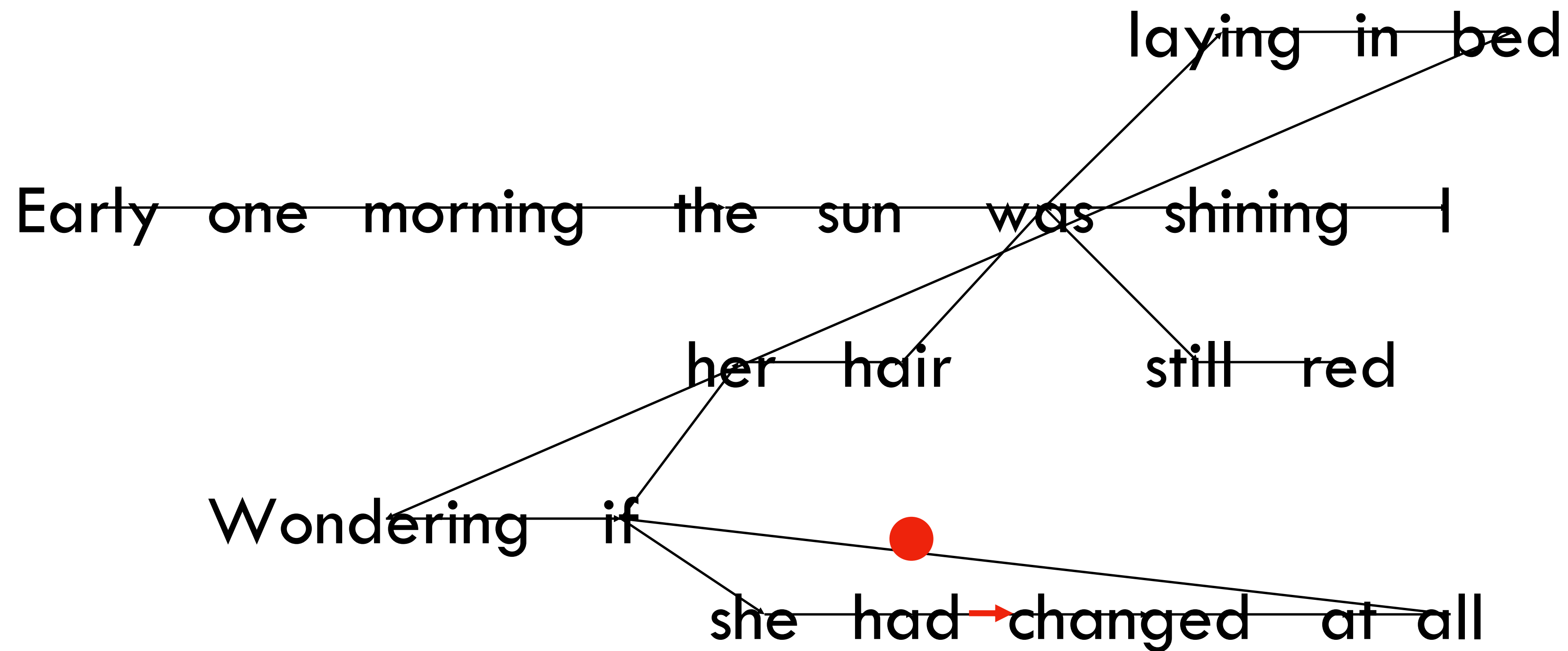
Early one morning the sun was shining I was laying in bed
Wondering if



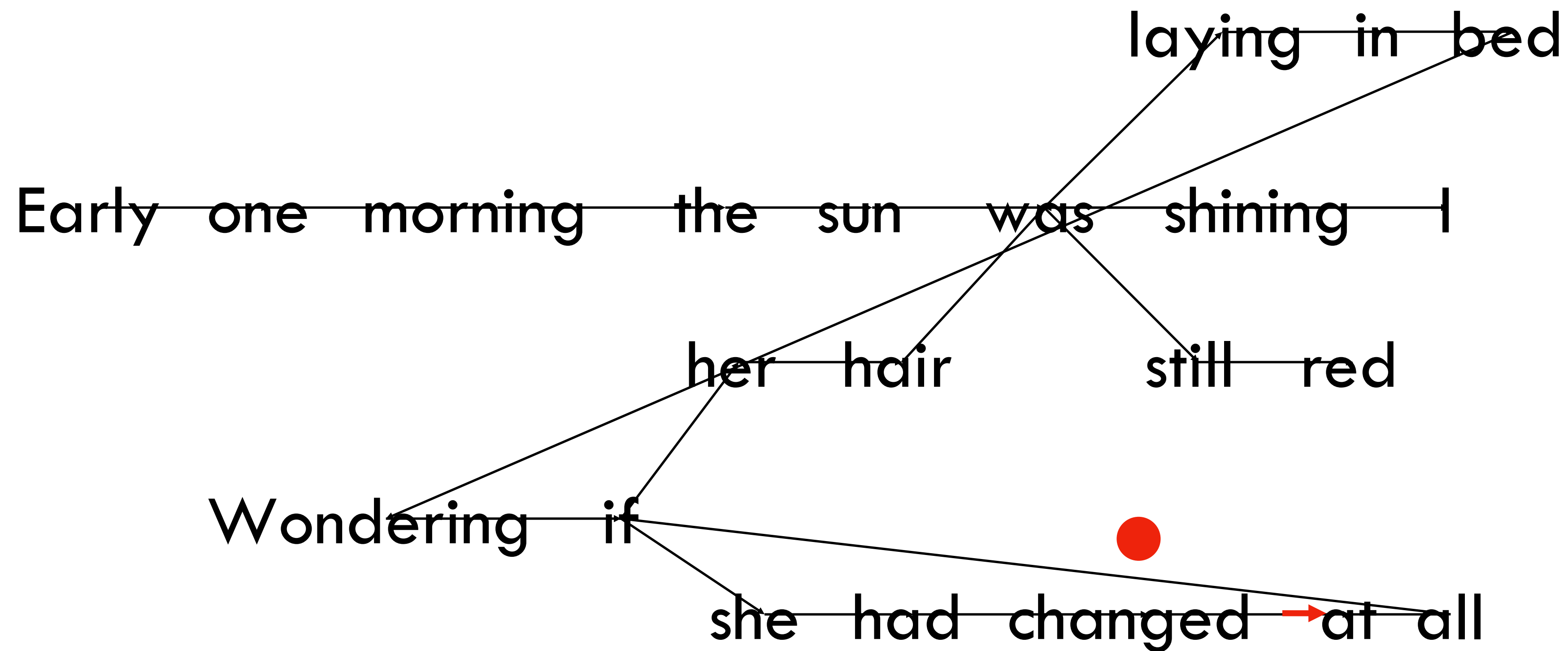
Early one morning the sun was shining I was laying in bed
Wondering if she



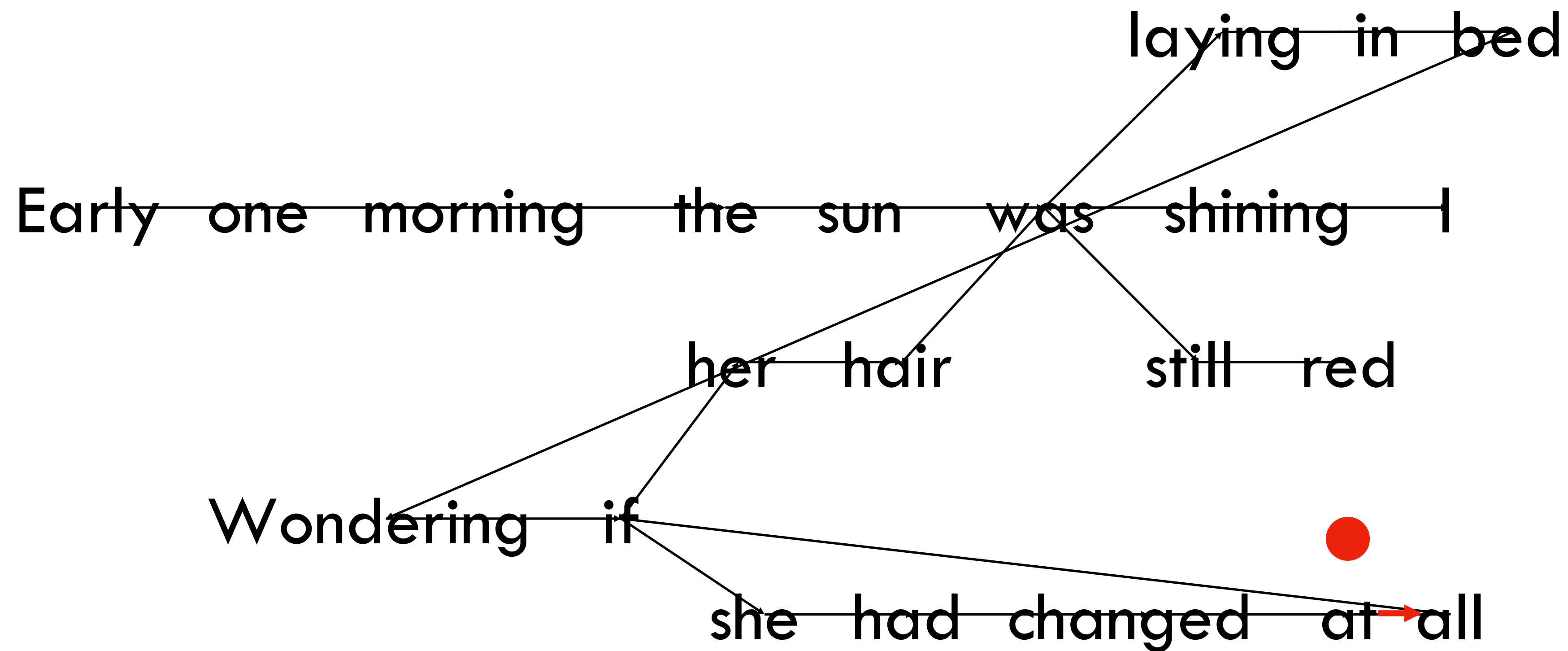
Early one morning the sun was shining I was laying in bed
Wondering if she had



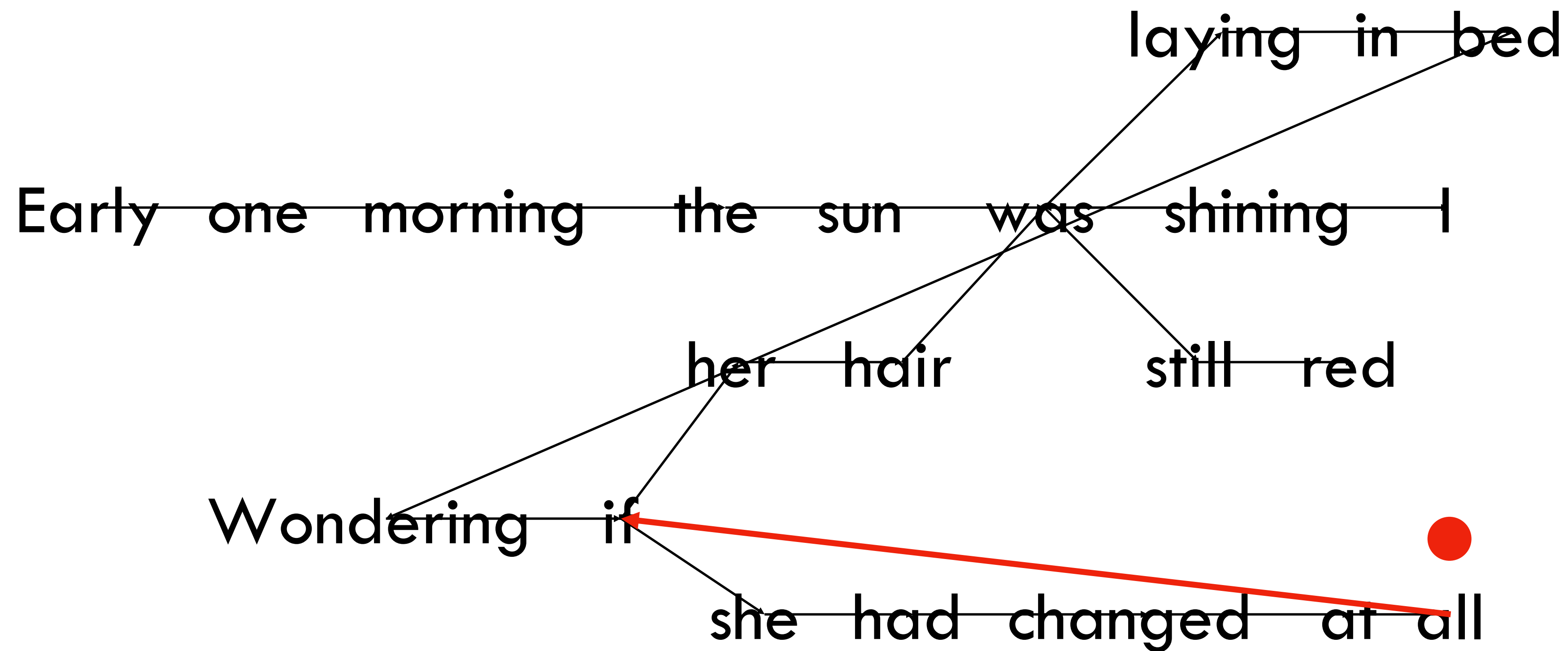
Early one morning the sun was shining I was laying in bed
Wondering if she had changed



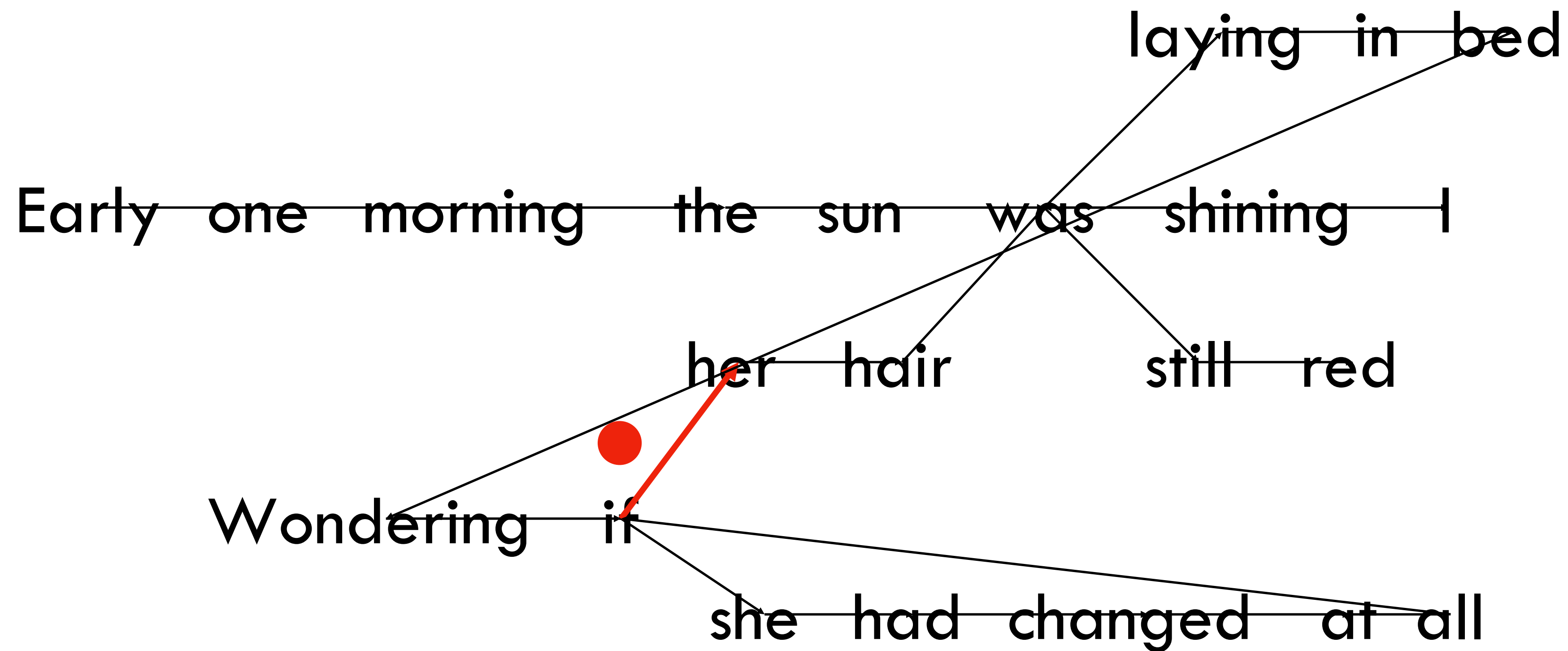
Early one morning the sun was shining I was laying in bed
Wondering if she had changed at



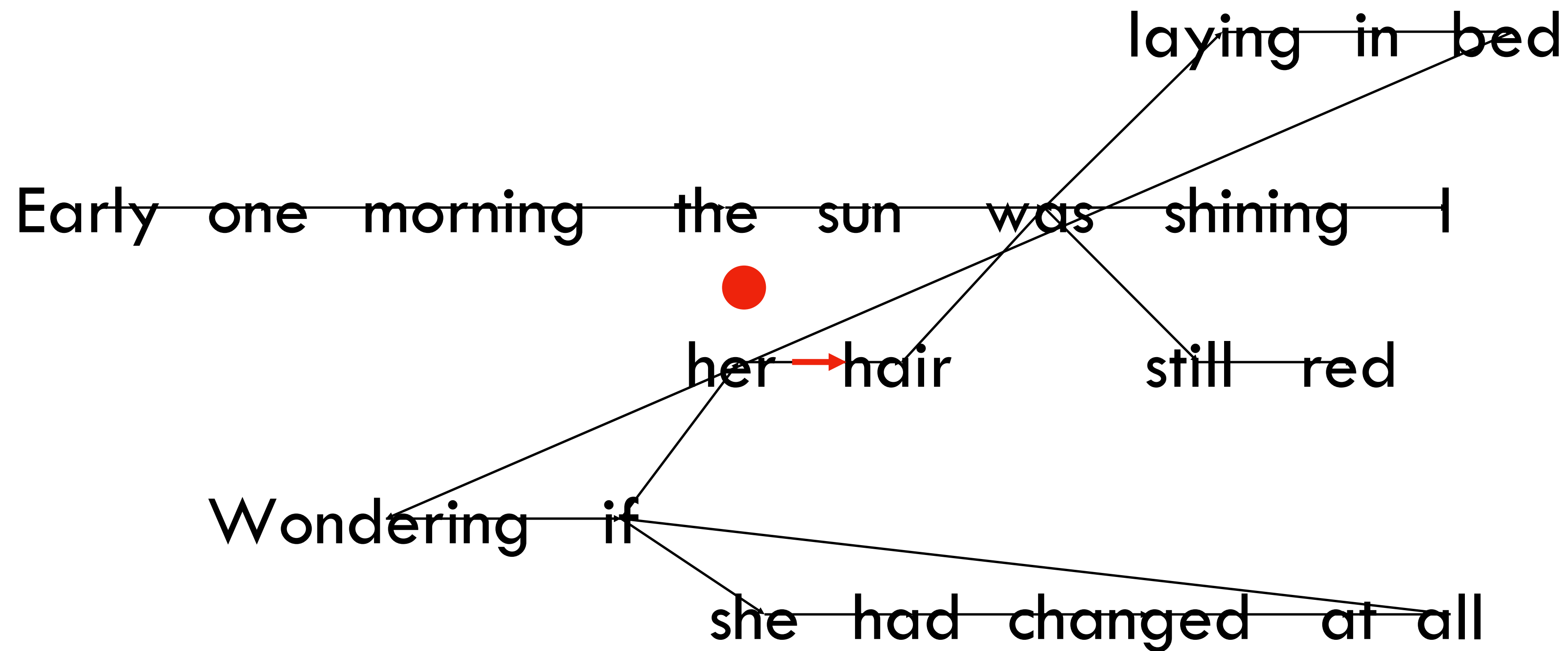
Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all



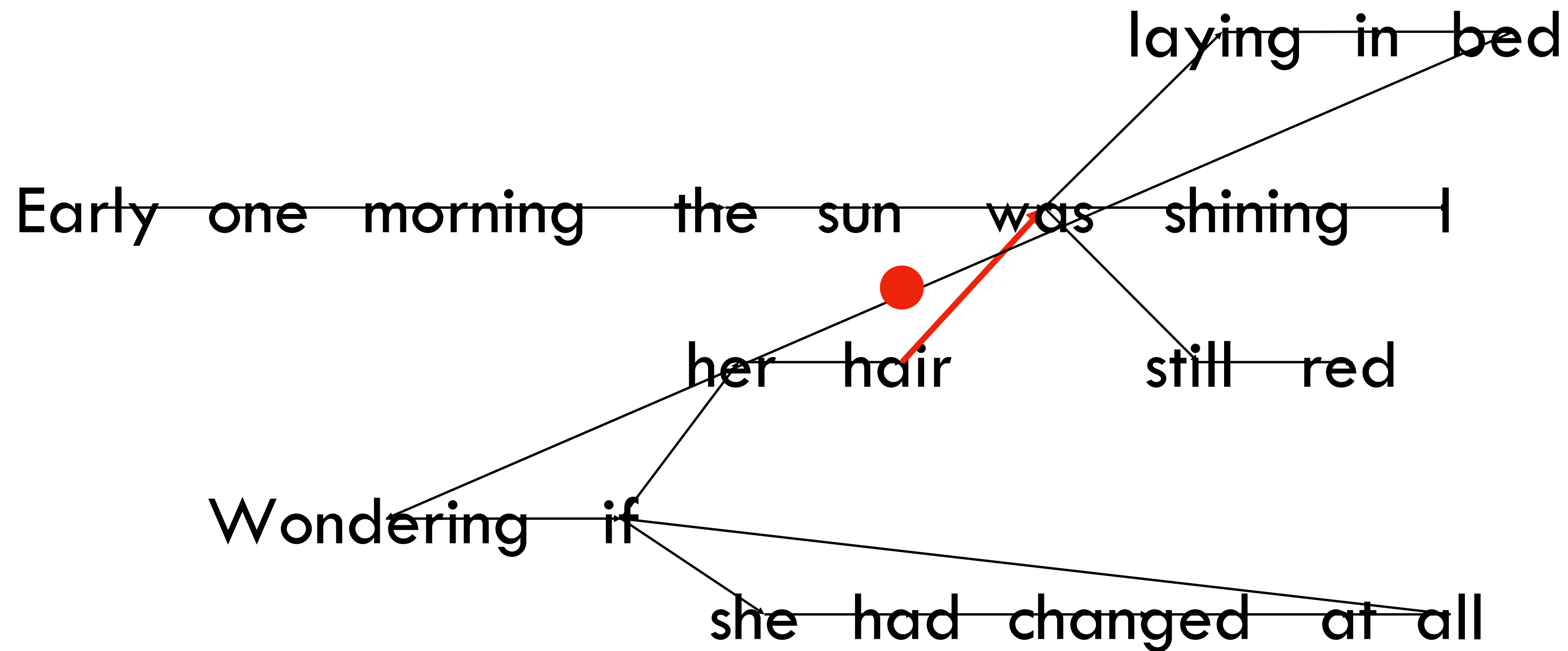
Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all if



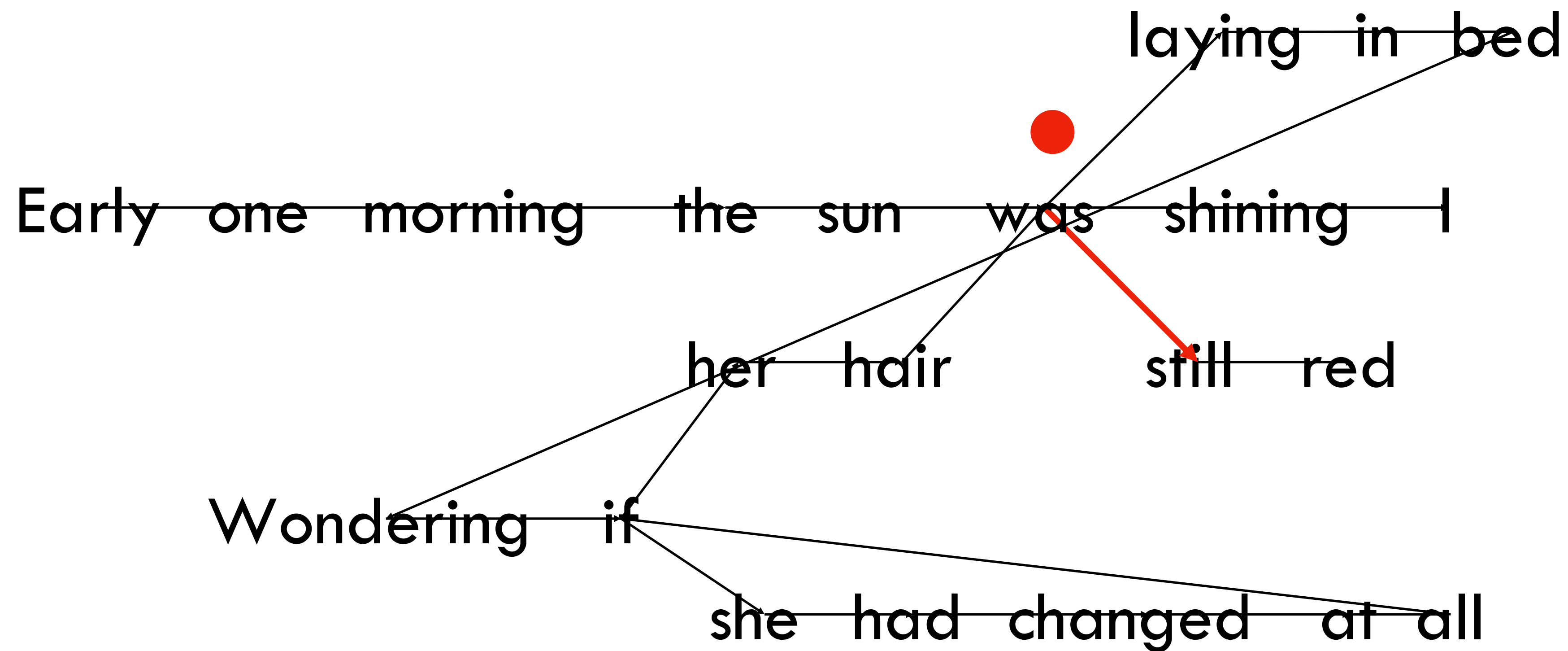
Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all if her



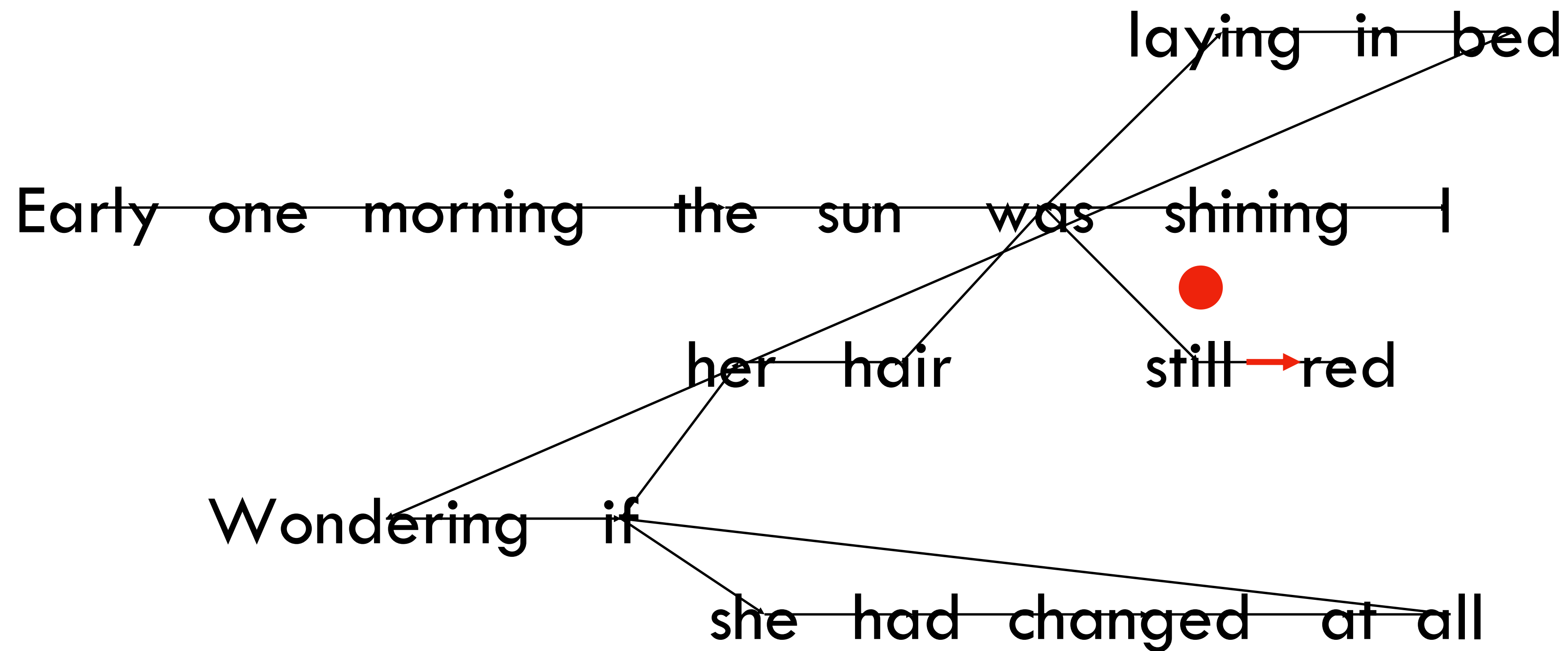
Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all if her hair



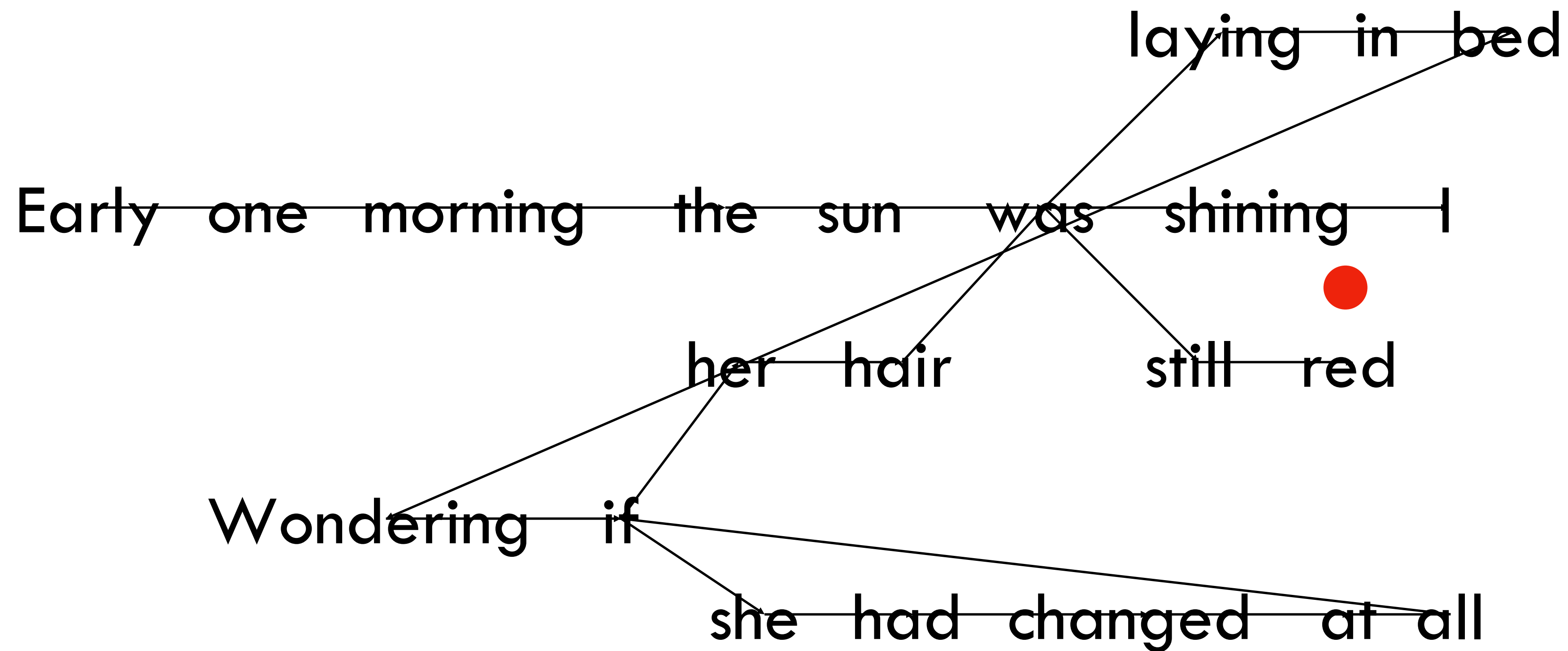
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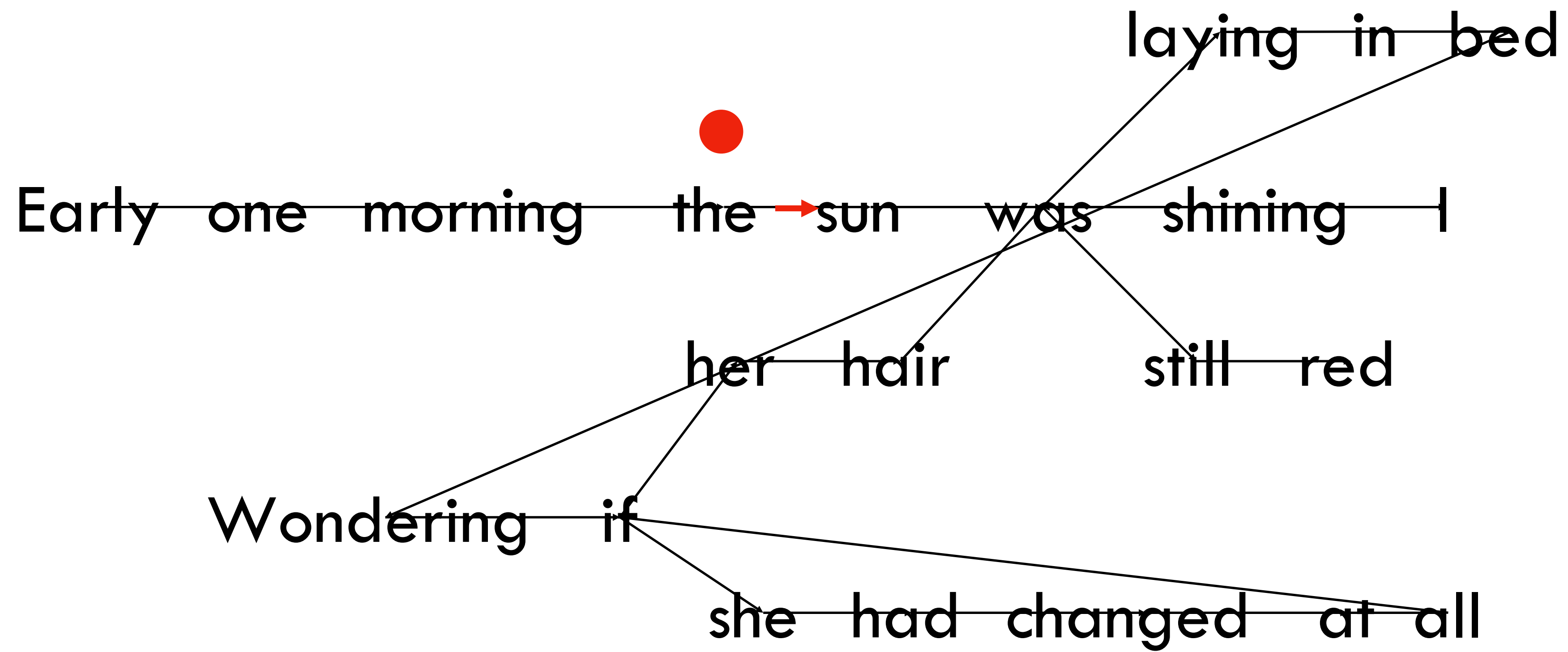
Early one morning the sun was shining I was laying in bed
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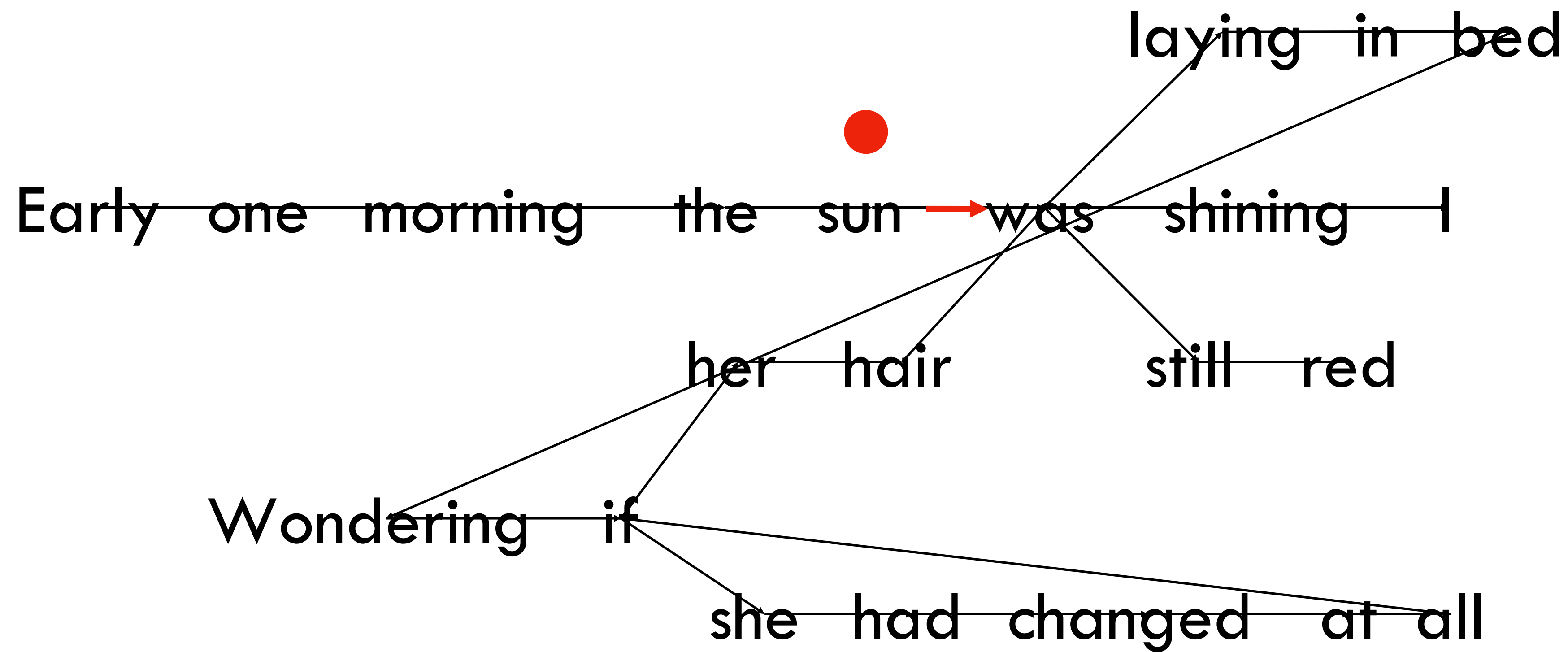
Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all if her hair was still red



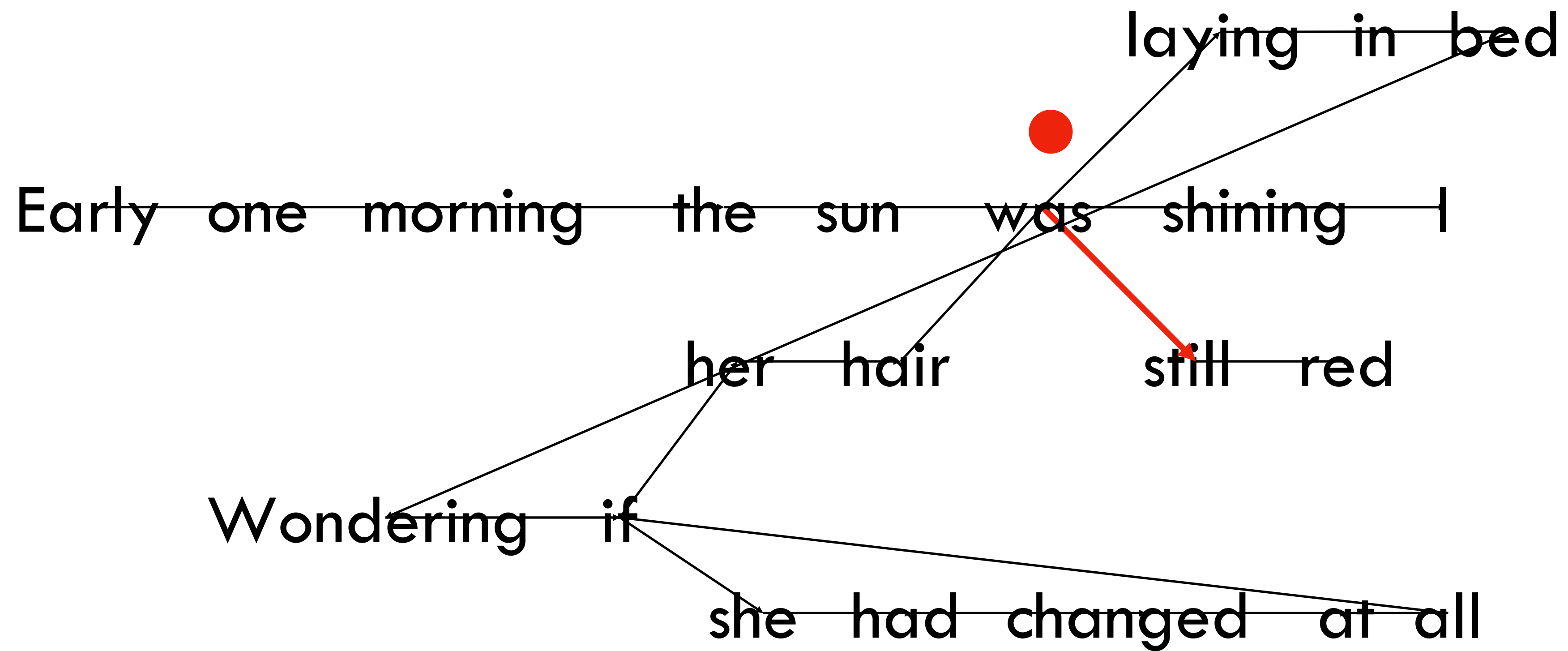
the



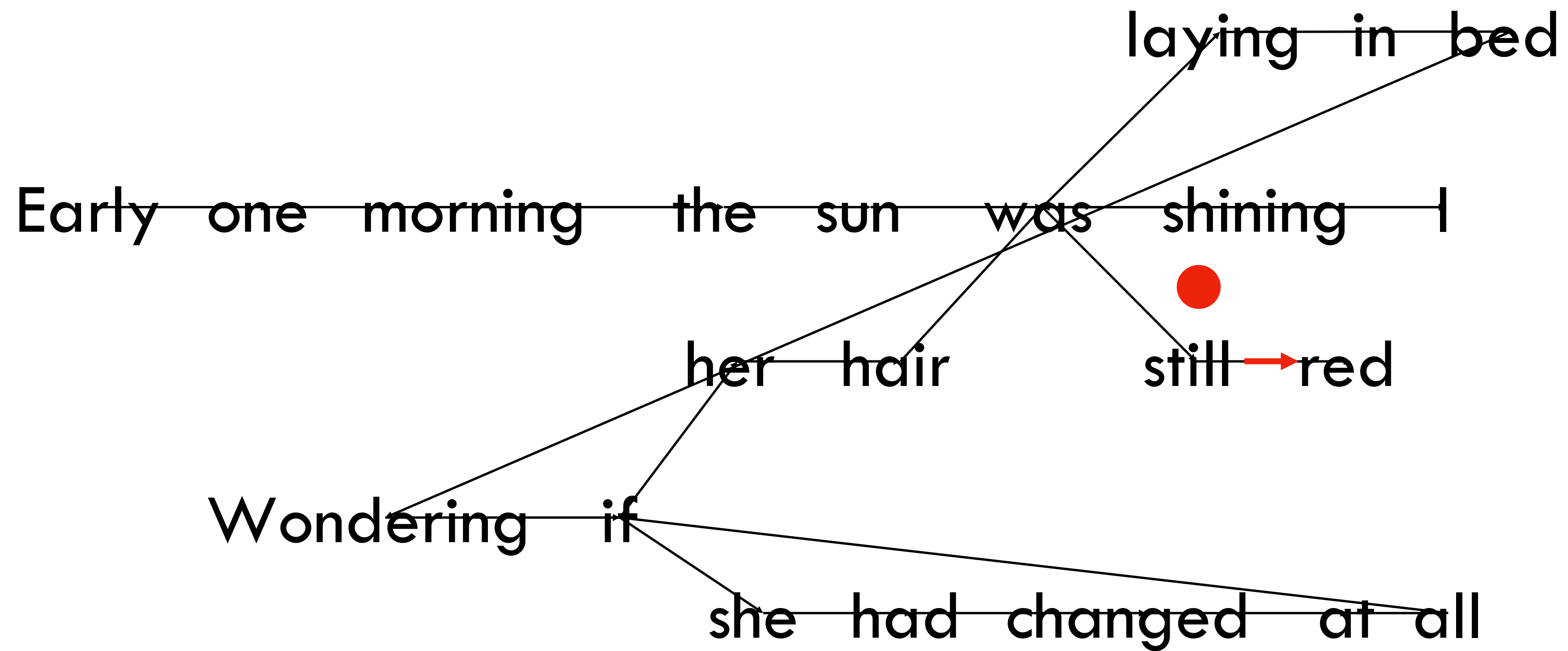
the sun



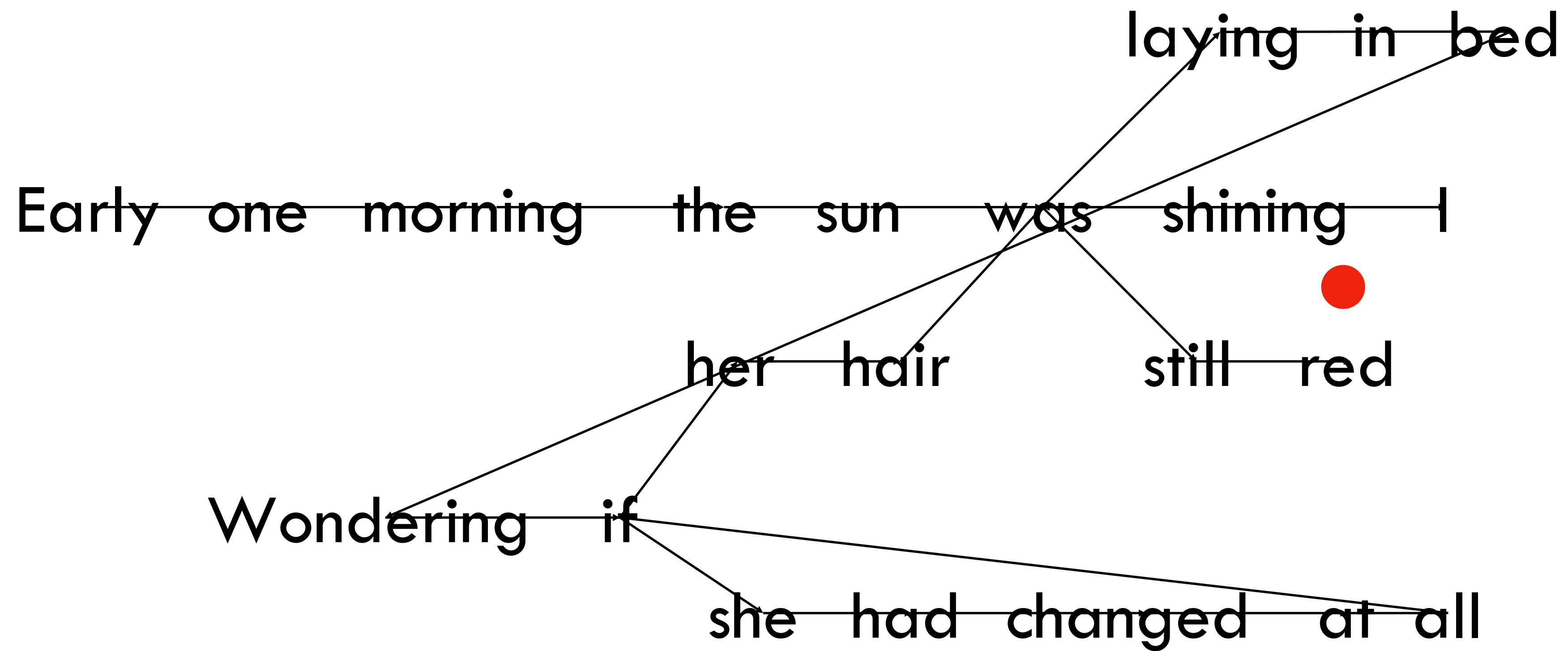
the sun was



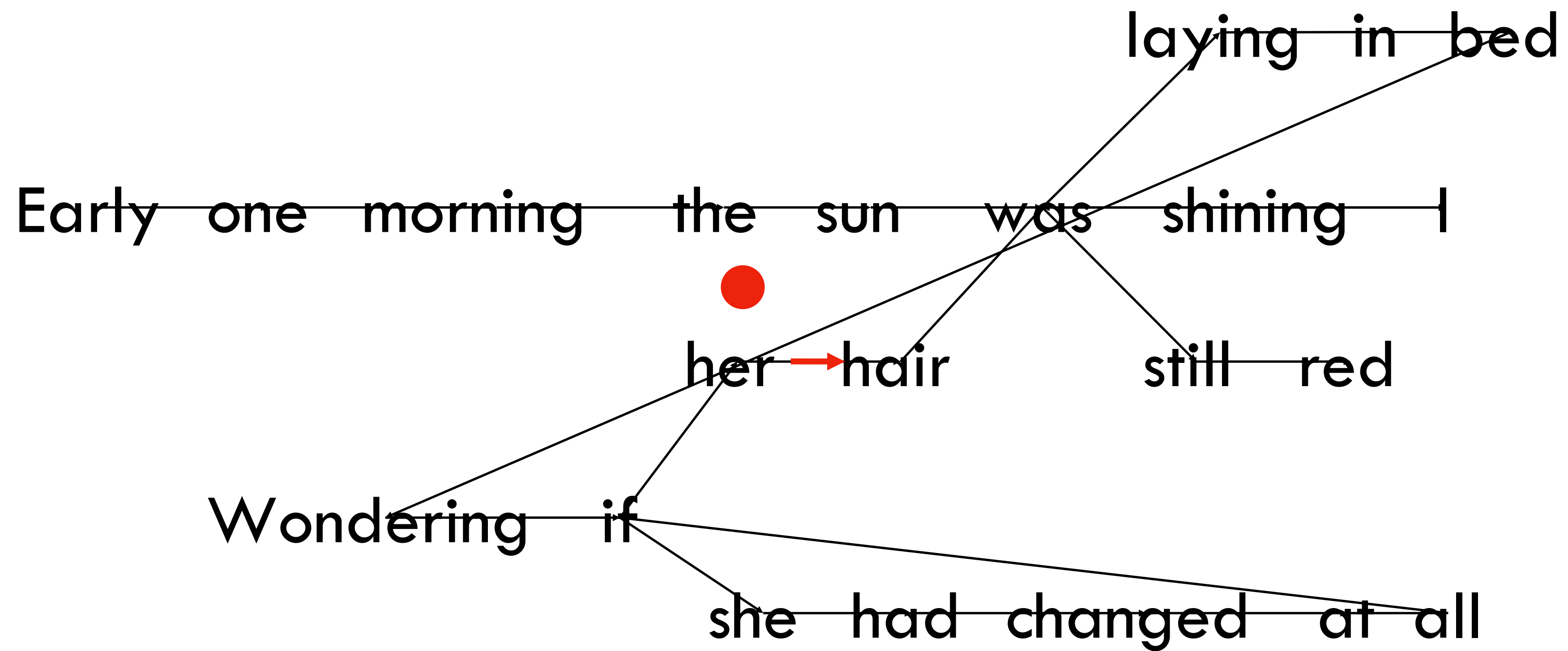
the sun was still



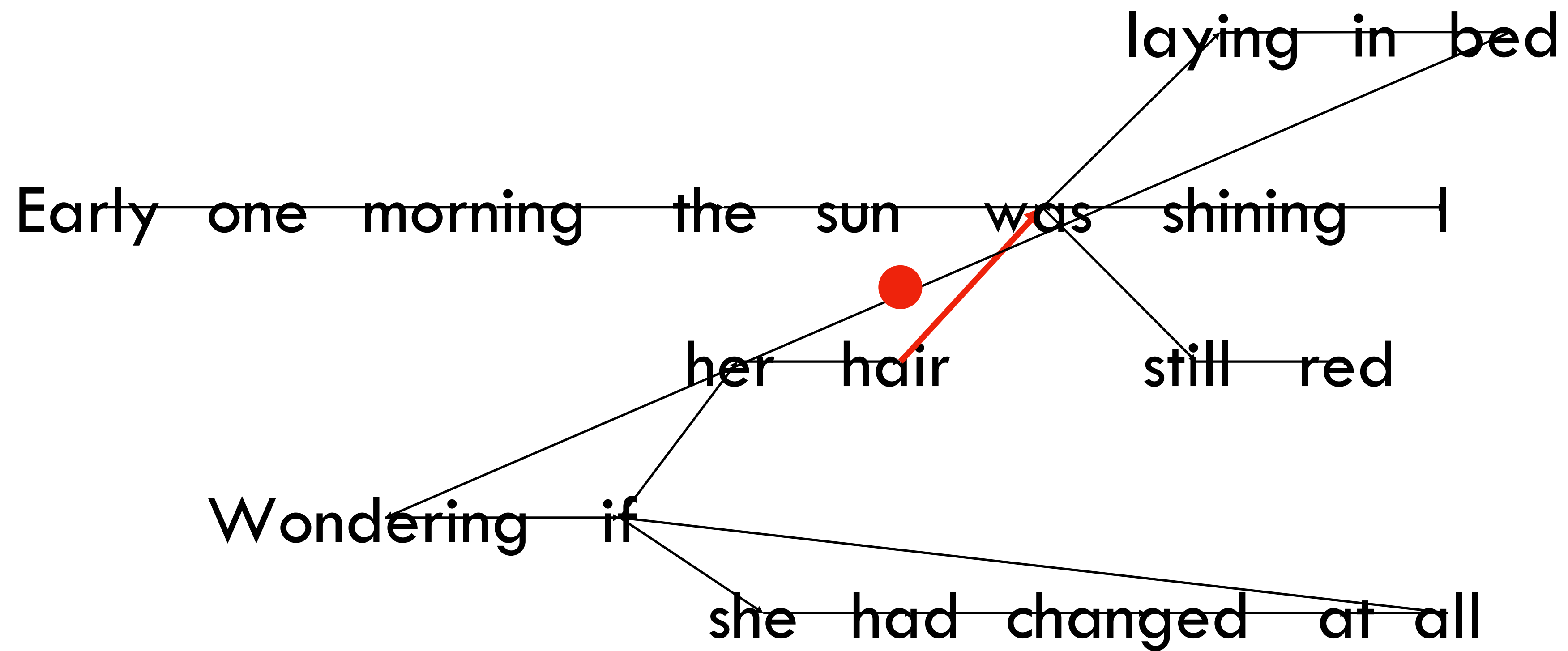
the sun was still red



the sun was still red
her

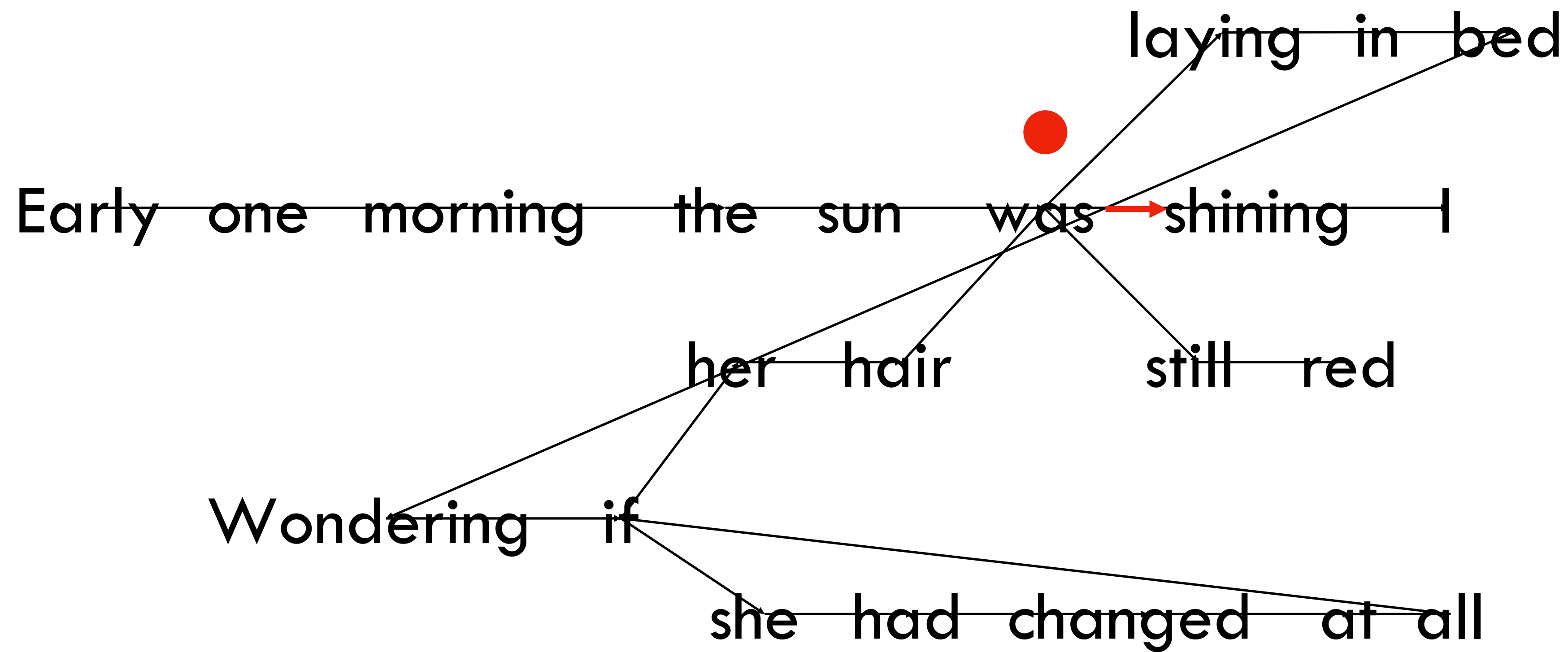


the sun was still red
her hair

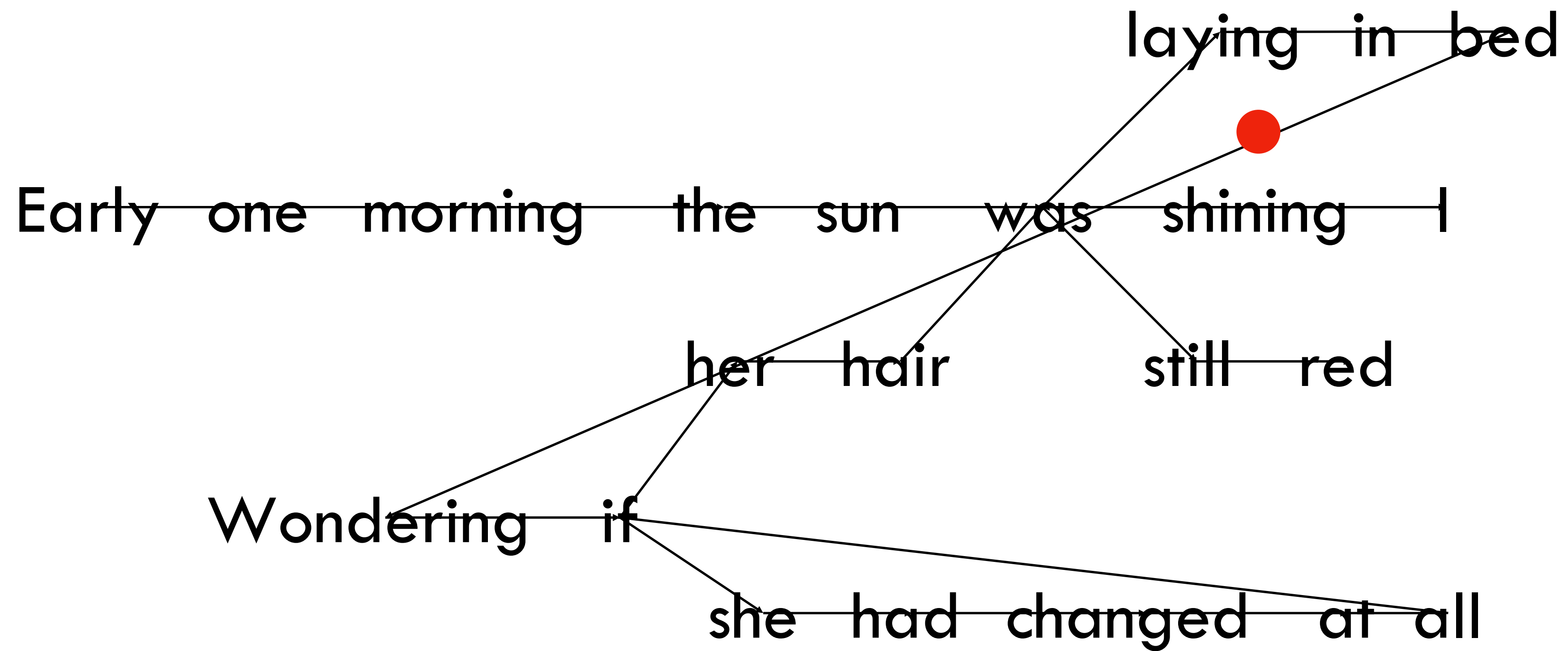


the sun was still red

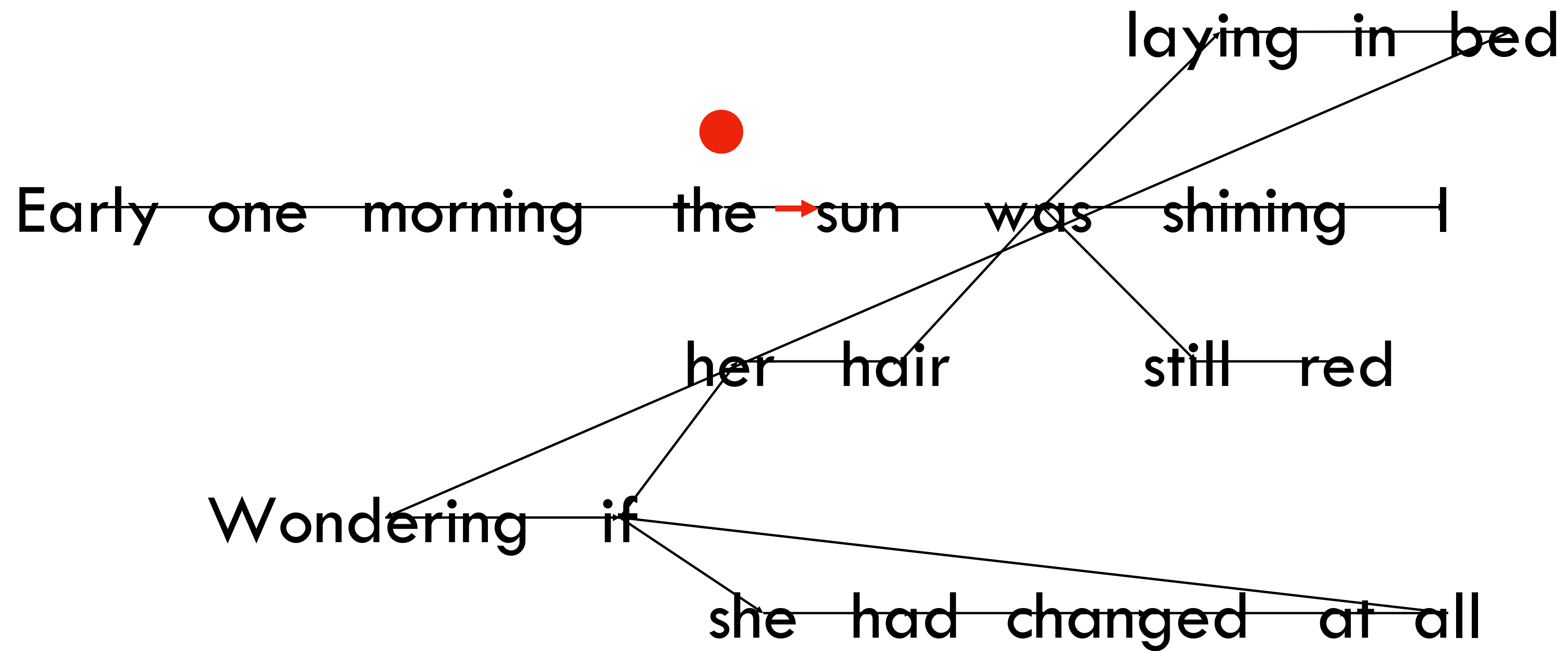
her hair was



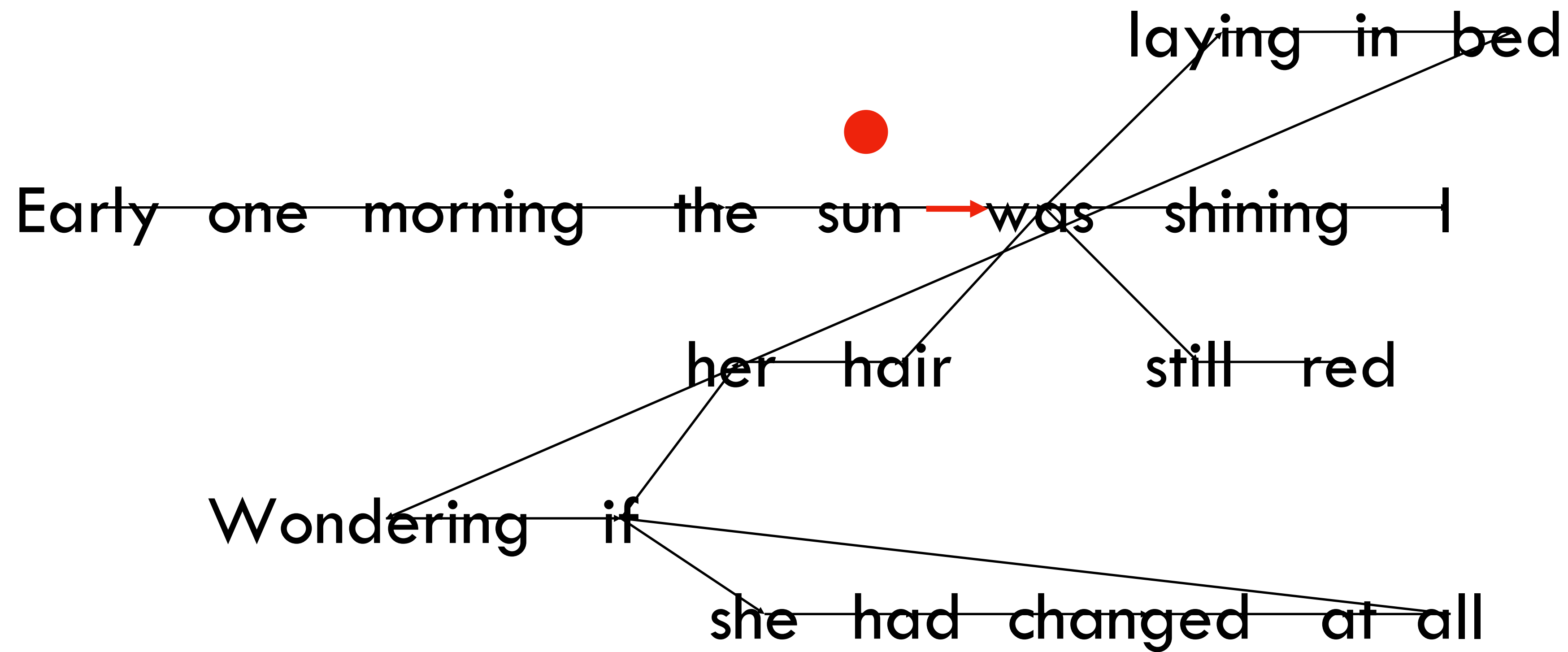
the sun was still red
her hair was shining



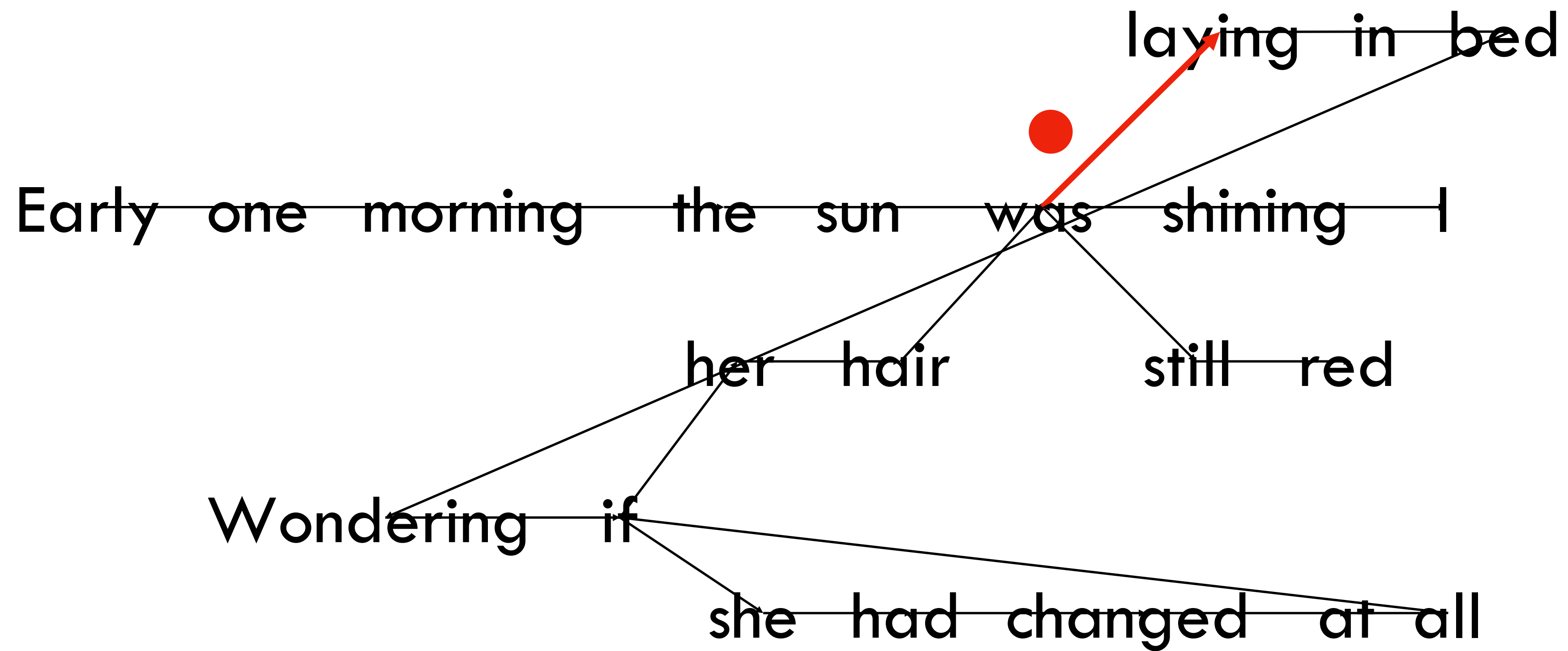
the



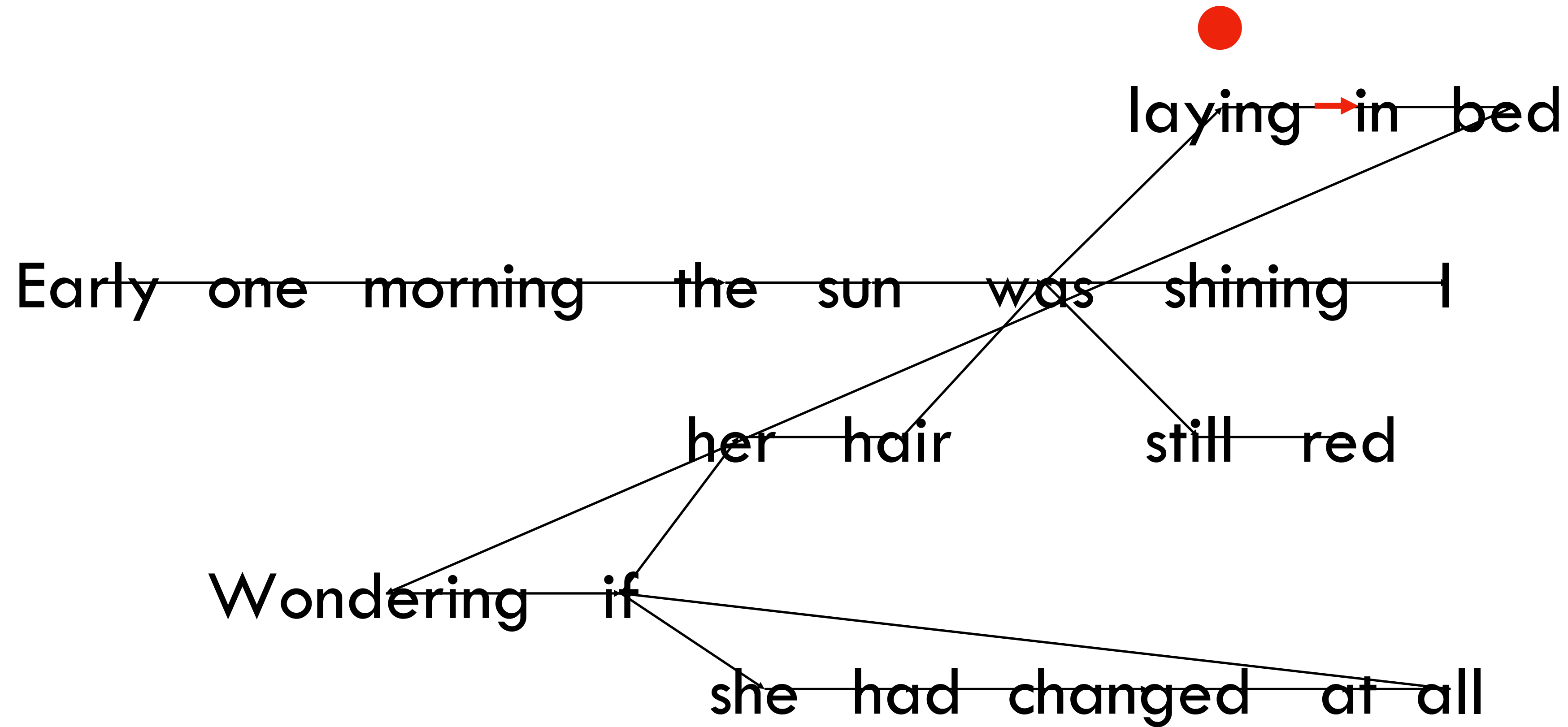
the sun



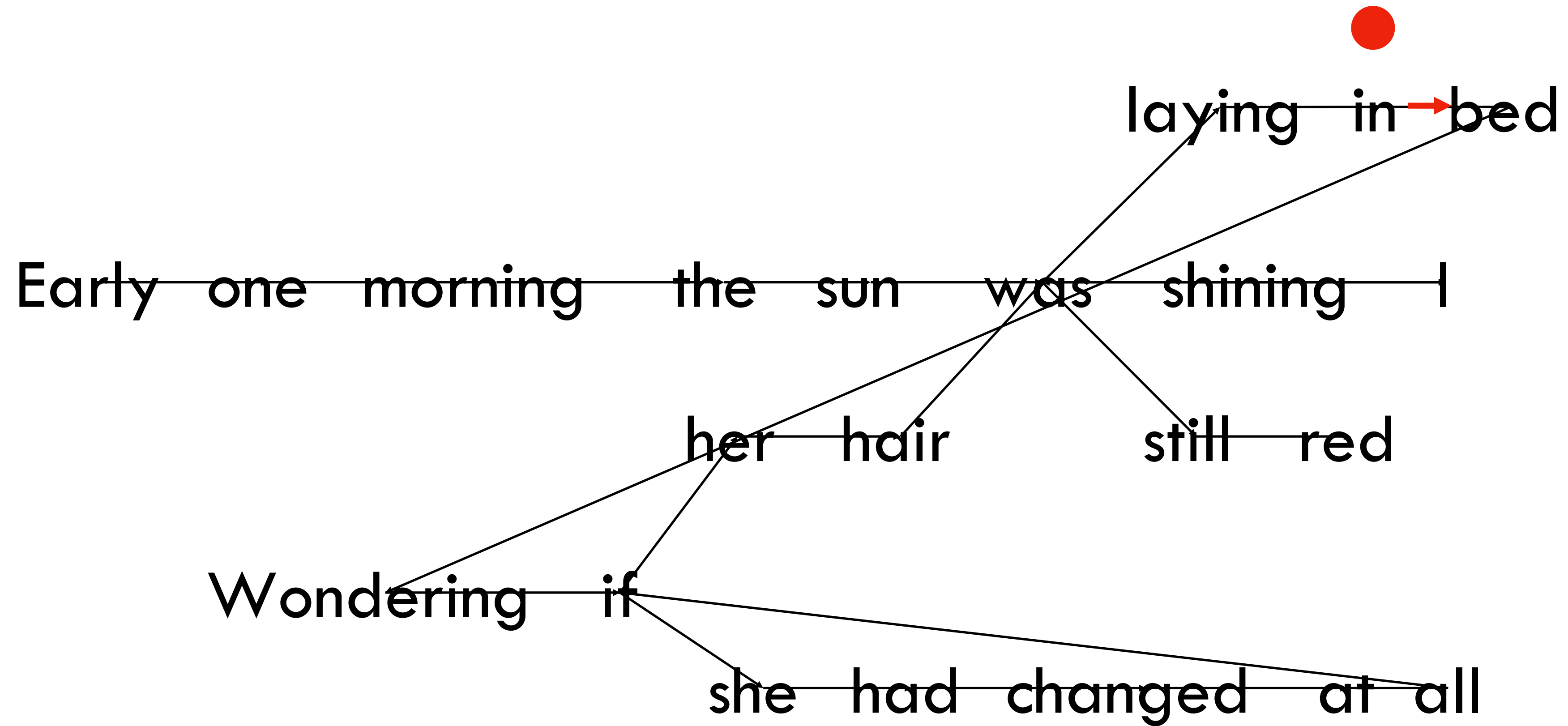
the sun was



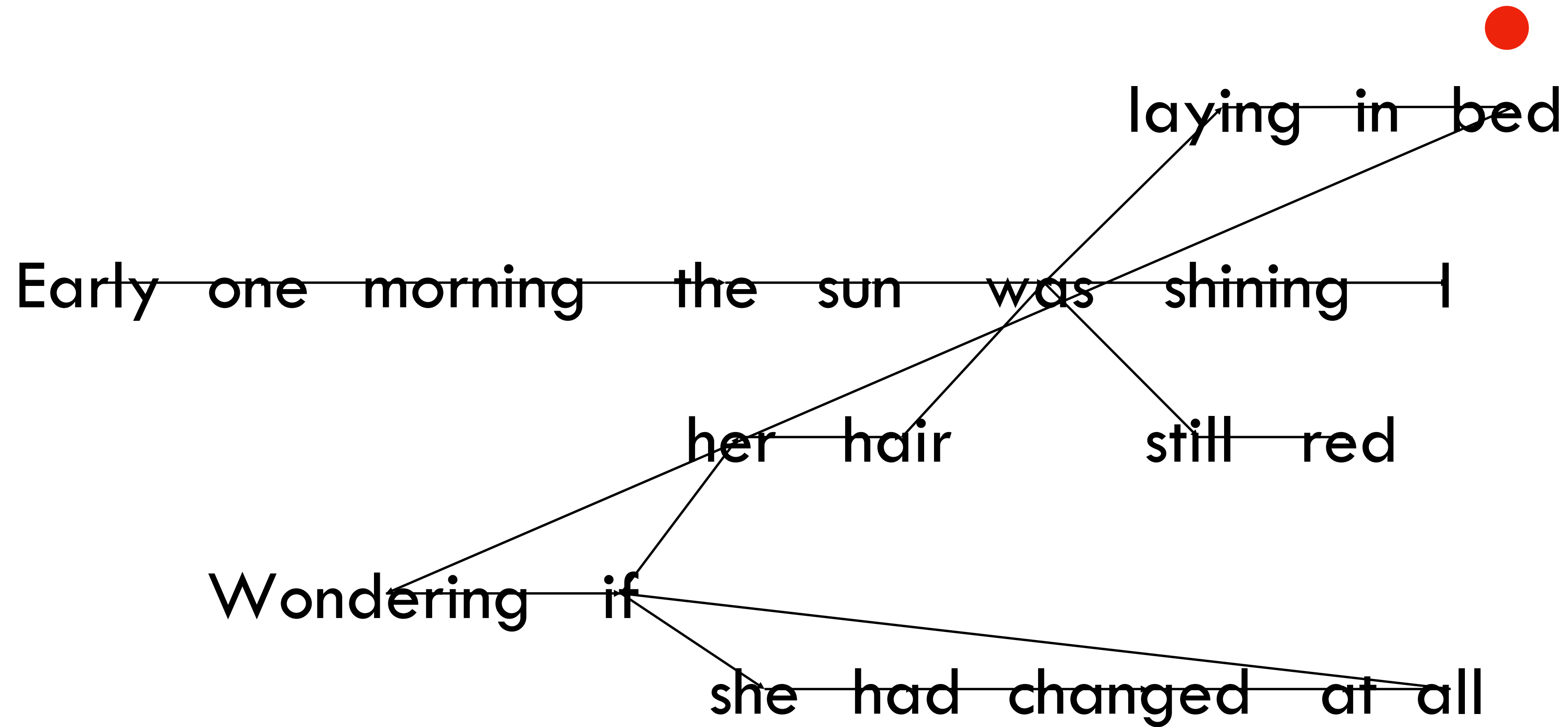
the sun was laying



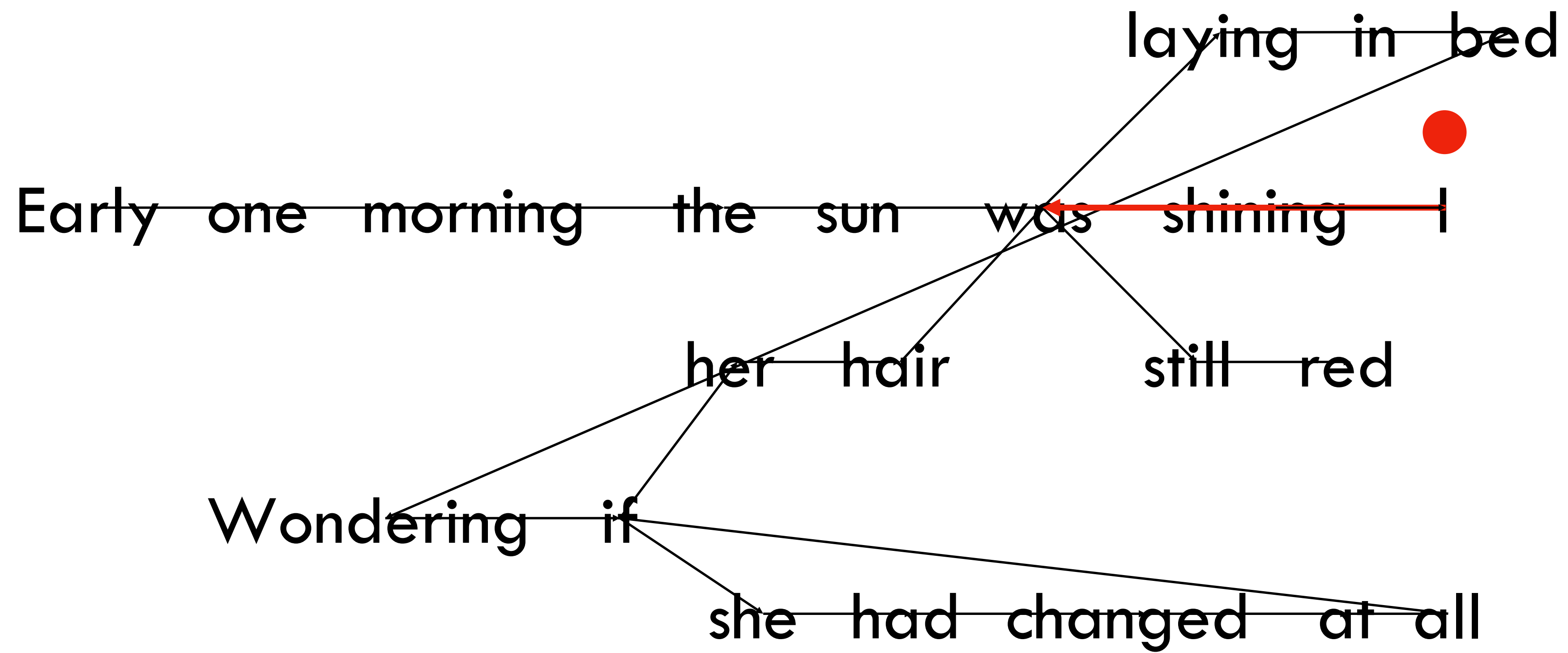
the sun was laying in



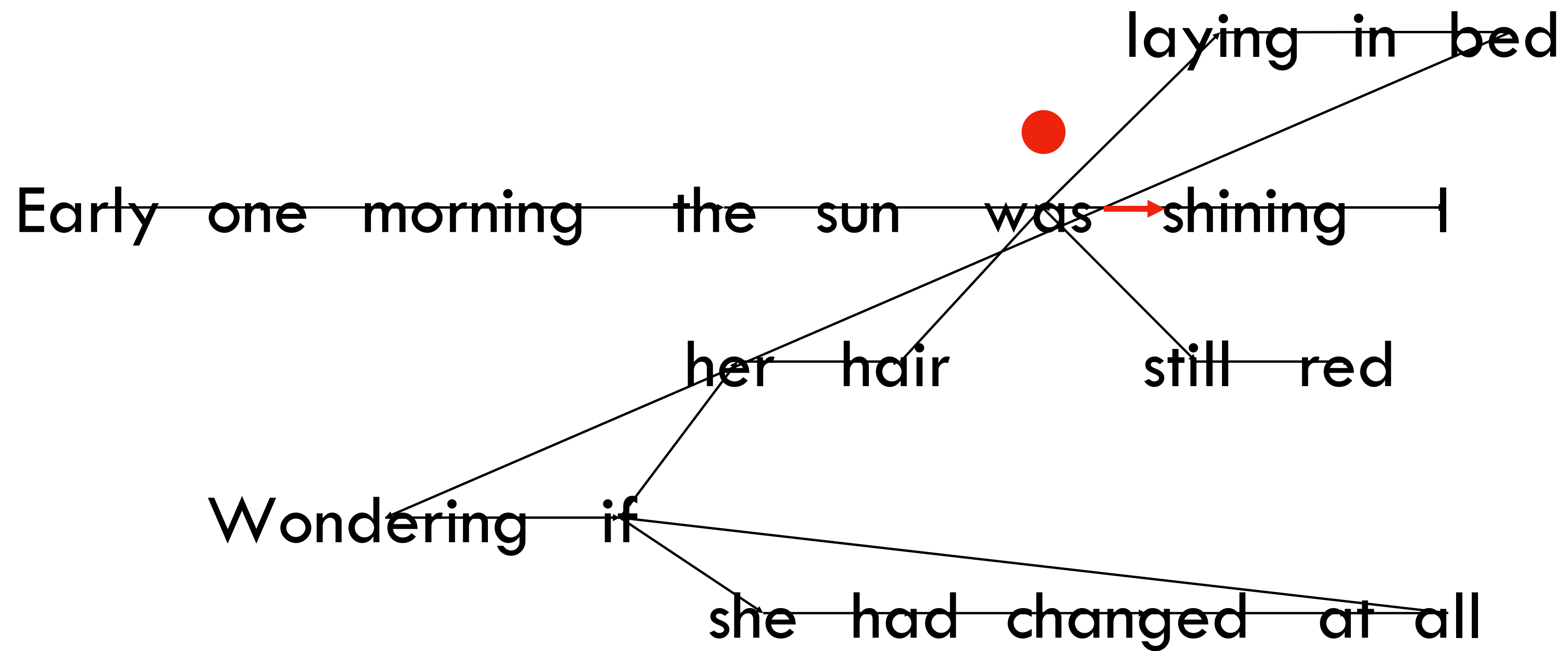
the sun was laying in bed



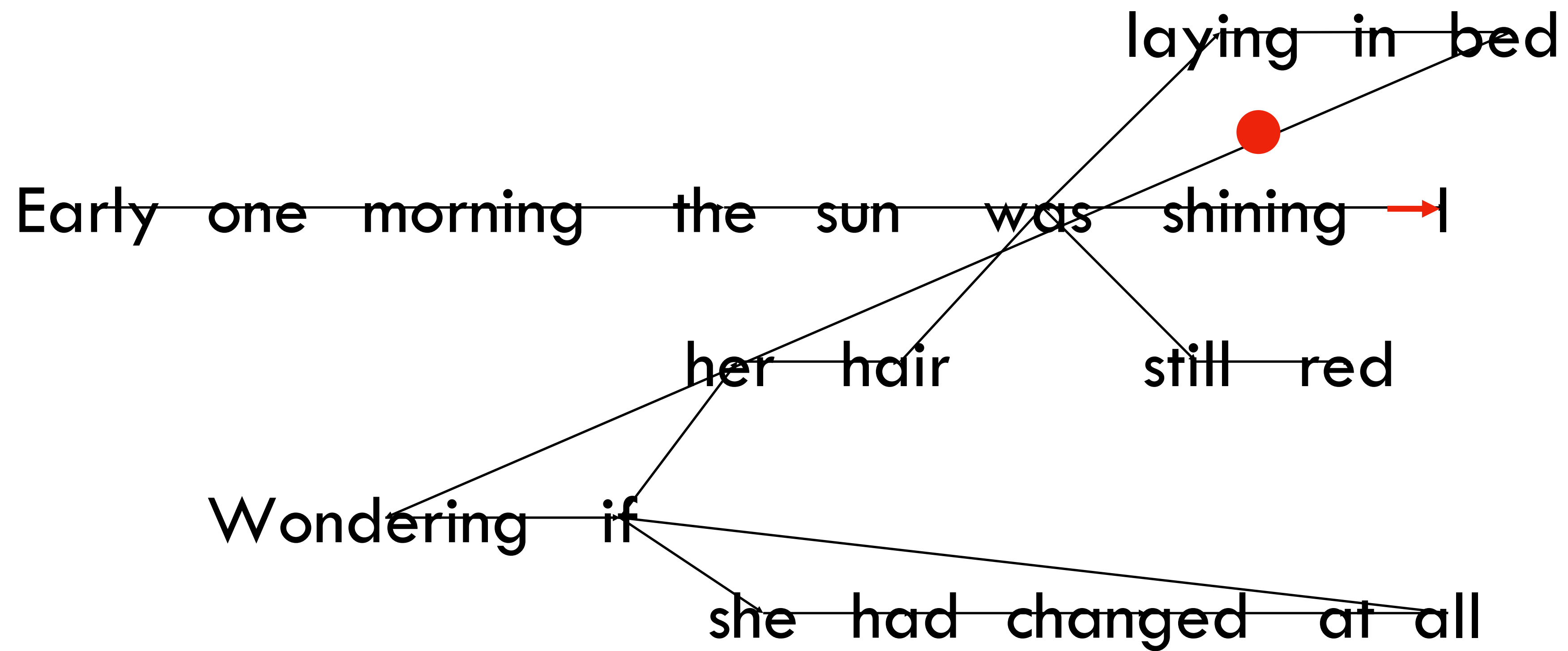
I



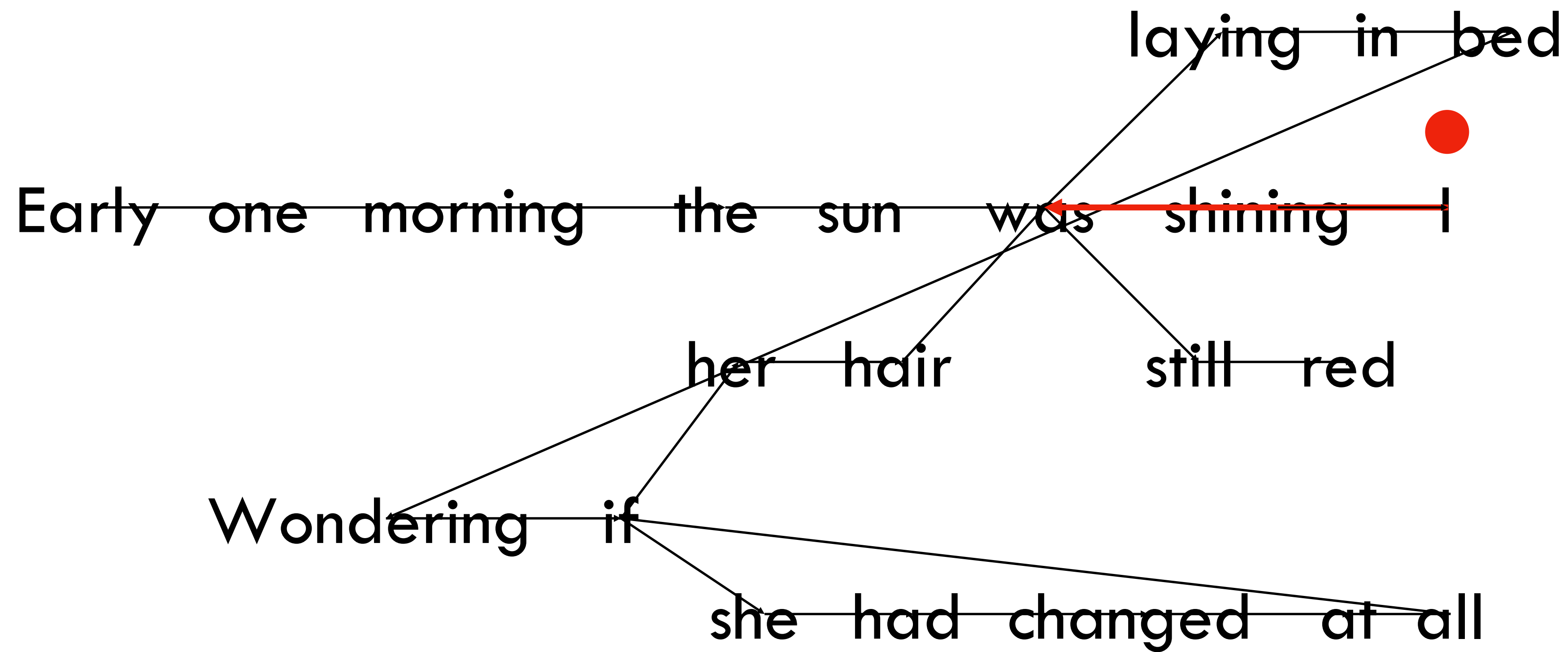
I was



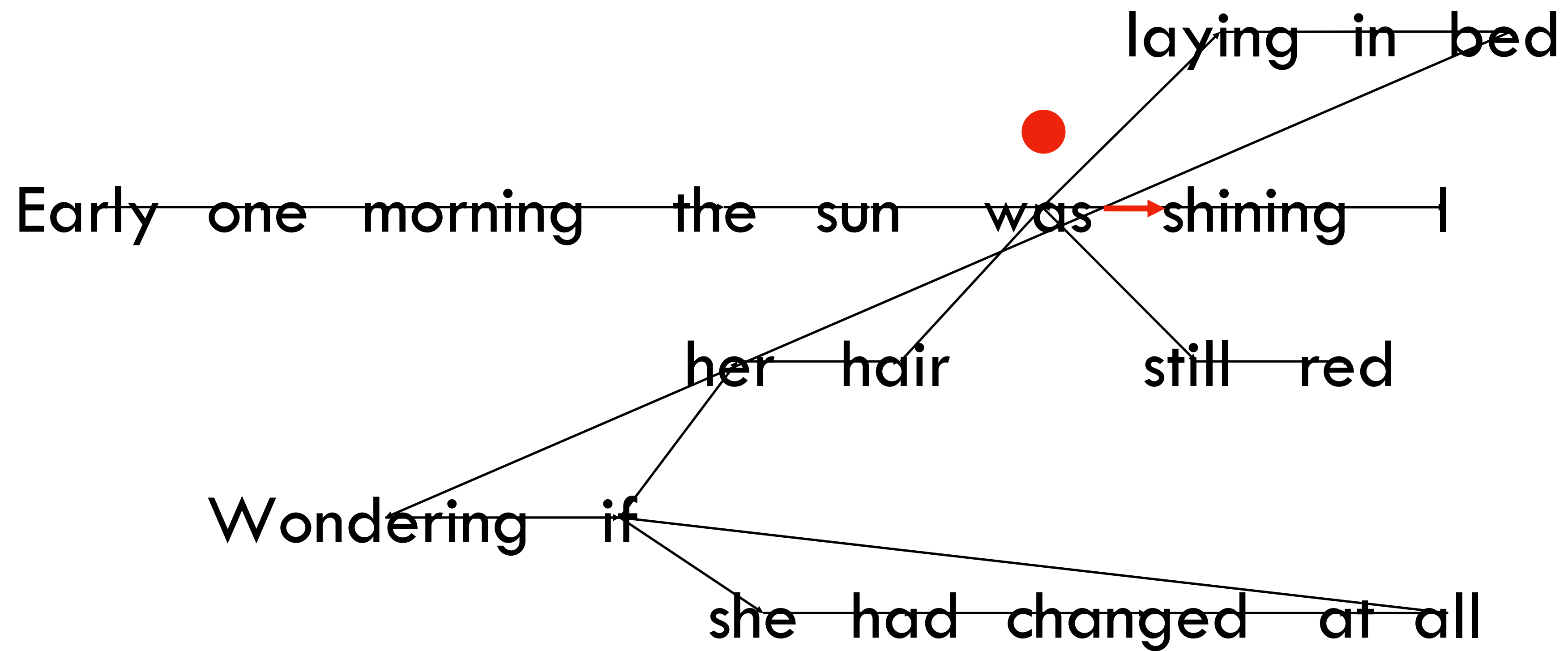
I was shining



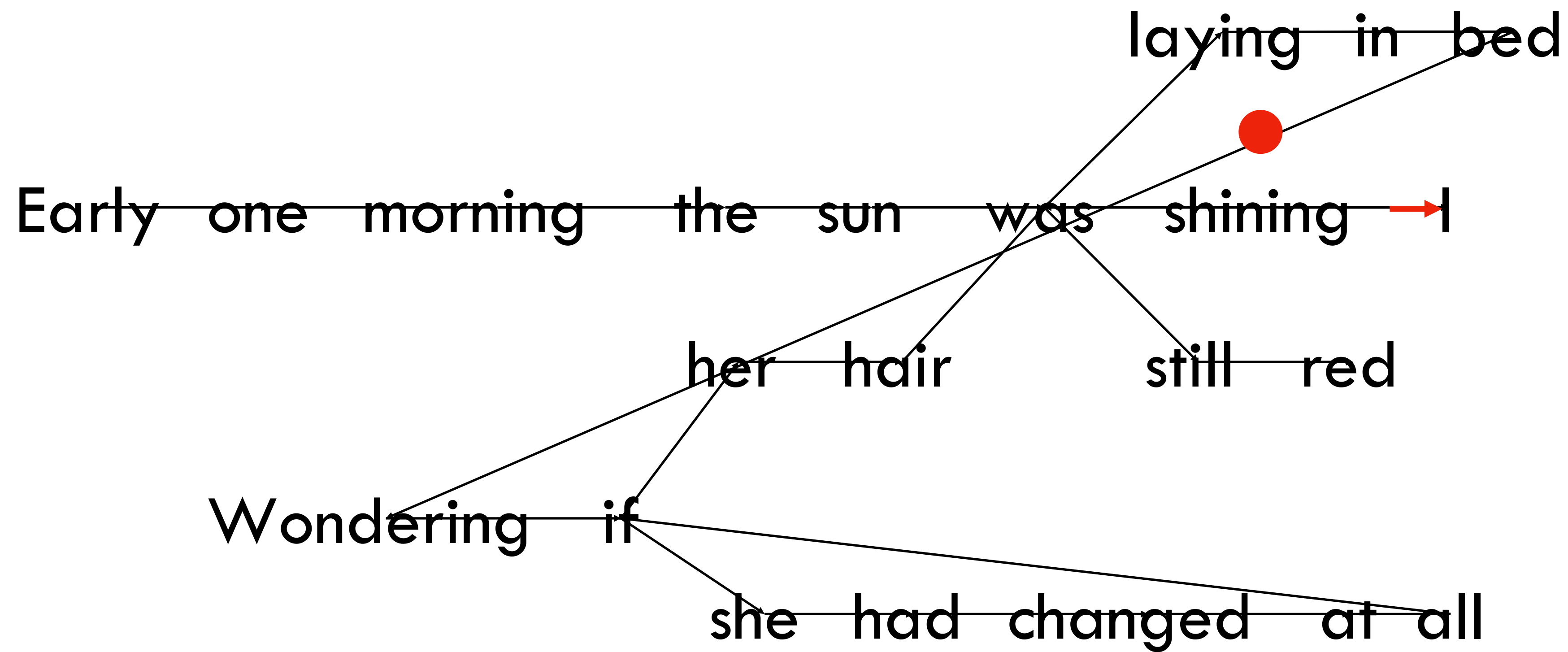
I was shining I



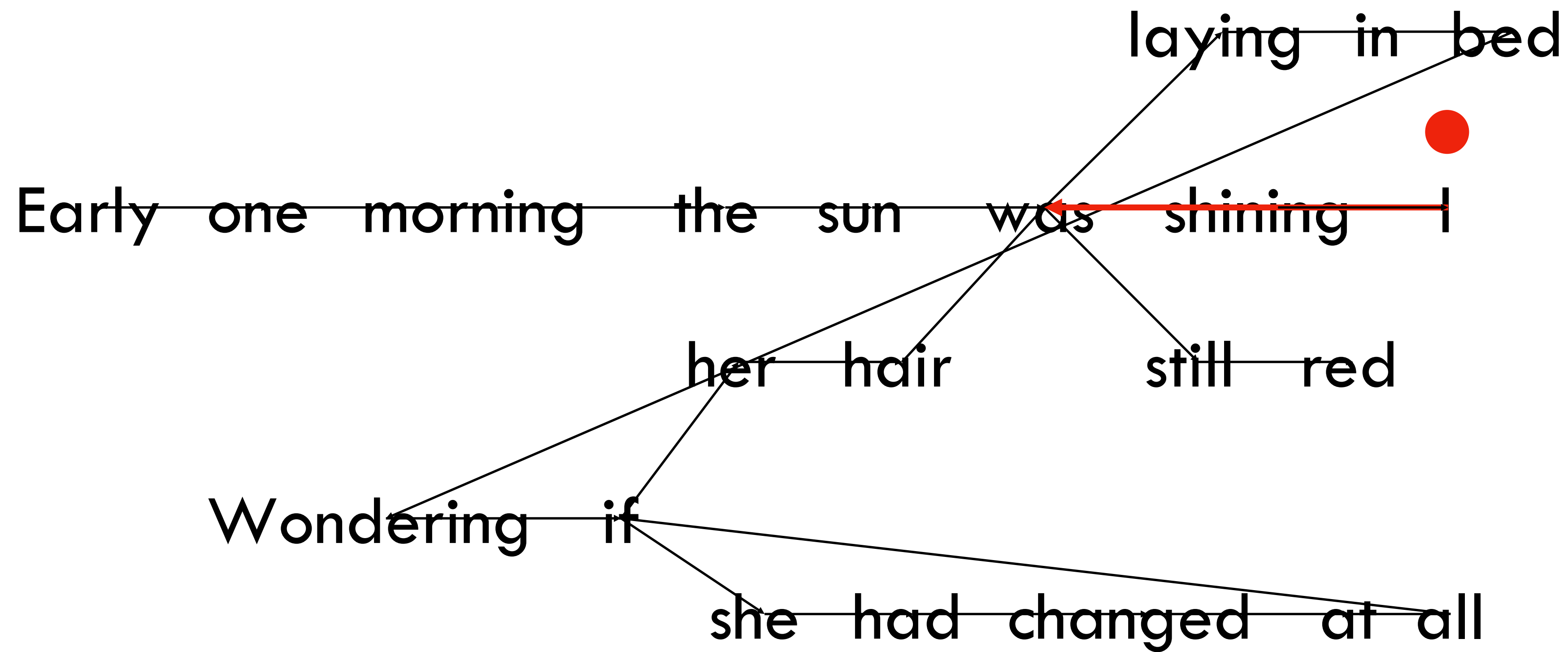
I was shining I was



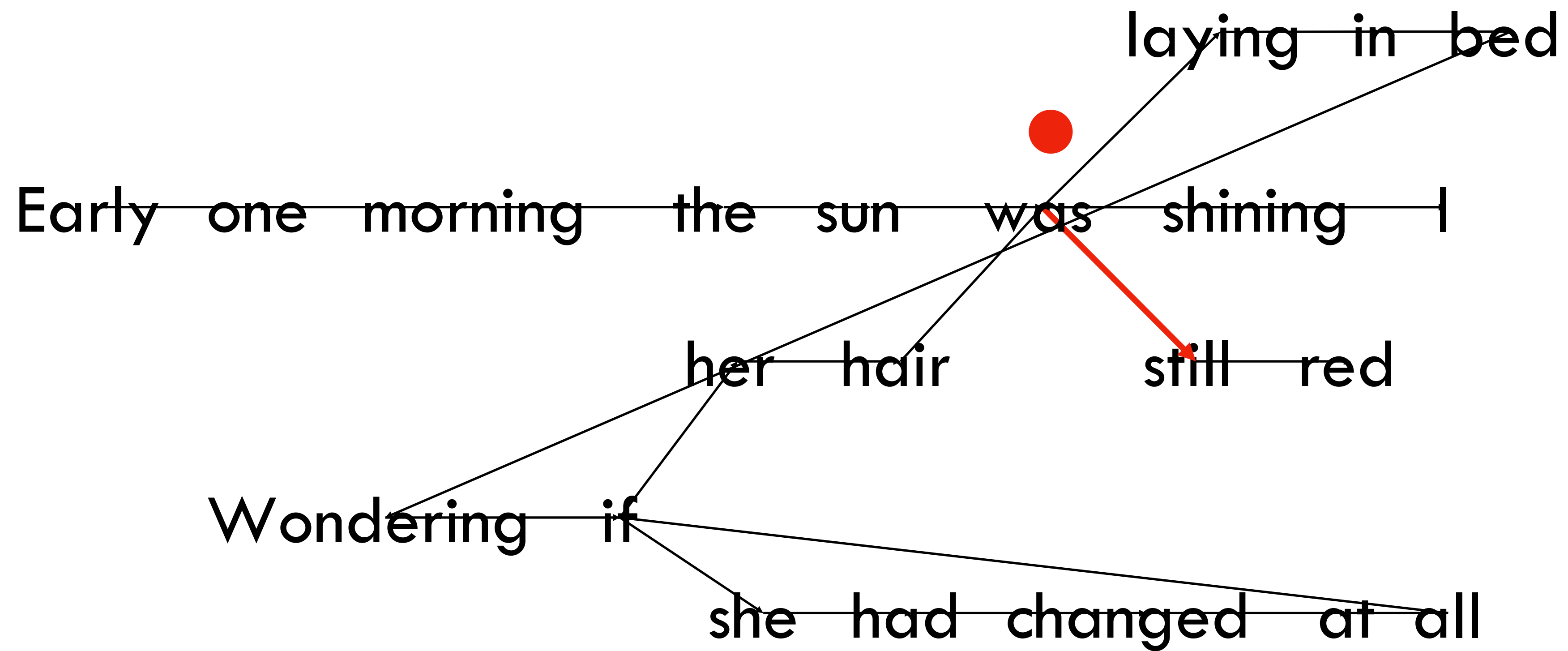
I was shining I was shining



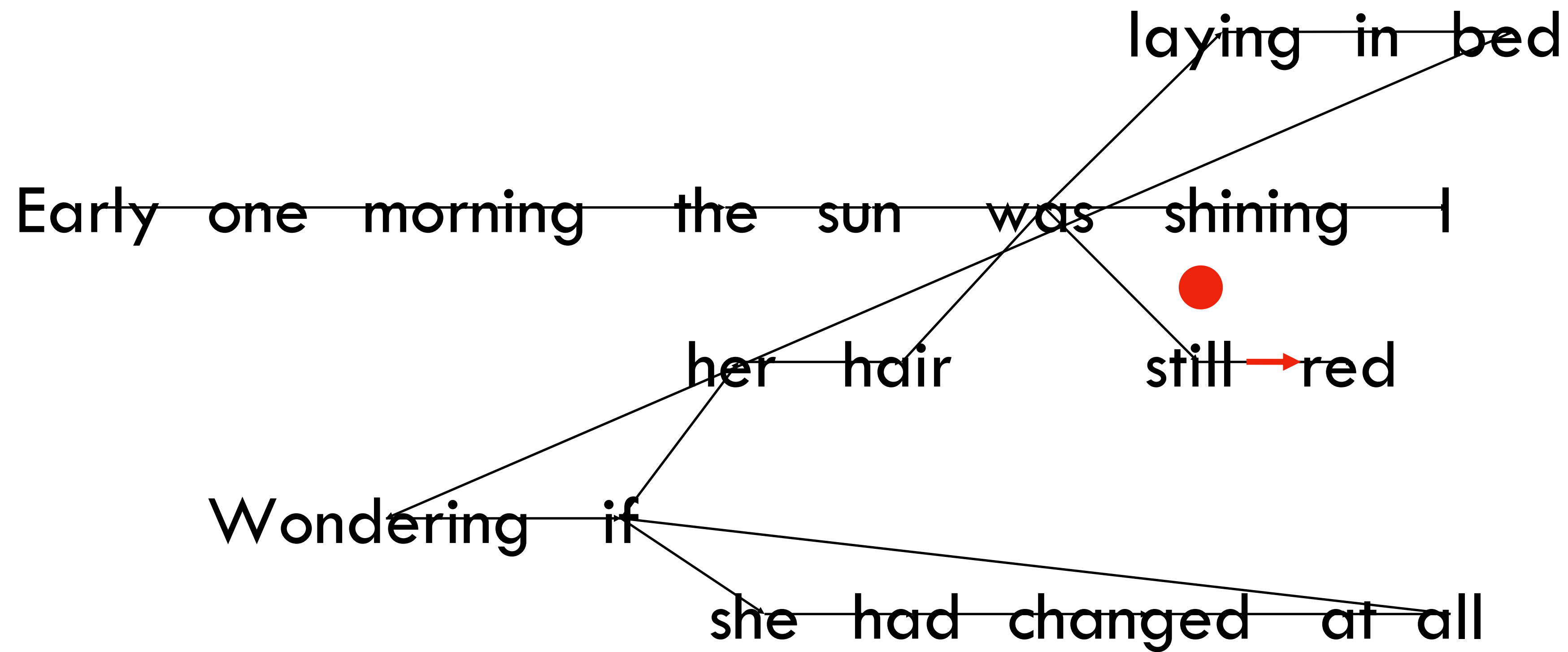
I was shining I was shining I



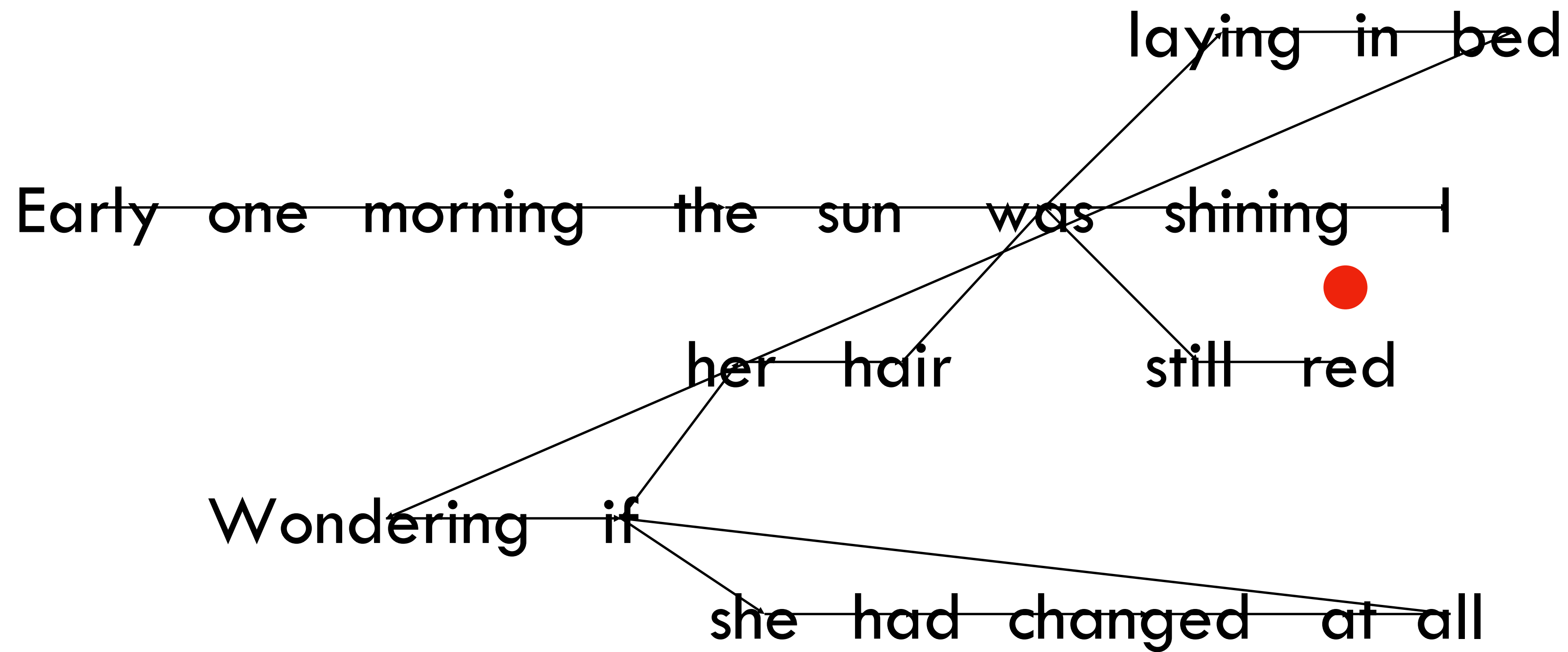
I was shining I was shining I was



I was shining I was shining I was still



I was shining I was shining I was still red



Early one morning the sun was shining
I was lying in bed
Wondering if that changed at all
If her hair was still red
Her hair they said our lives together
Sure was going to rough
They never did like Marlon's homemade dress
Papa's backhoe went by enough
And I was standing on the side of the road
Hair falling on my shoes
Heading out for the East Coast
Lynn knows he just some those getting through
Tangled up in blue
She was married after we first met
Seem to be divorced
I stepped her out of a job I guess
But I used a little too much force
We drove that car so far we could
Abandon it out there
Apt up in a dark red night
Both agreeing I was bad
She turned around to look at me
As I was walking away
I heard her say over my shoulder
That most again someday on the avenue
Tangled up in blue
I had a job in the great north woods
Working as a cook for a spell
But I never did that it all that much
And one day she just left
So I drifted down to New Orleans
Where I happened to be employed
Waiting for a while in a fishing boat
Right outside of Jackson
But all the while I was alone
The past was closed behind
I seen a lot of women
But she never escaped my mind and I just grew
Tangled up in blue
She was working in a liquor place
And I stopped in for a beer
I just had looking at the side of her face
In the spotlight so clear
And later on as the crowd formed out
I was just about to do the same
She was standing there in back of my chair
Said to me Girl I know your name
I murmured something underneath my breath
She looked the lines on my face
I must admit I felt a little shrewd
When she bent down to tie the laces of my shoe
Tangled up in blue
She is a burner on the stove
And offered me a pipe
I thought you'd hear say baby she said
You look like the silent type
Then she opened up a book of poems
And handed it to me
Written by an Italian poet
From the fourteenth century
And every one of them sounds long true
And glossed the burning coal
Pouring off of every page
Like it was written in my soul from me to you
Tangled up in blue
I lived with them on Monroque Street
In a basement down the stairs
There was music in the walls at night
And revolution in the air
Then he started the dealing with power
And something inside of him said
She had to sell everything she owned
And broke up with
And when finally the bottom fell out
I became withdrawn
The only thing I know how to do
Was to keep on keeping on that a job that line
Tangled up in blue
So now I'm going back again
I got to get to her somehow
All the people are used to know
They're go down to me now
Some are professional
Some are independent wives
Don't know how it all got started
I don't know what they're doing with their lives
But me I'm still on the road
Heading for another joint
We always did hear the advice
We just saw it from a different point of view
Tangled up in blue

she was standing on the side of my mind

...

side of my shoes heading out of my face

...

one of my chair said our lives together

...

Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all if her hair was still red

Early one morning

trigrams

Early one morning the sun was shining I was laying in bed

Wondering if she had changed at all if her hair was still red

Early one morning

one morning the

trigrams

Early one morning the sun was shining I was laying in bed

Wondering if she had changed at all if her hair was still red

Early one morning
one morning the
morning the sun

trigrams

Early one morning the sun was shining I was laying in bed

Wondering if she had changed at all if her hair was still red

Early one morning
one morning the
morning the sun
the sun was

trigrams

Early one morning the sun was shining I was laying in bed

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Early one morning
one morning the
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trigrams

Early one morning the sun was shining I was laying in bed

Wondering if she had changed at all if her hair was still red

Early one morning

one morning the

morning the sun

the sun was

sun was shining

was shining I

shining I was

I was laying

...

trigrams

$$P(x_n | x_{n-1}, x_{n-2})$$

Early one → morning
one morning → the
morning the → sun
the sun → was
sun was → shining
was shining → I
shining I → was
I was → laying
...

Early one morning the sun was shining
I was lying in bed
Wondering if time changed at all
If her hair was still red
Her hair they said our lives together
Sure was going to rough
They never did like Marsha's homemade dress
Papa's backhoe went by enough
And I was standing on the side of the road
Hair falling on my shoes
Heading out for the East Coast
Lynn knows he just came home getting through
Tangled up in blue
She was married after we first met
Seem to be divorced
I helped her out of a jam - I guess
But I wasn't a little too much time
We drove that car for as long as we could
Abandoned it out there
Apt up in a dark wet night
Both agreeing I was tired
She turned around to look at me
As I sat smiling away
I helped her say over my shoulder
That most again someday on the avenue
Tangled up in blue
I had a job in the great north woods
Working as a cook for a spell
But I never did that it all that much
And one day she just left
So I drifted down to New Orleans
Where I happened to be employed
Working for a while on a fishing boat
Right outside of Delcambre
But all the while I was alone
The past was closed behind
I seen a lot of women
But she never escaped my mind and I just grew
Tangled up in blue
She was working in a lousy place
And I stopped in for a beer
I just had looking at the side of her face
In the sunlight so clear
And later on as the crowd formed out
I was just about to do the same
She was standing there in back of my chair
Said to me Girl I know your name
I mumbled something underneath my breath
She noticed the tears on my face
I must admit I felt a little shrewish
When she bent down to tie the laces of my shoe
Tangled up in blue
She is a burner on the stove
And offered me a pipe
I thought you'd know why folks she said
You look like the silent type
Then she opened up a book of poems
And handed it to me
Written by an Italian poet
From the fourteenth century
And every one of them sounds long true
And glossed the burning coal
Pouring off of every page
Like it was written in my soul from me to you
Tangled up in blue
I lived with them on Monroque Street
In a basement down the stairs
There was music in the walls at night
And revolution in the air
Then he started the dealing with poems
And something inside of him said
She had to see everything she owned
And broke up inside
And when finally the bottom fell out
I became withdrawn
The only thing I know how to do
Was to keep on keeping on that a poet that she
Tangled up in blue
So now I'm going back again
I got to get to her somehow
All the people are used to know
They're go down to me now
Some are professionalists
Some are independent artists
Don't know how it all got started
I don't know what they're doing with their lives
But me I'm still on the road
Heading for another joint
We always did hear the advice
We just saw it from a different point of view
Tangled up in blue

well meet again someday on the stove ...

standing there in back of my shoe tangled ...

i was standing on the stove and offered me a pipe

Early one morning the sun was shining I was laying in bed

Wondering if she had changed at all if her hair was still red

Early one morning the sun was shining I was laying in bed
Wondering if she had changed at all if her hair was still red

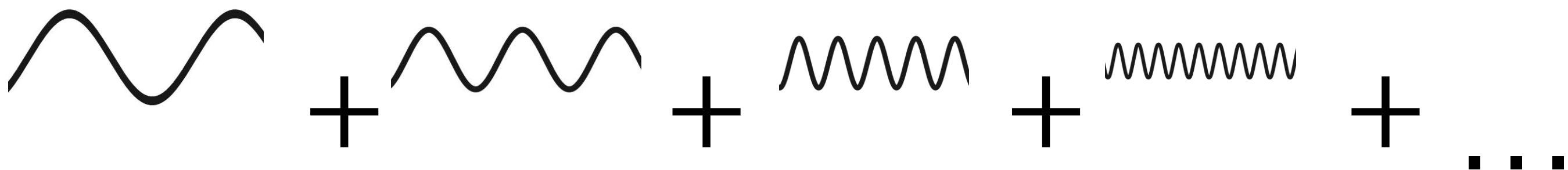



Early one morning the sun was shining I was laying in bed

Wondering if she had changed at all if her hair was still red




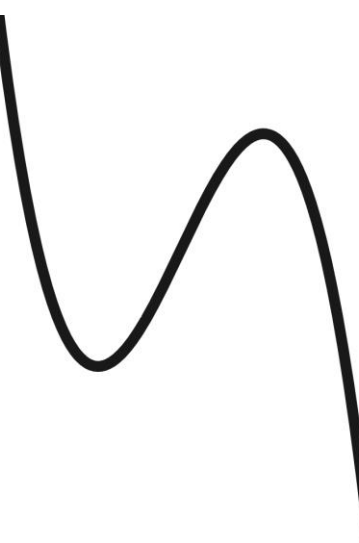
$$P(x_n | x_{n-1}, x_{n-2}, x_{n-3}, x_{n-4}, x_{n-5}, x_{n-6}, x_{n-7}, x_{n-8}, x_{n-9}, x_{n-10}, x_{n-11}, x_{n-12}, x_{n-13})$$

10^{70} combinations

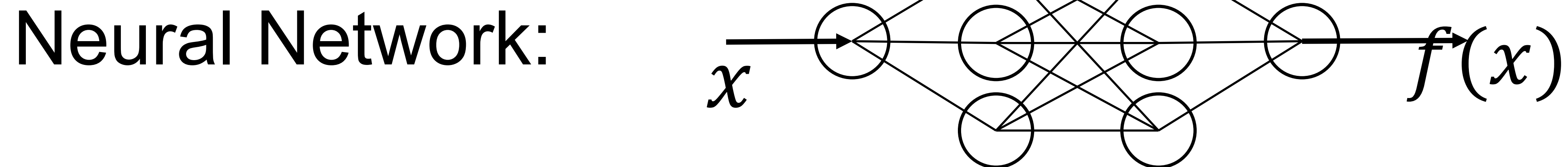
Function Approximation

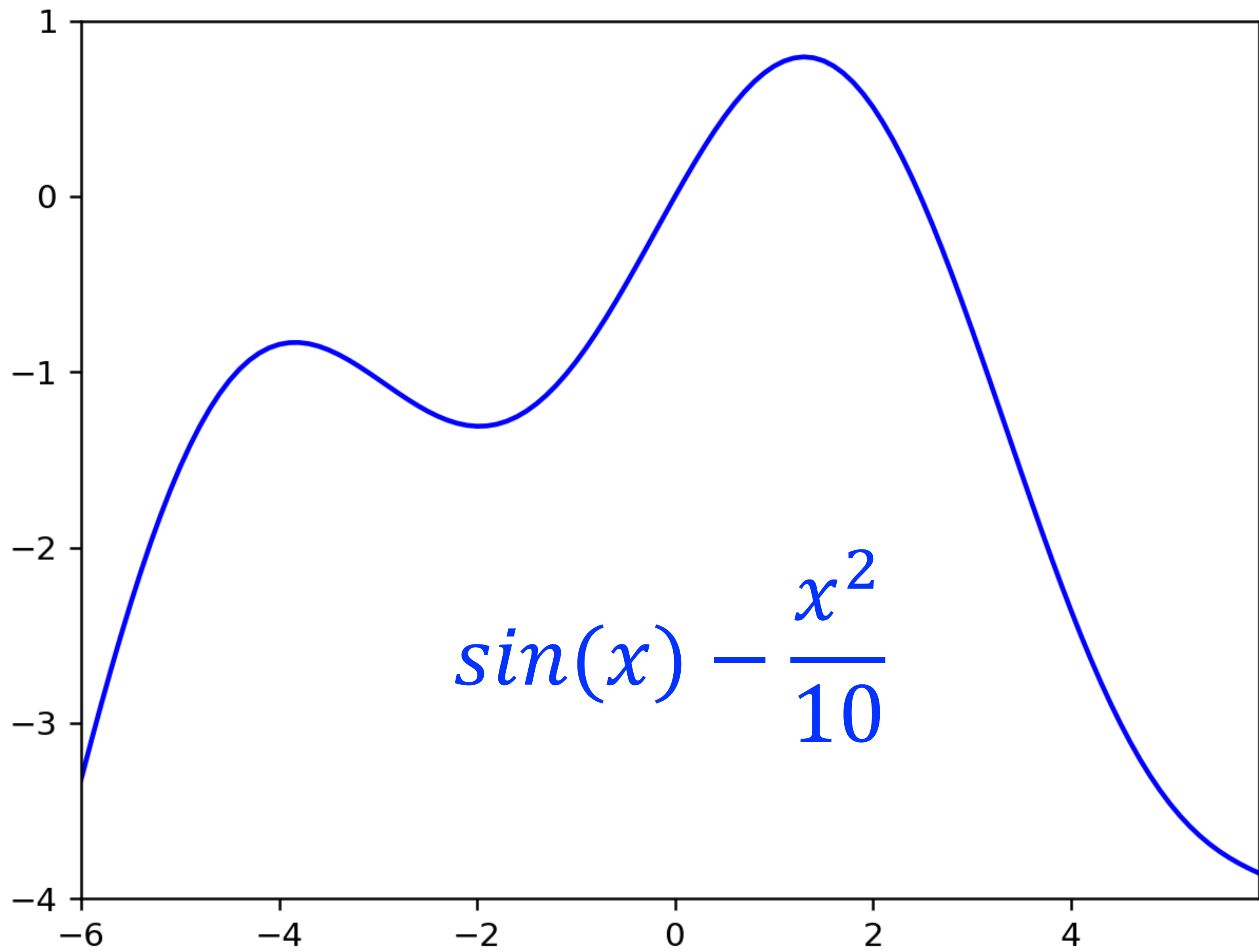
Fourier Series: $f(x) =$  $+$  $+$  $+$  $+$...

The diagram shows the Fourier series approximation of a function $f(x)$ as a sum of sine waves. The first term is a single sine wave. The second term is a sine wave with a higher frequency. The third term is a sine wave with an even higher frequency. The fourth term is a sine wave with a very high frequency. The series continues with more terms, indicated by an ellipsis.

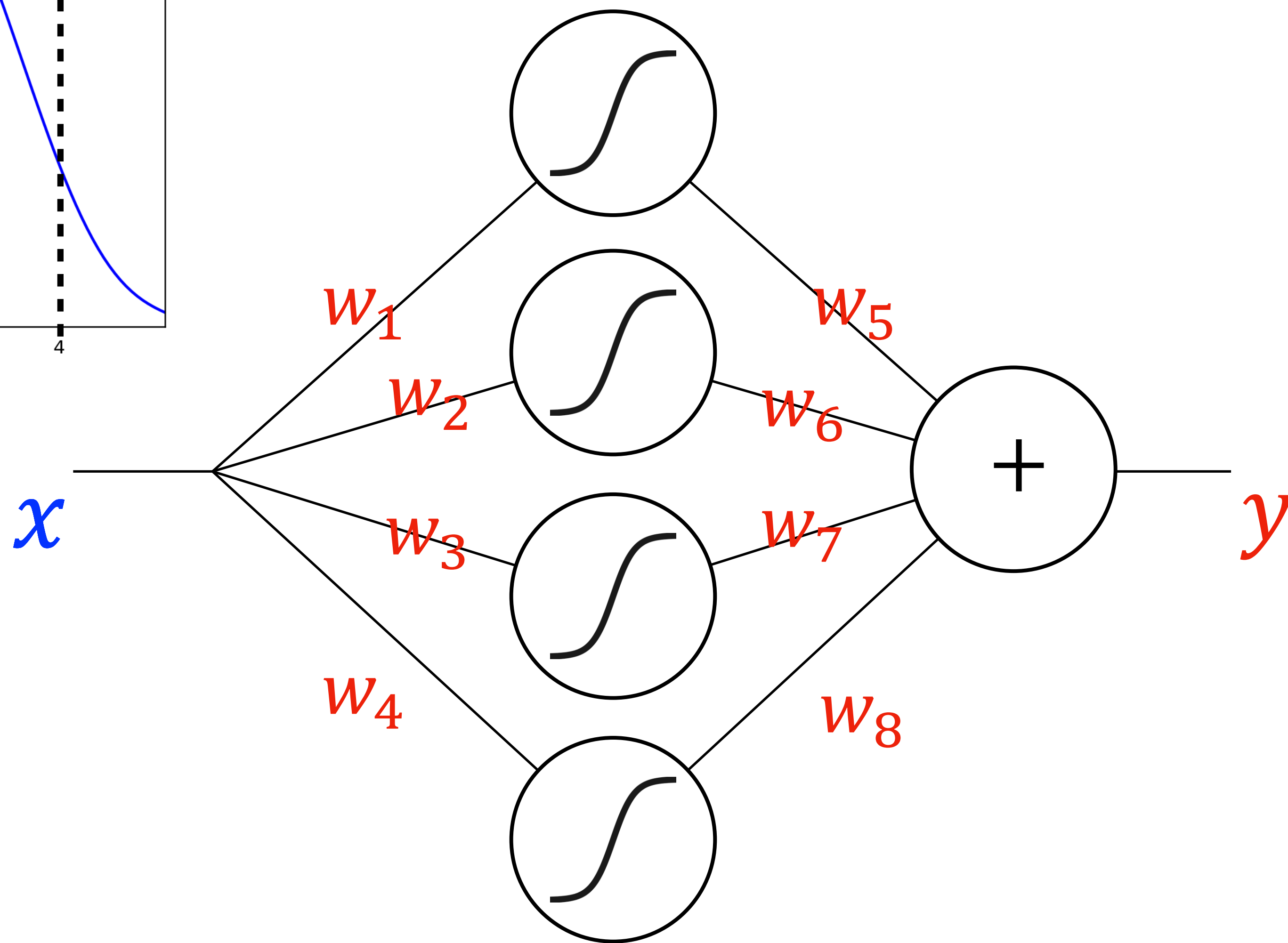
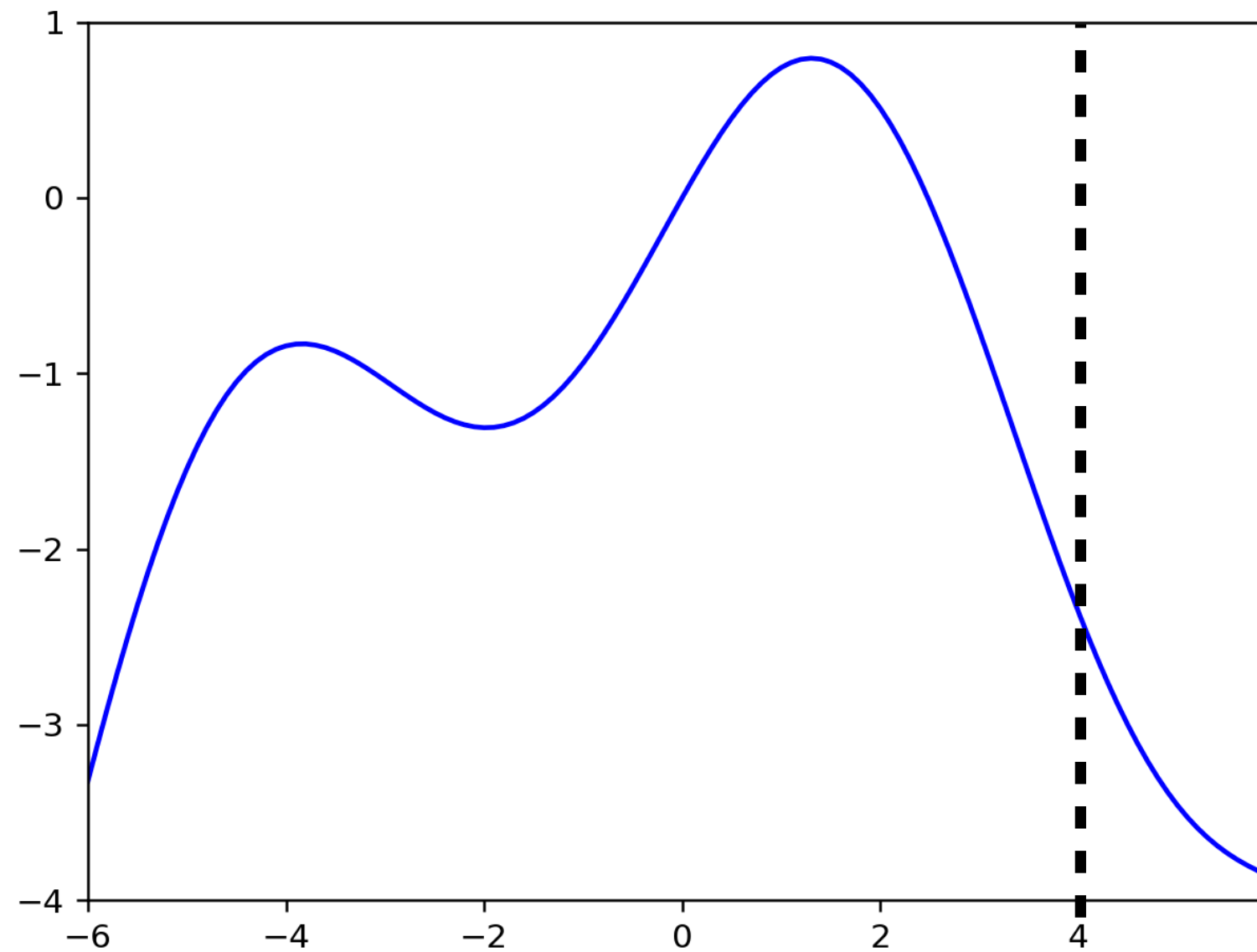
Taylor Series: $f(x) =$  $+$  $+$  $+$  $+$...

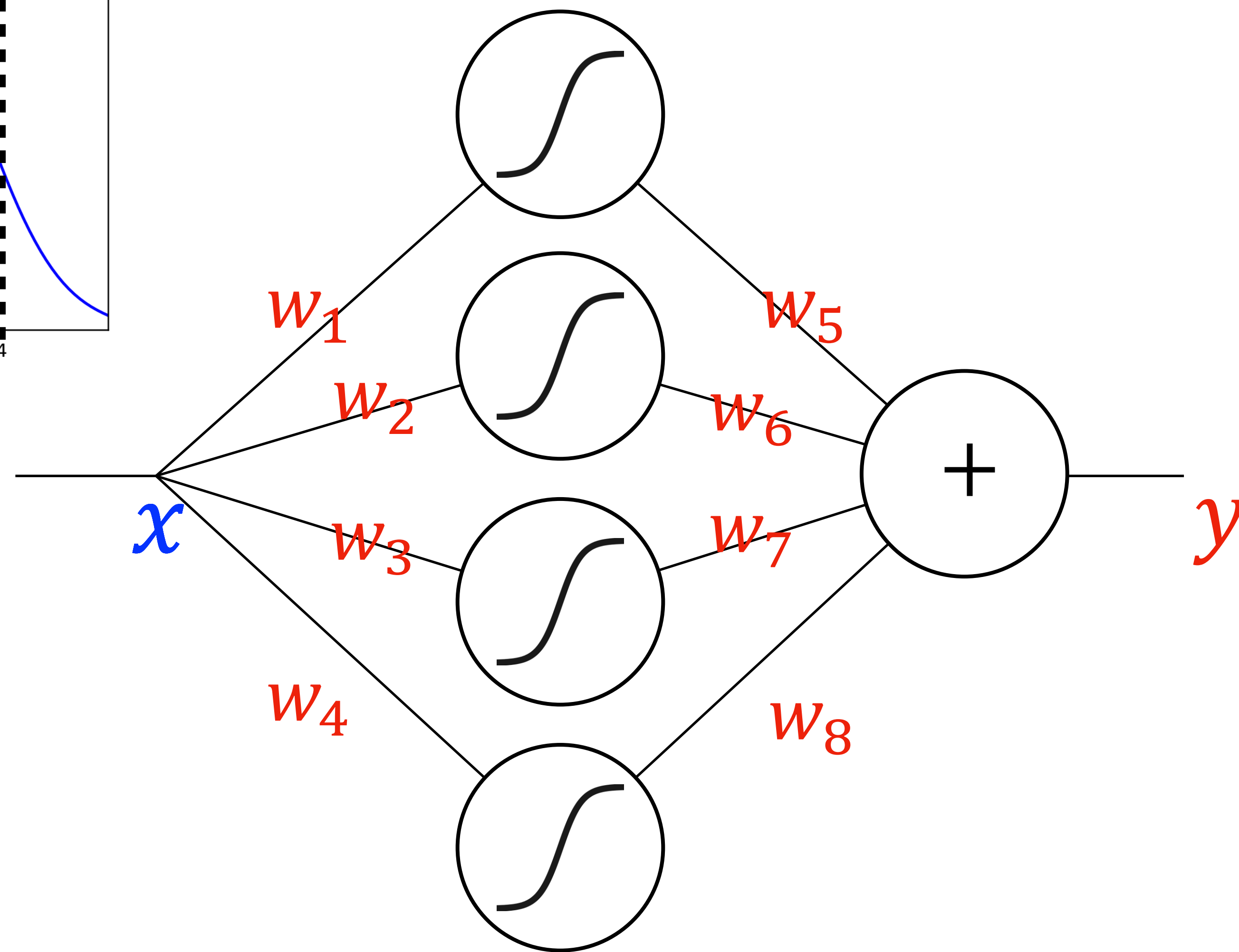
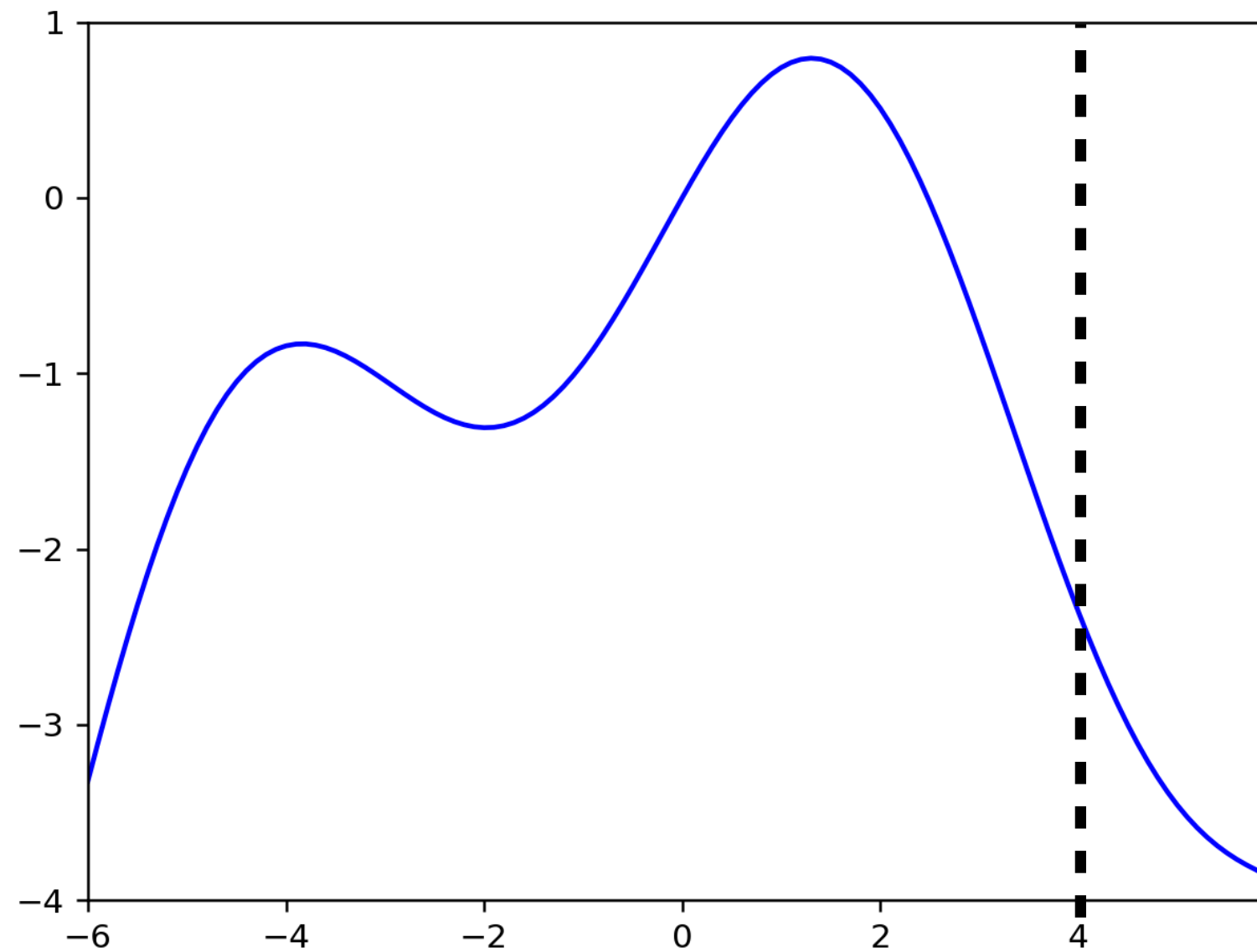
The diagram shows the Taylor series approximation of a function $f(x)$ as a sum of polynomial terms. The first term is a constant (a horizontal line). The second term is a linear term (a diagonal line). The third term is a quadratic term (a parabola). The fourth term is a cubic term (a curve). The series continues with more terms, indicated by an ellipsis.

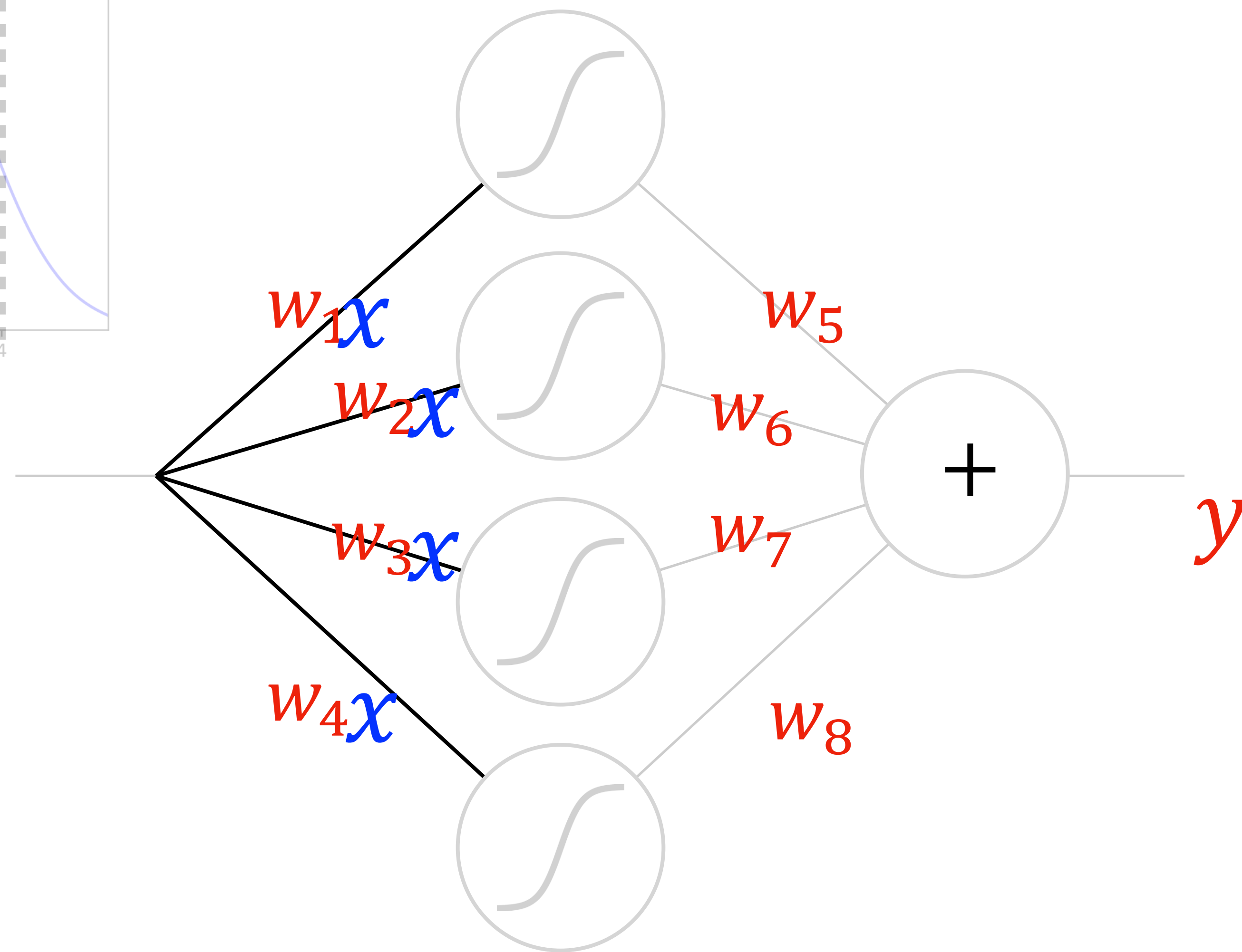
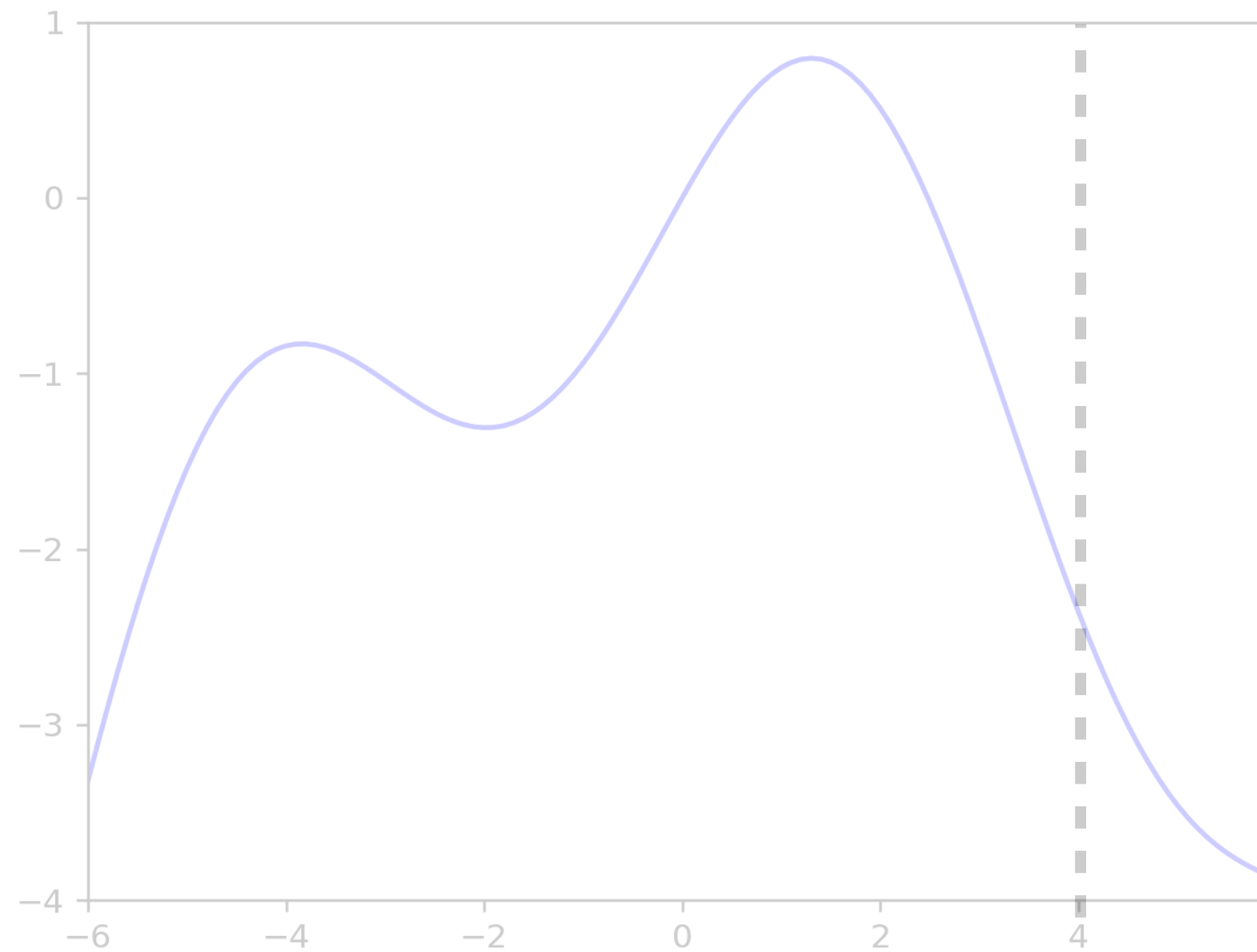


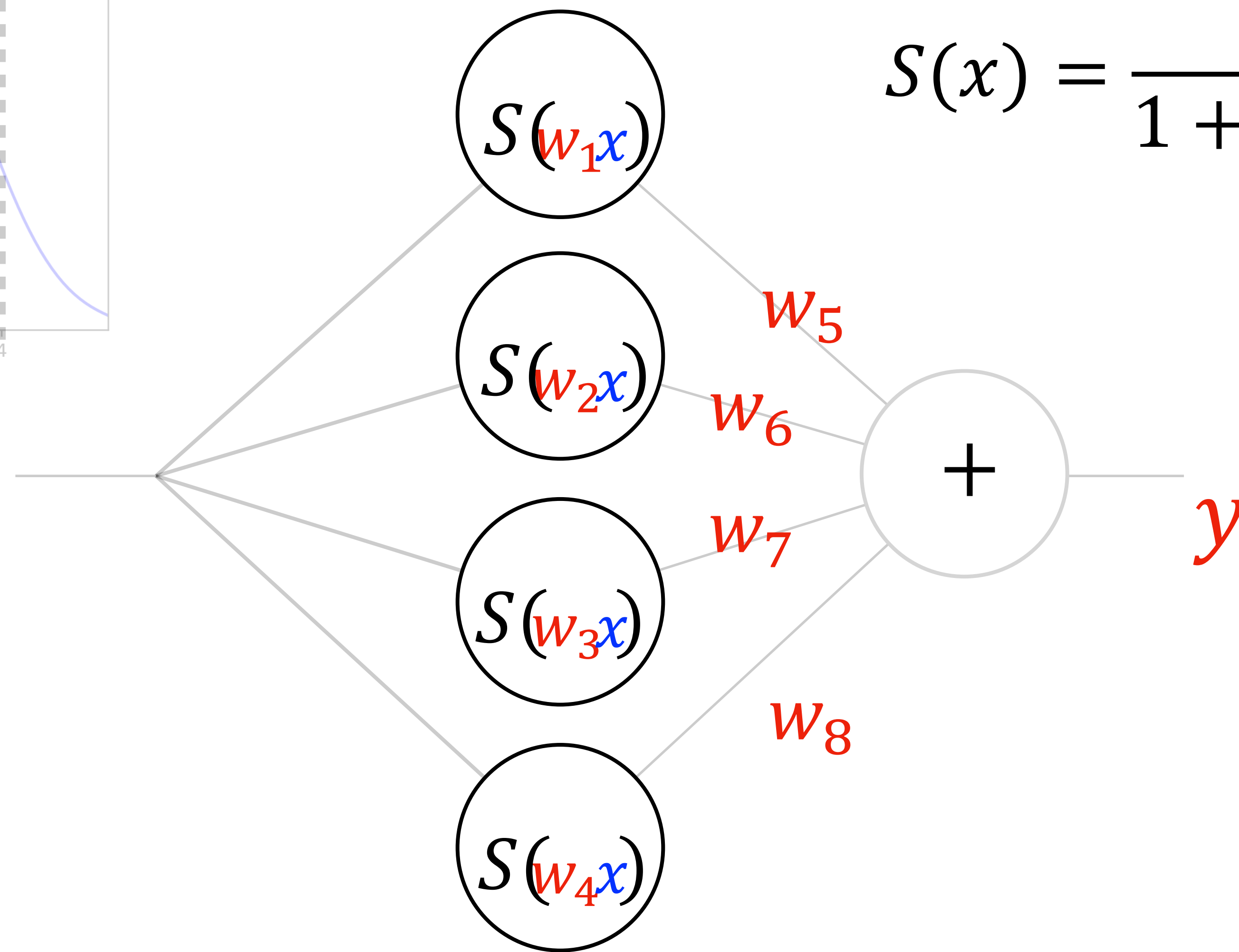
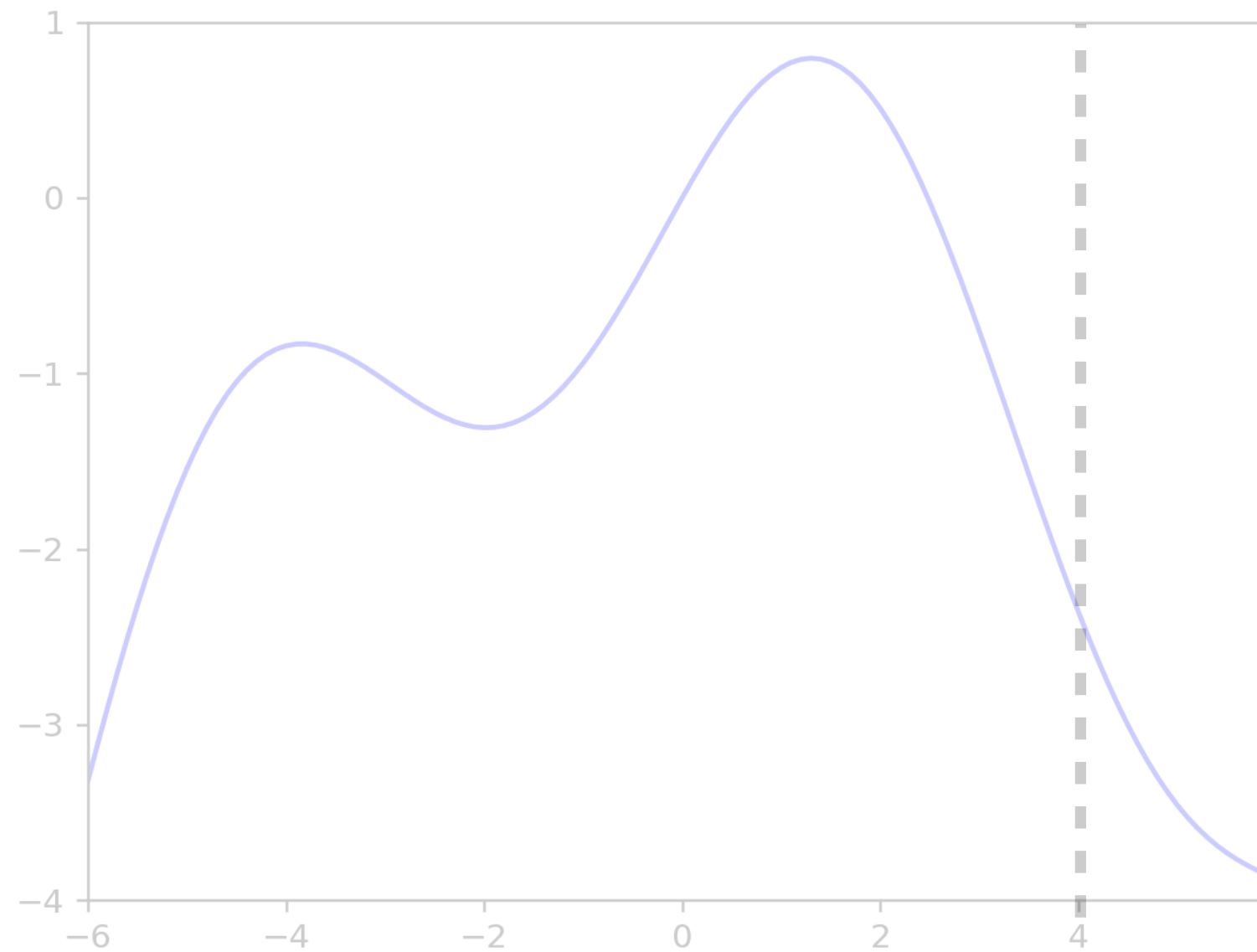


sigmoid

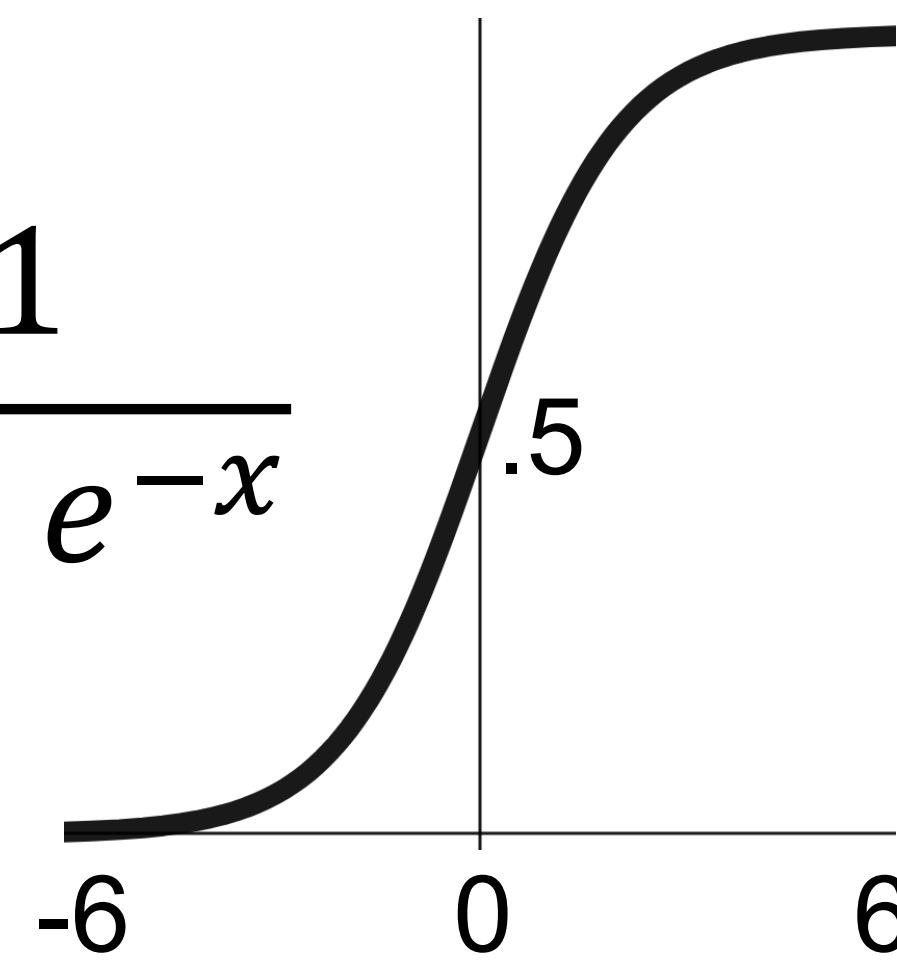


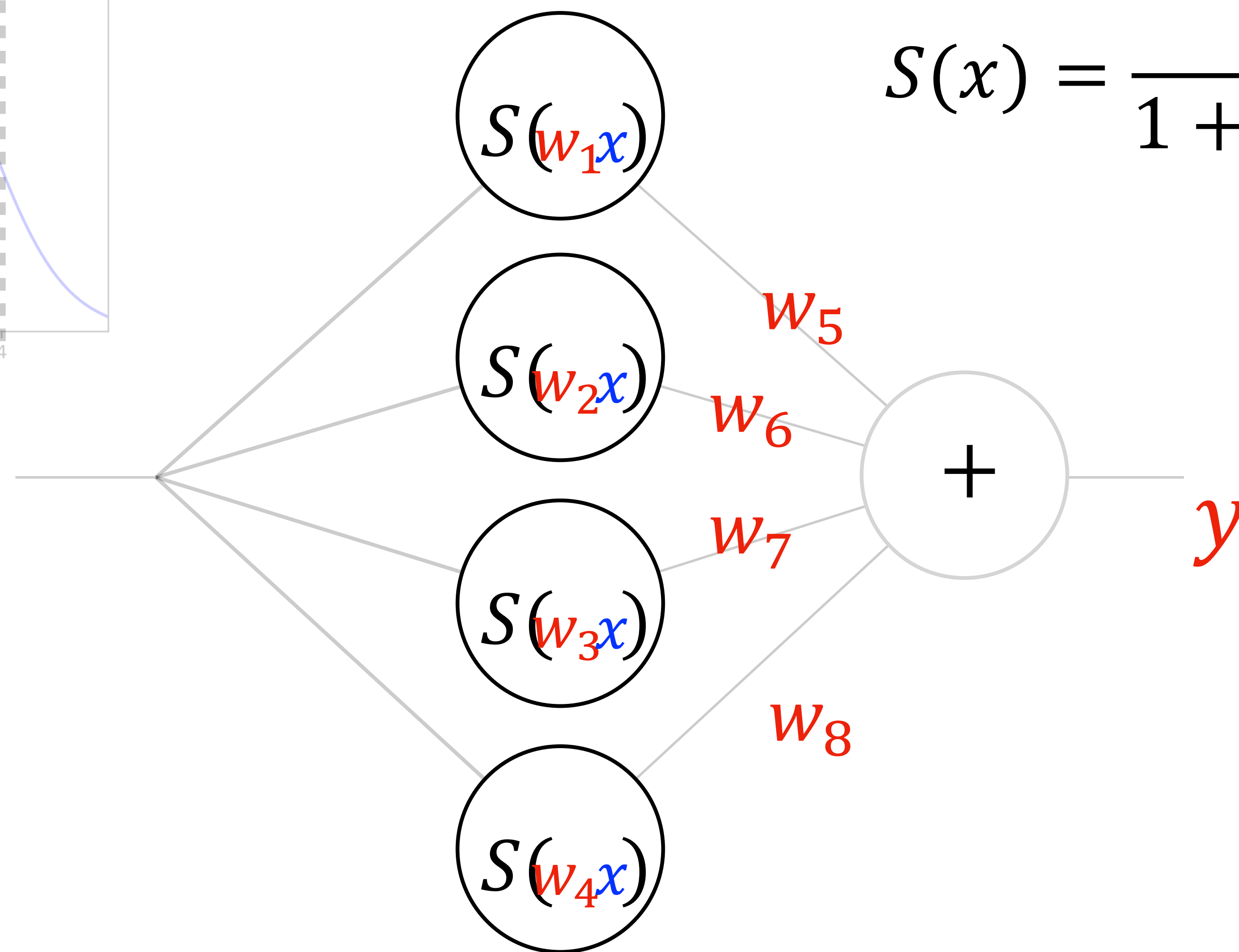
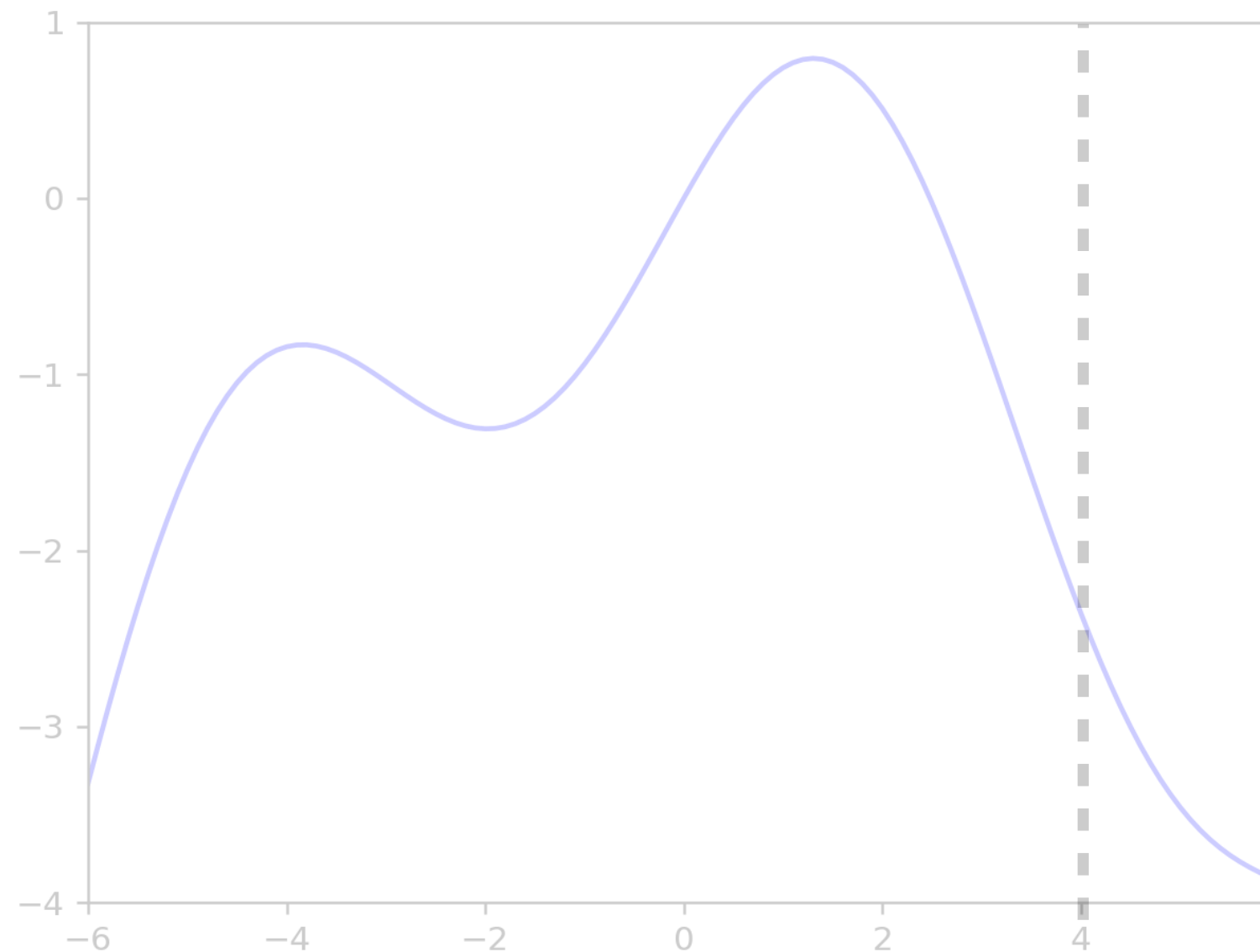




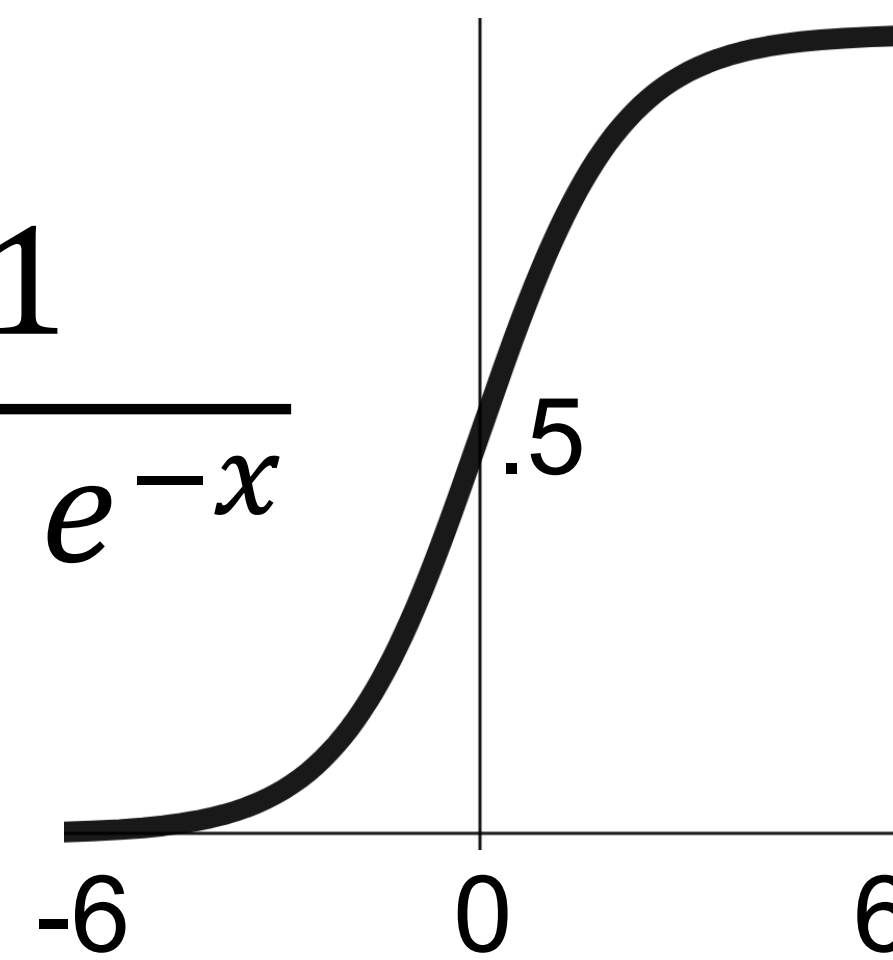


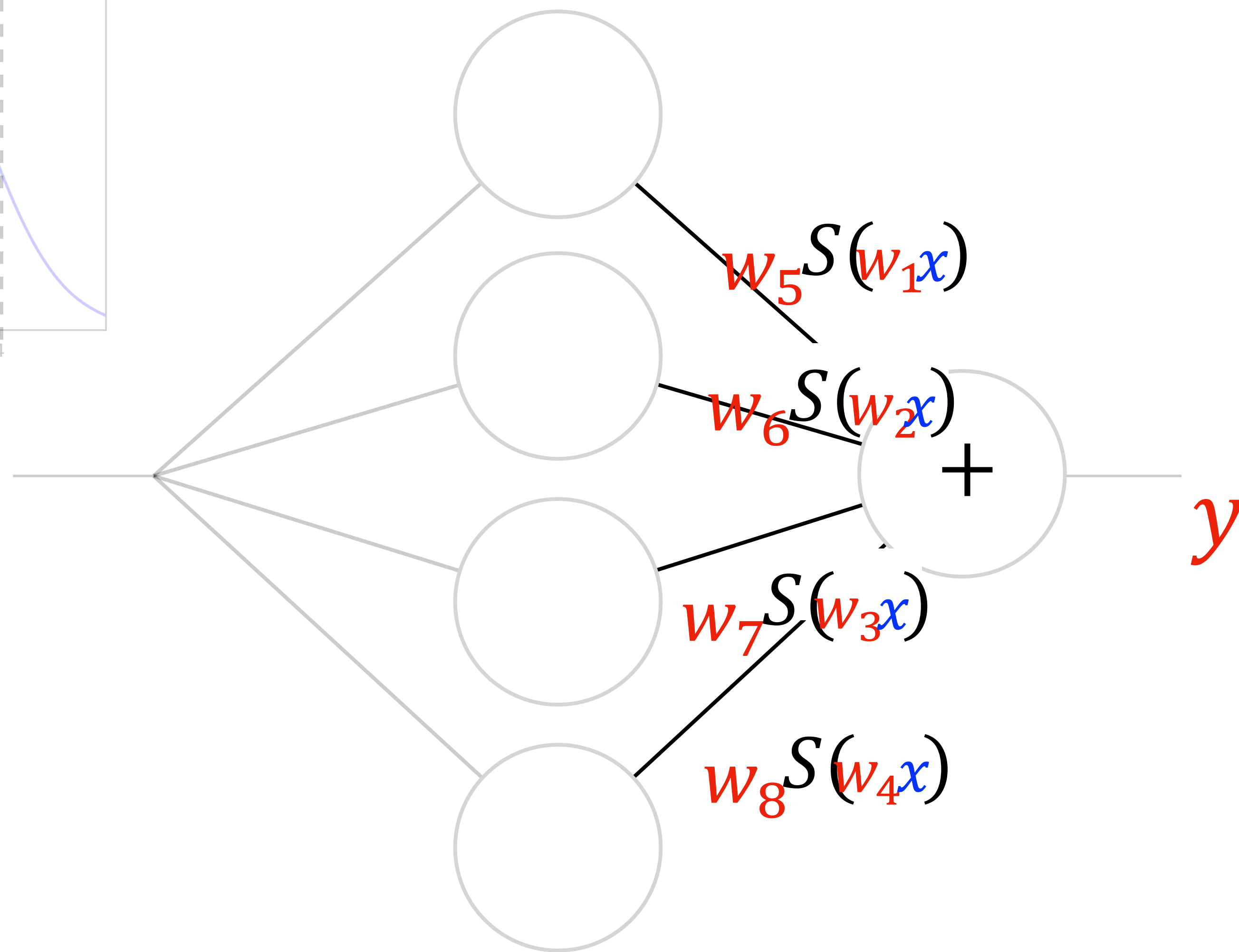
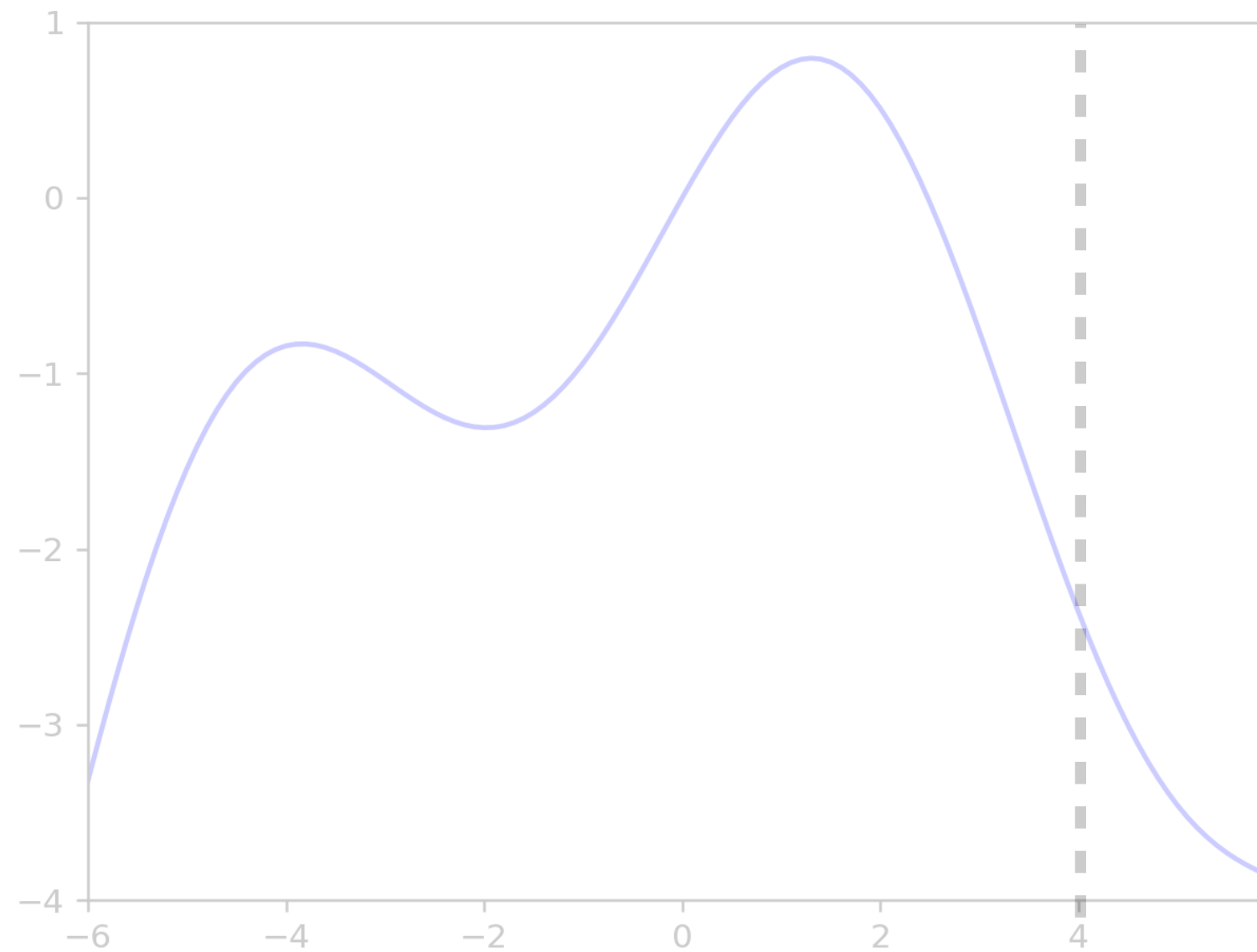
$$S(x) = \frac{1}{1 + e^{-x}}$$

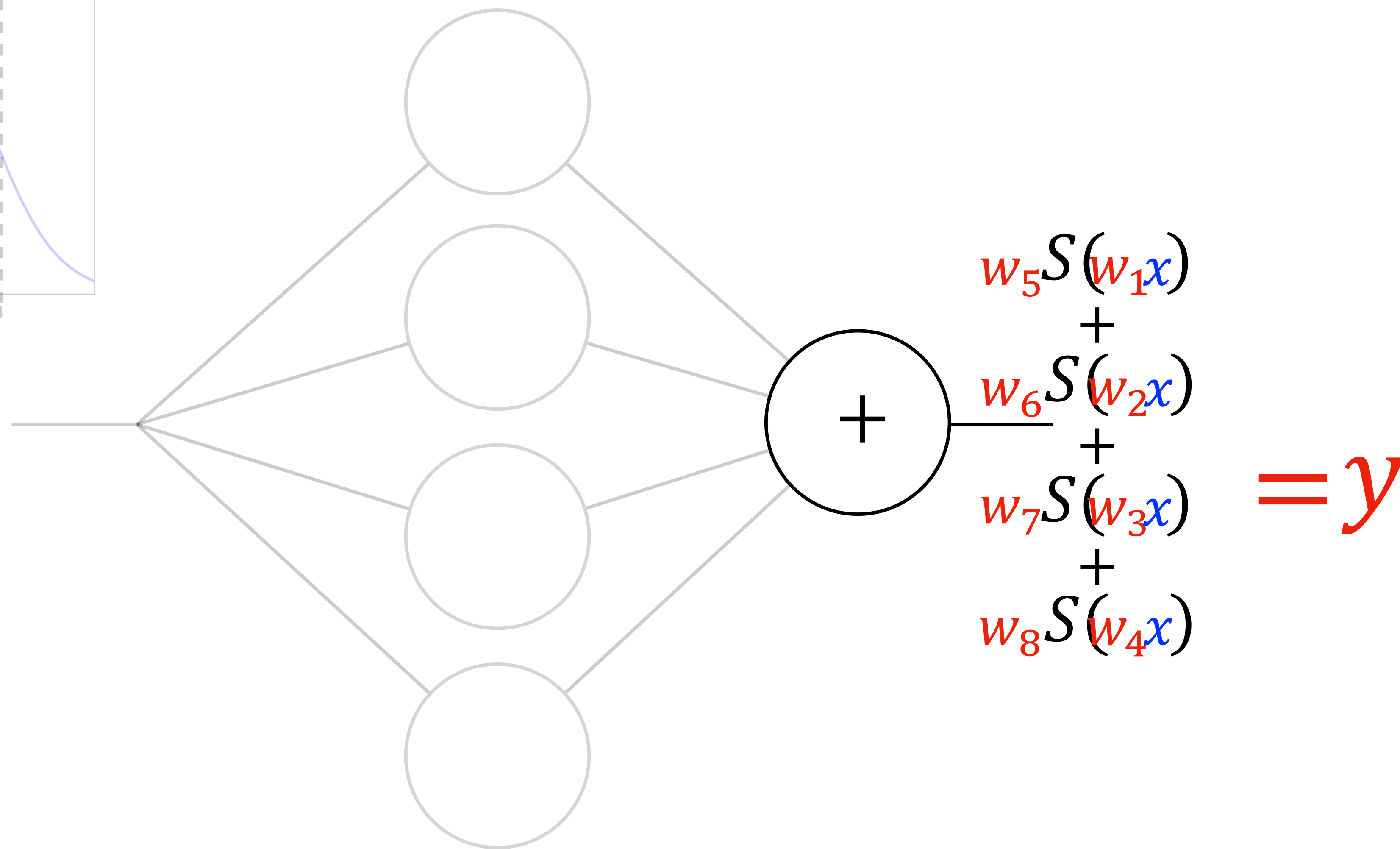
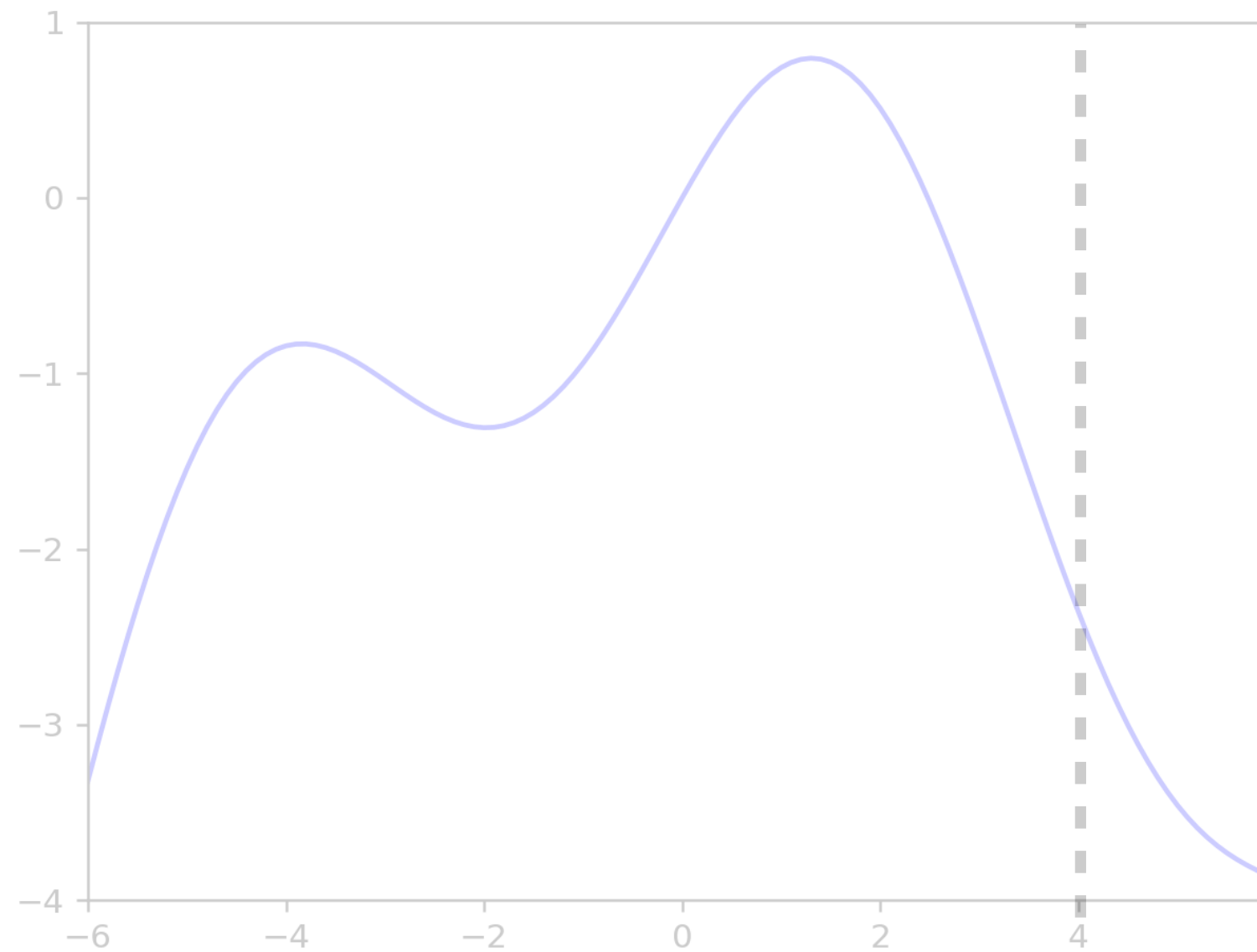


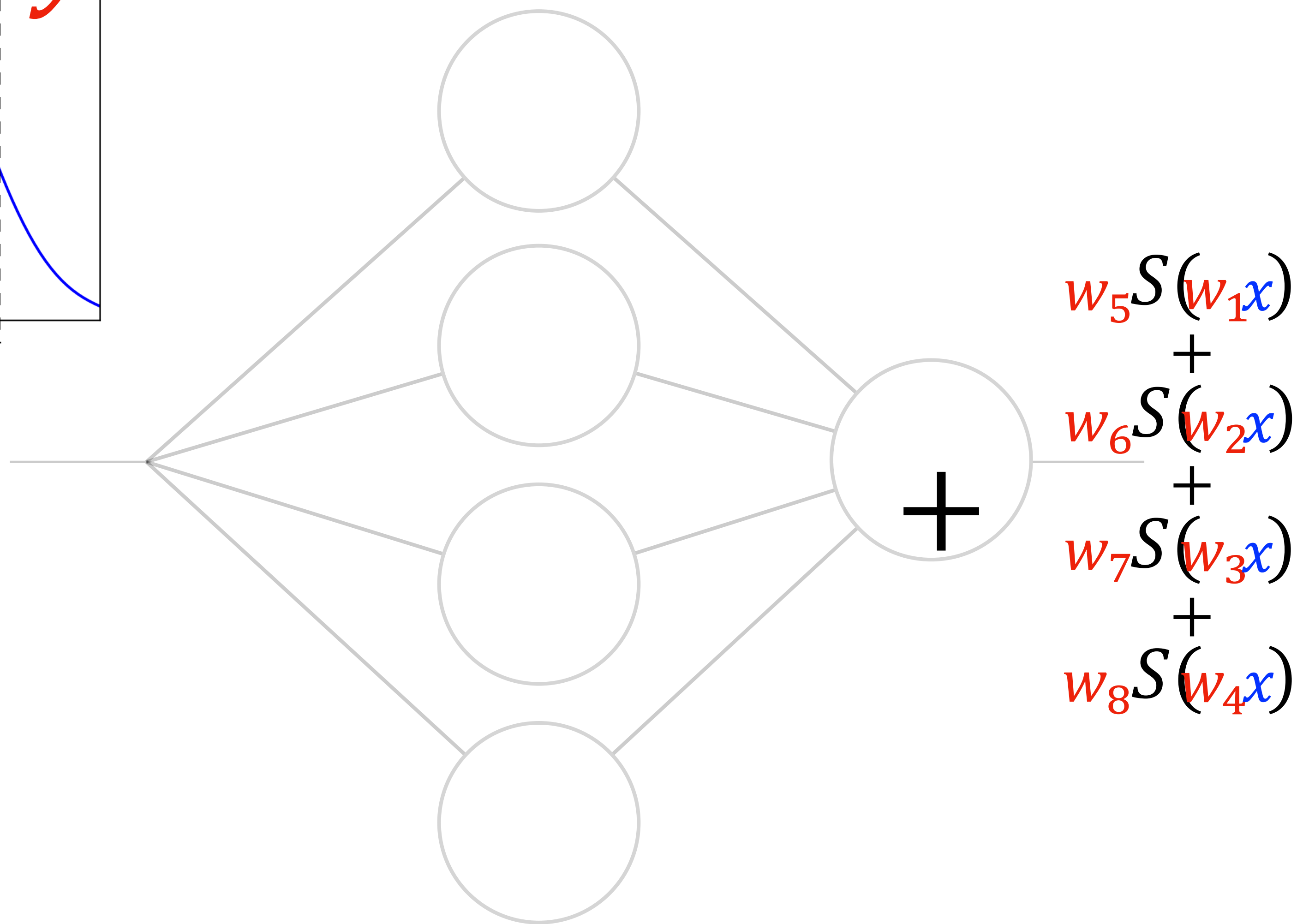
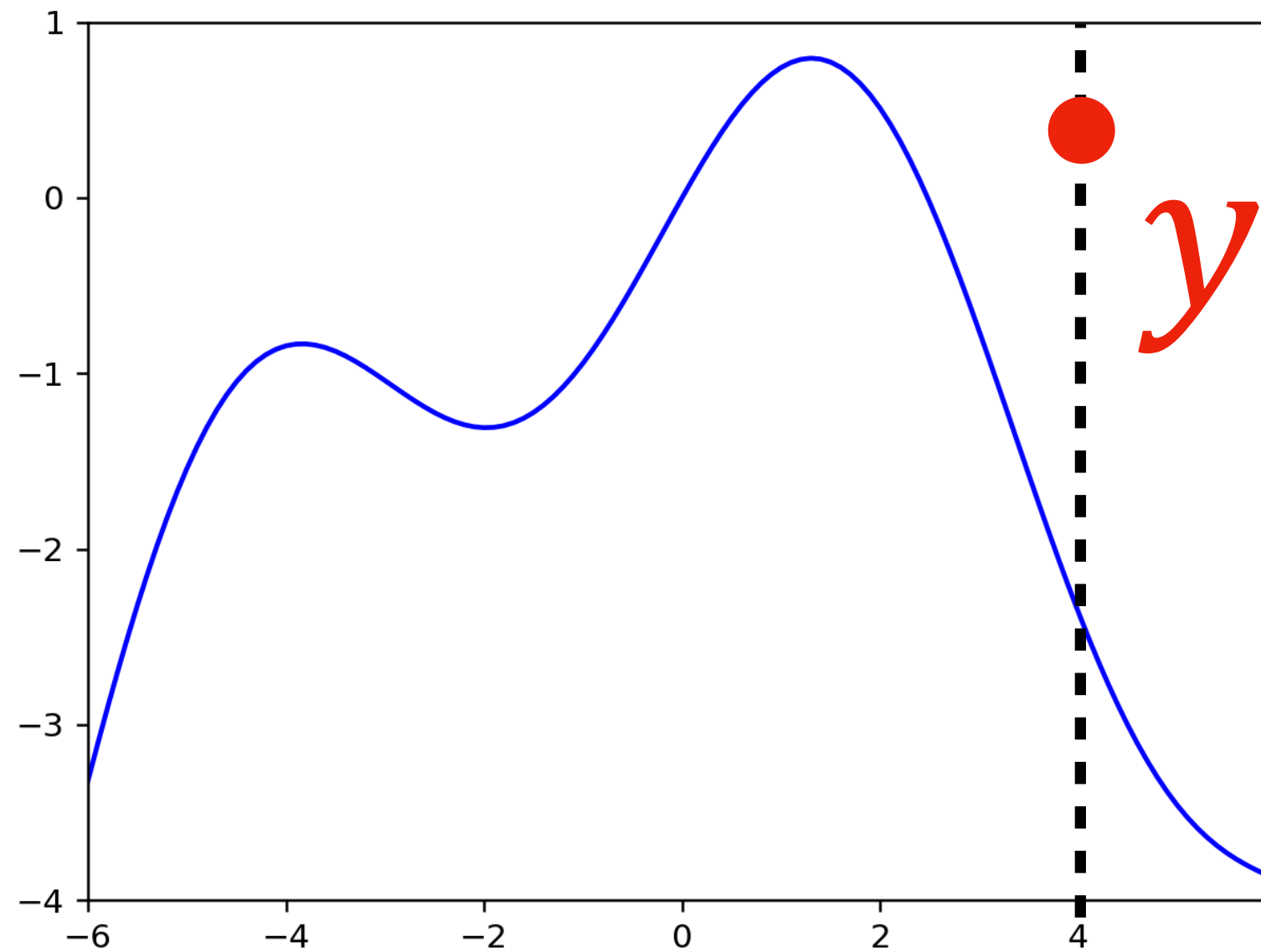


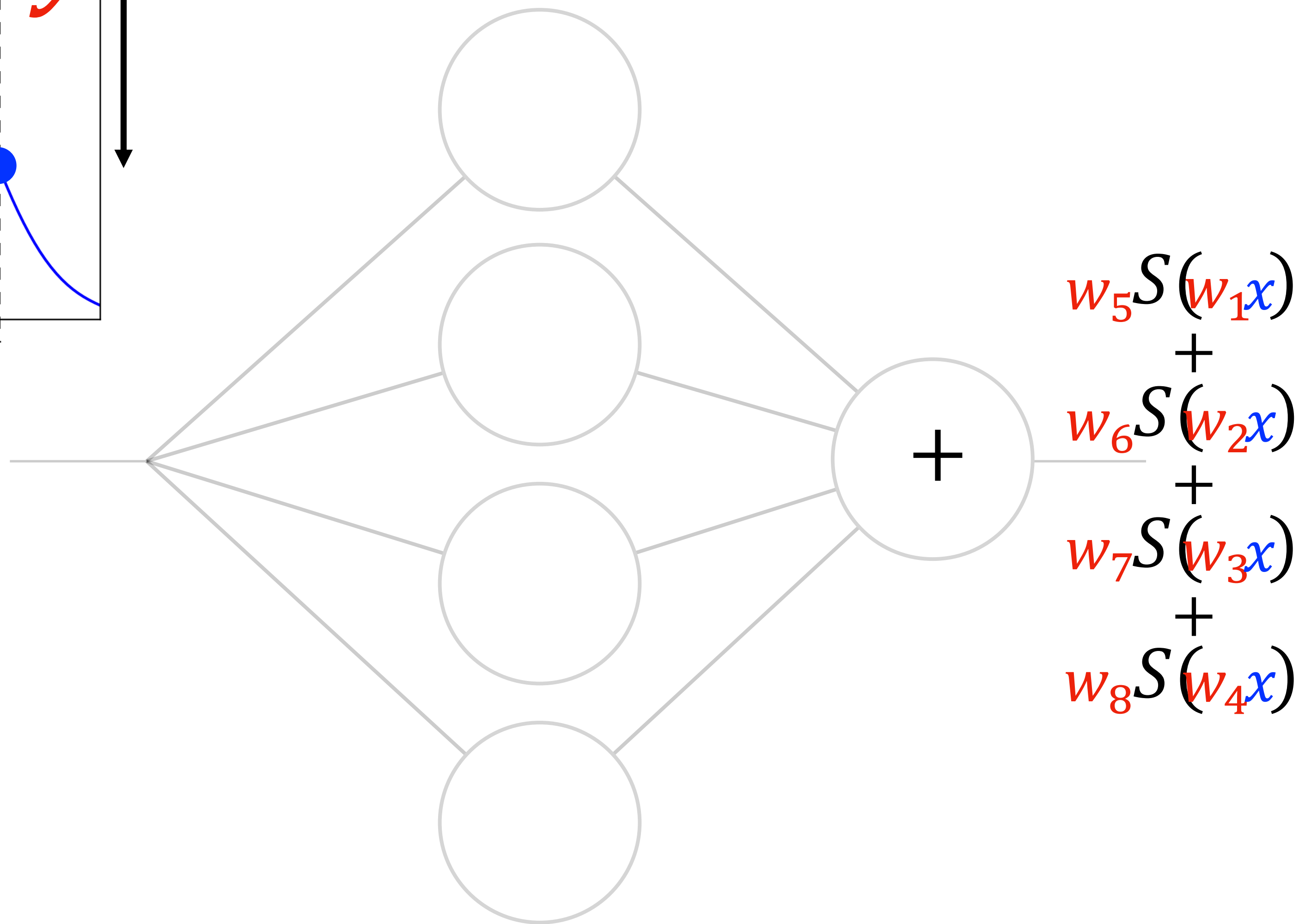
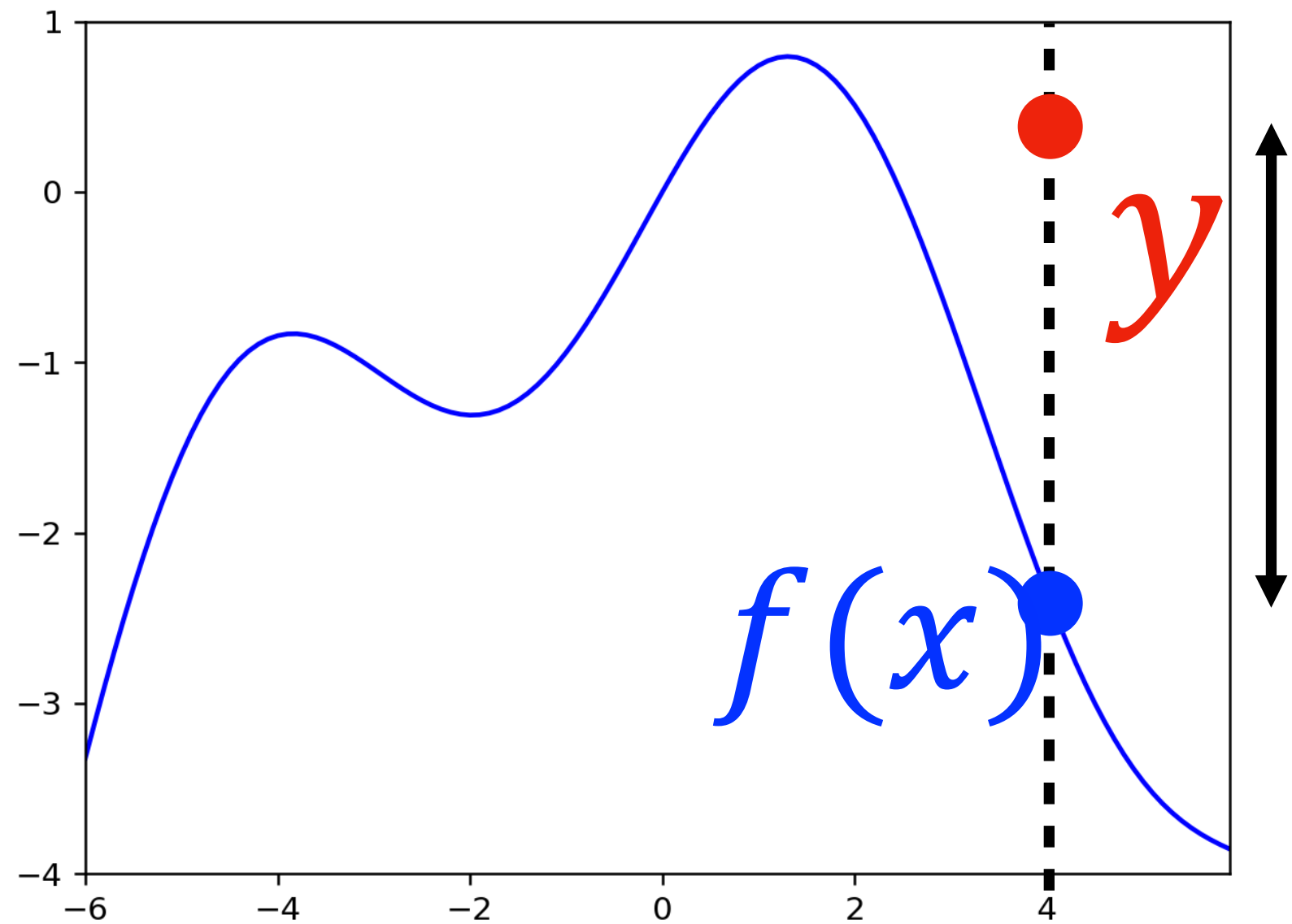
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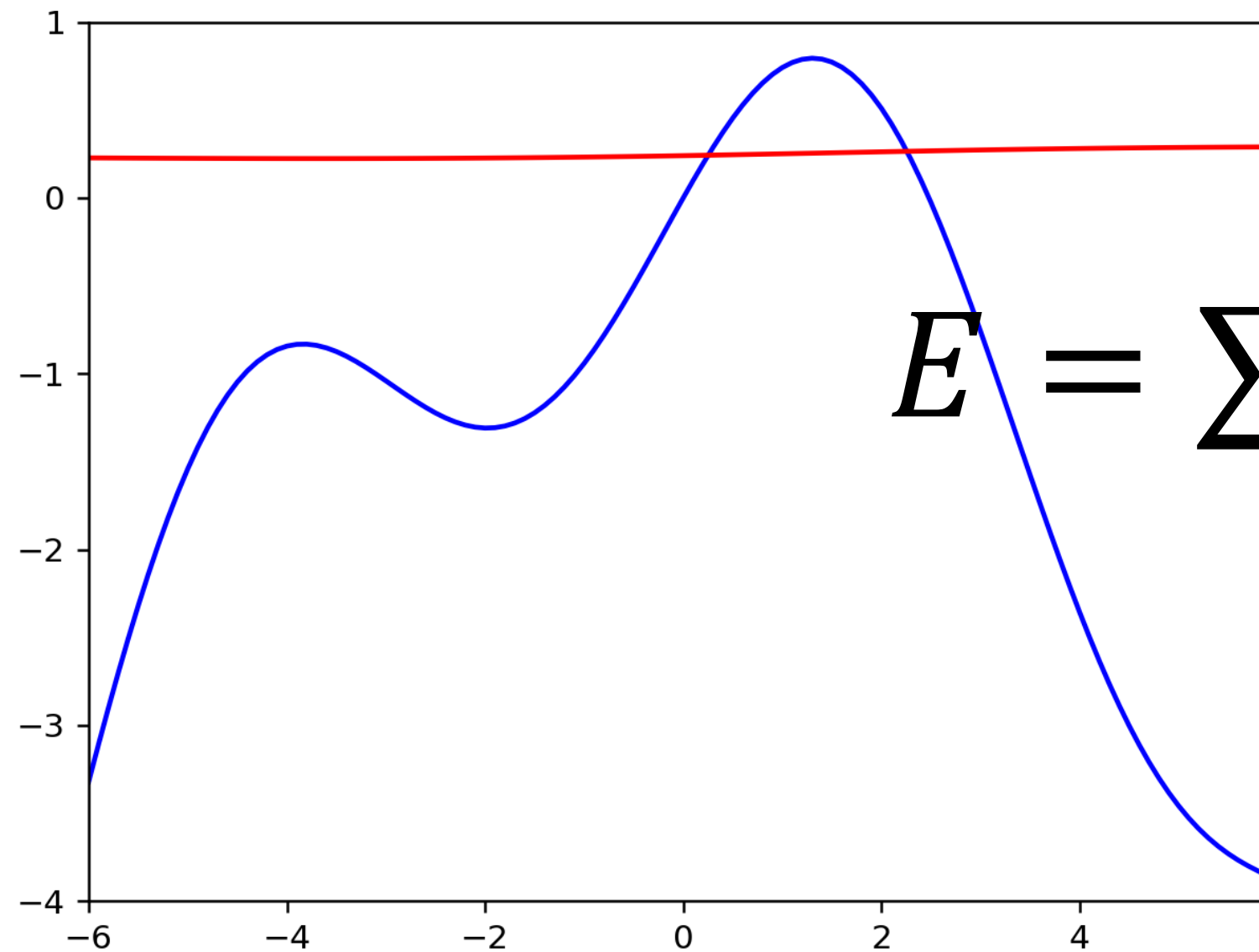




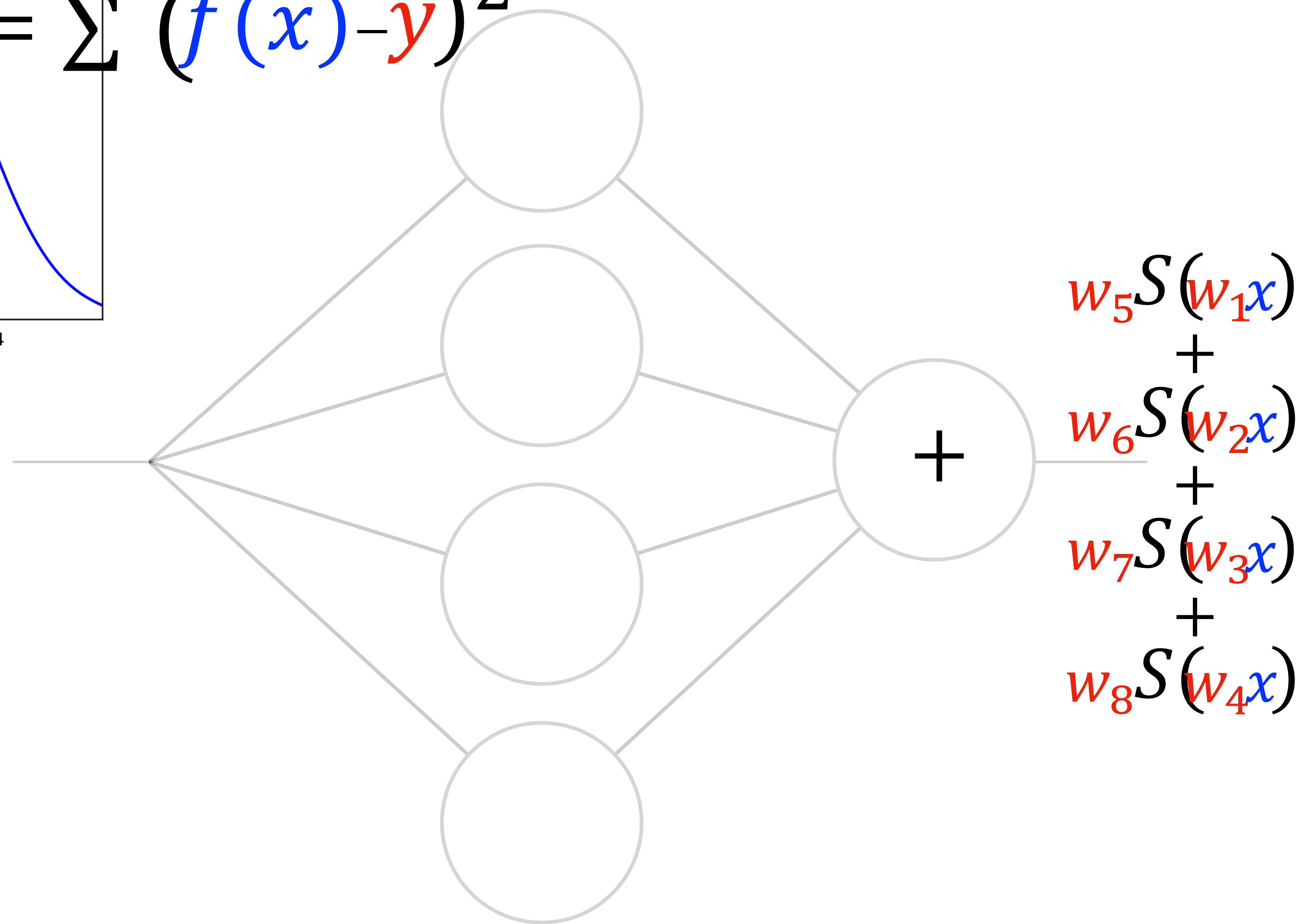


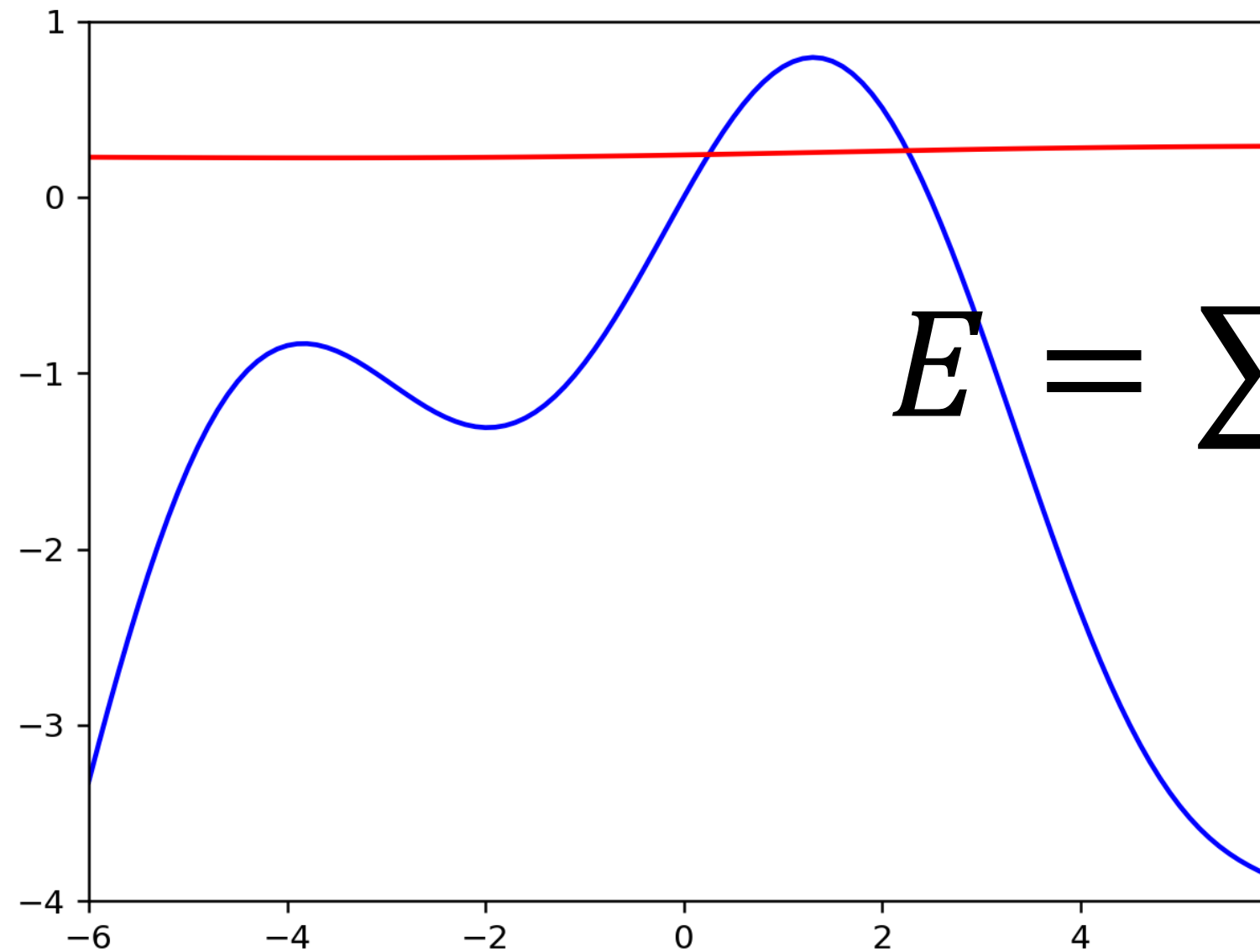




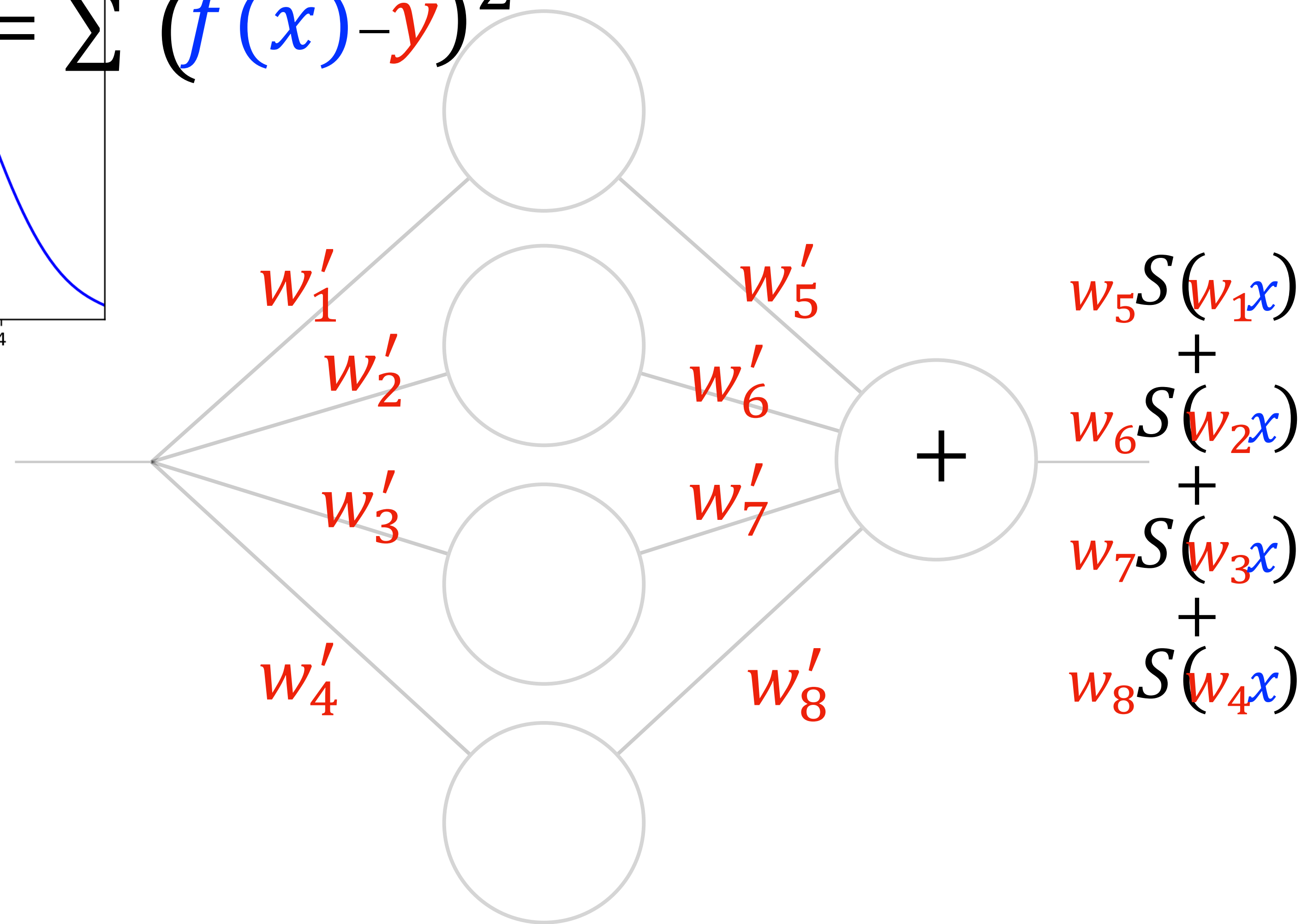


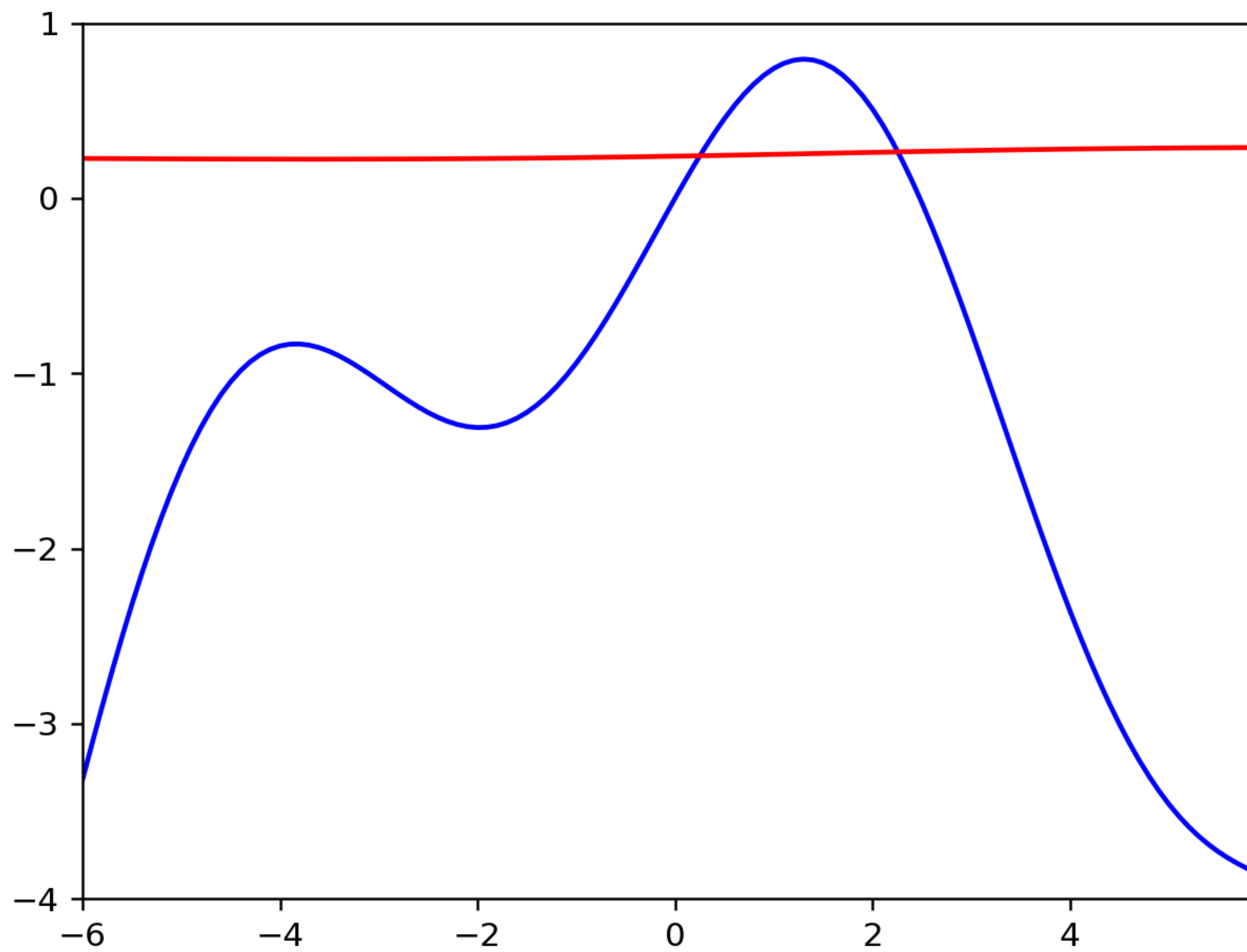
$$E = \sum (f(x) - y)^2$$

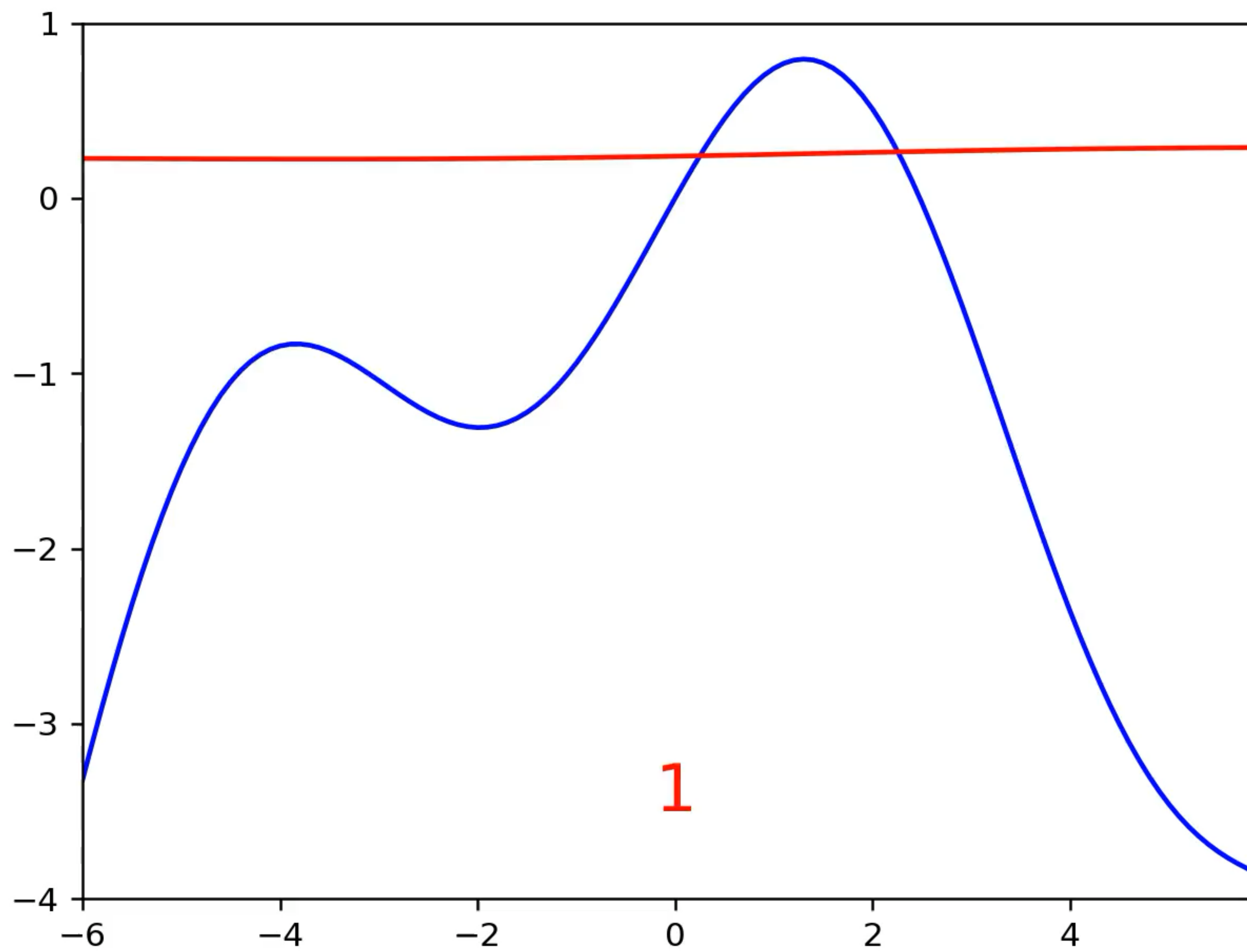




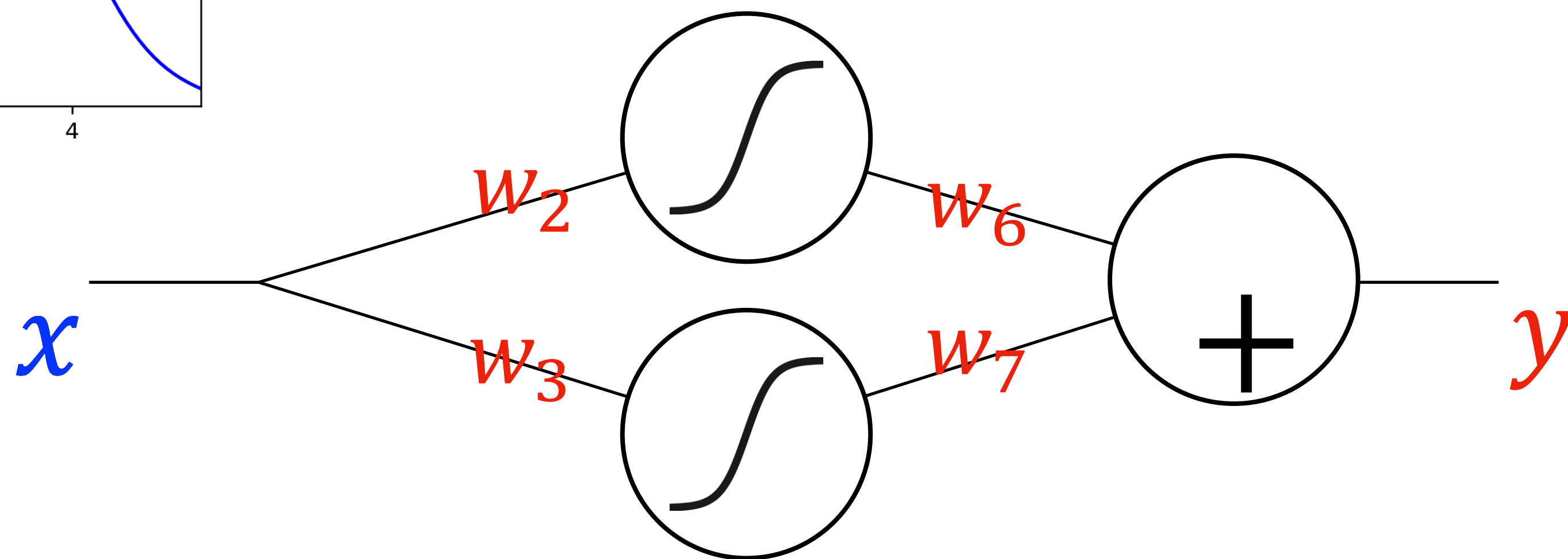
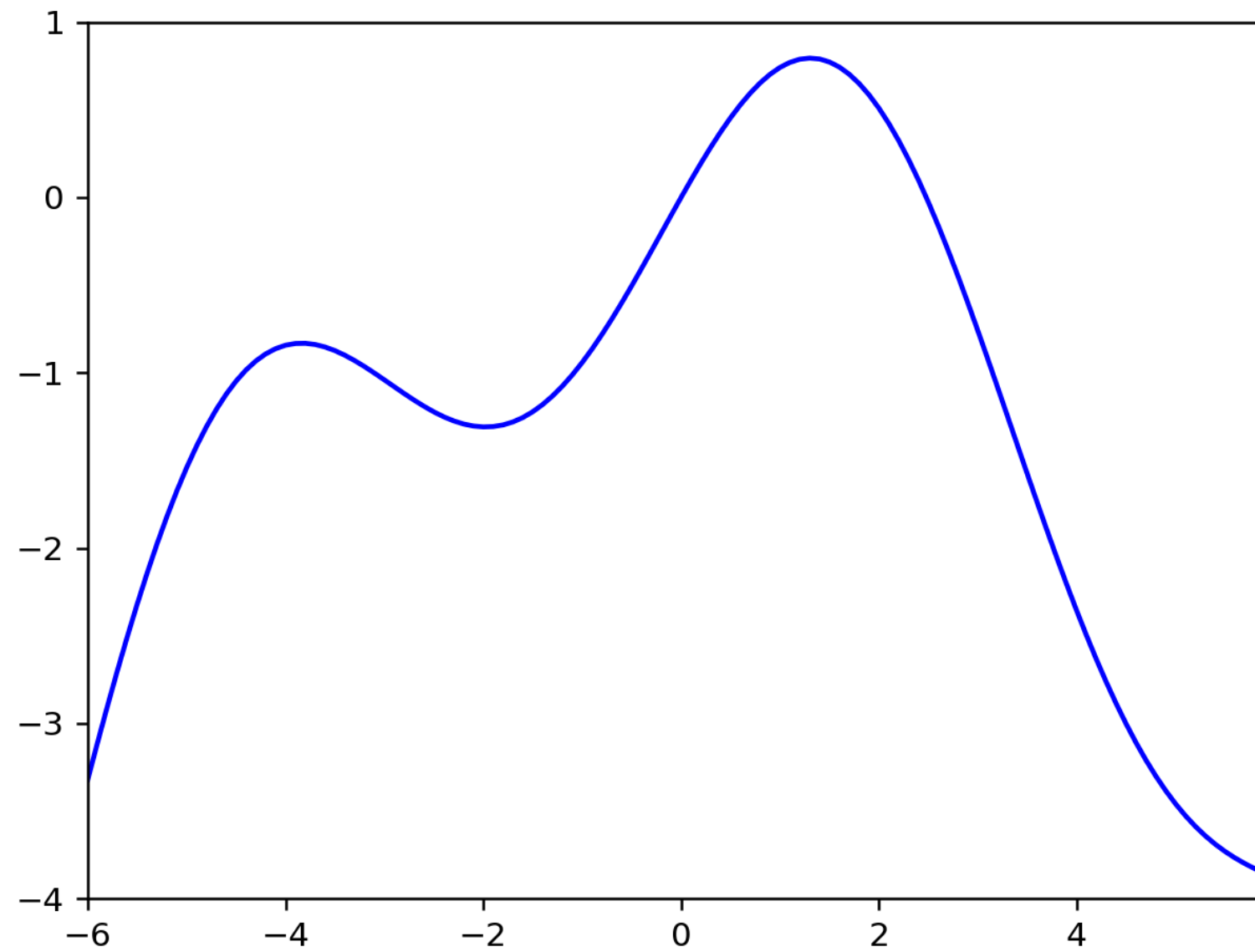
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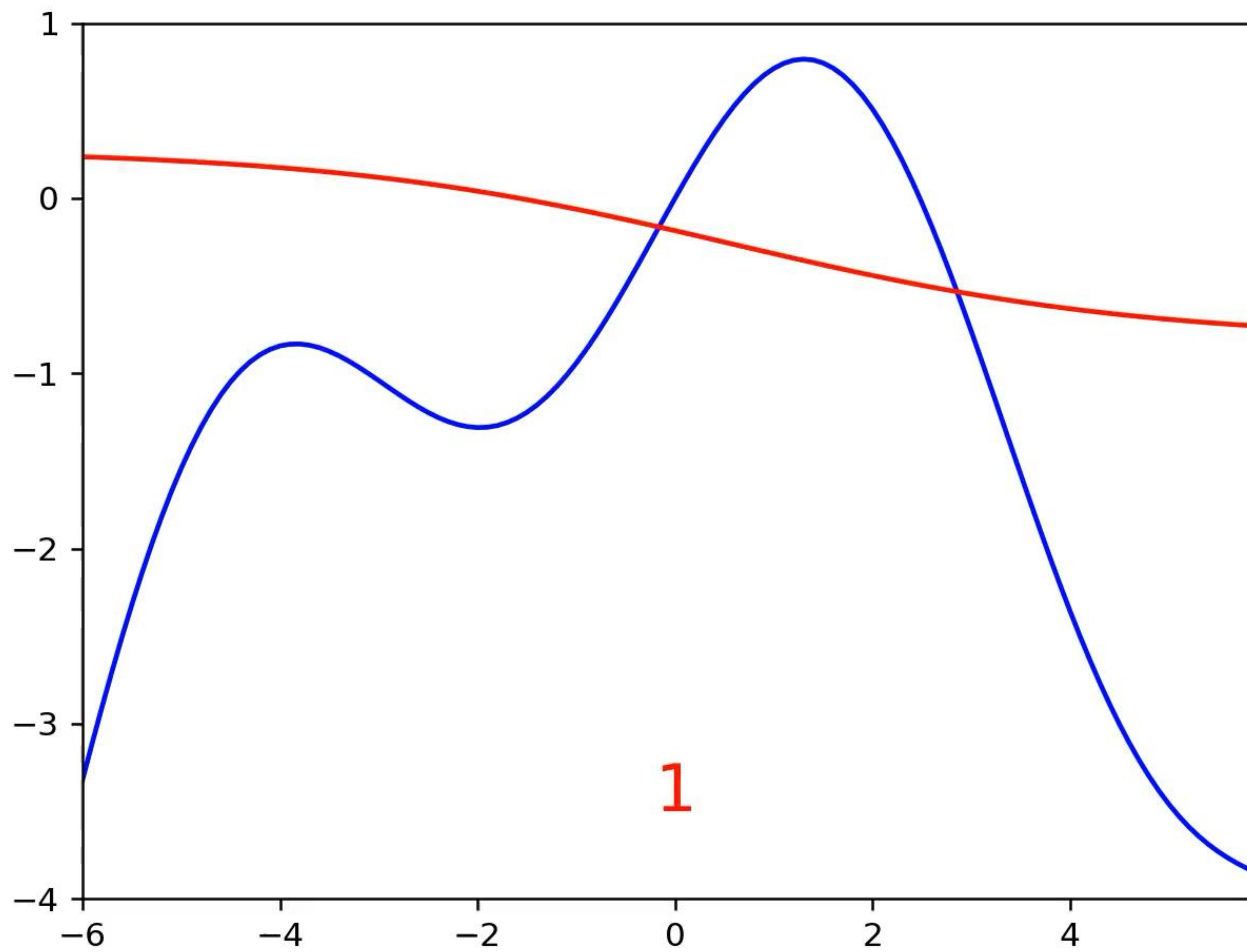


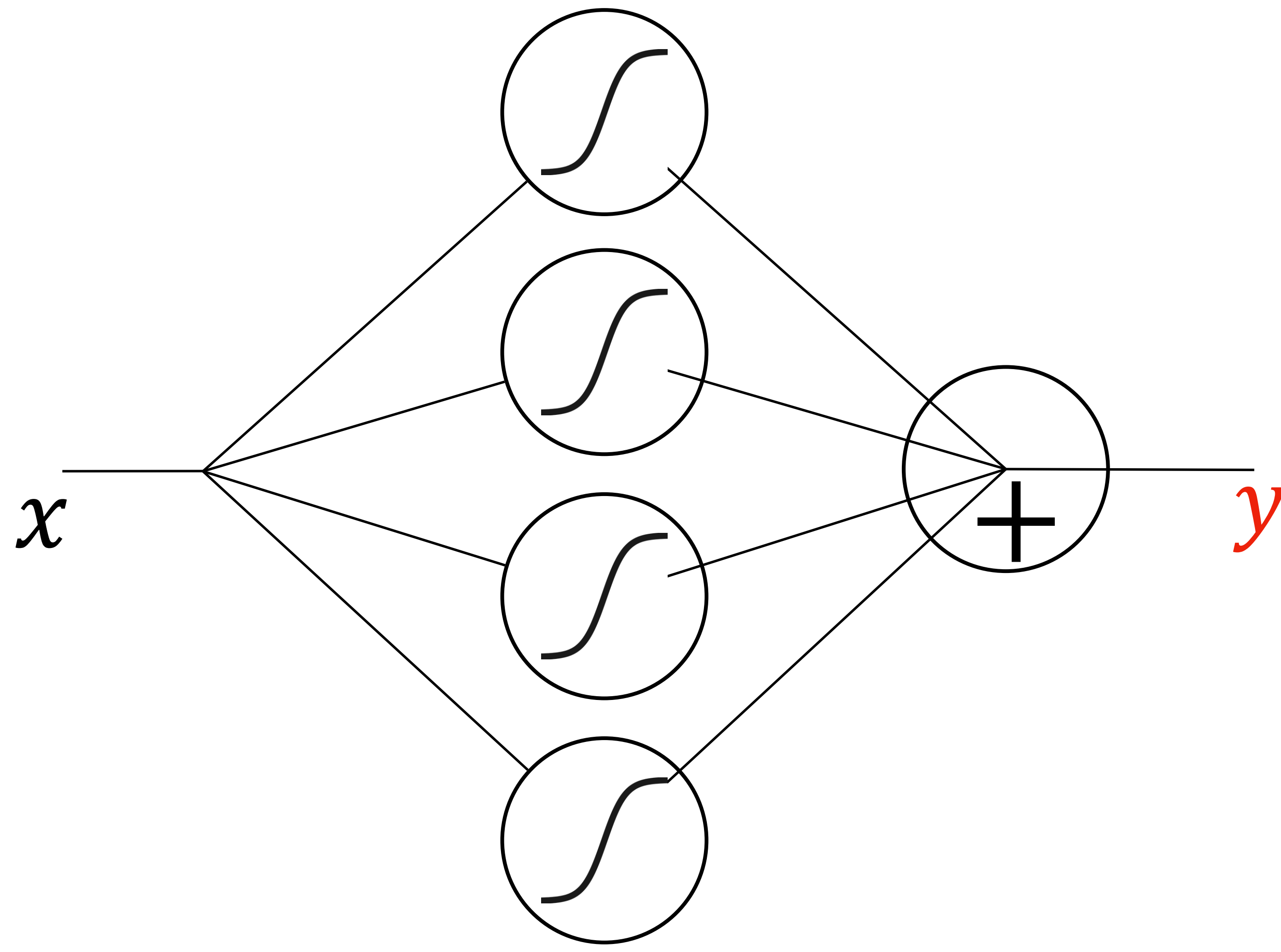


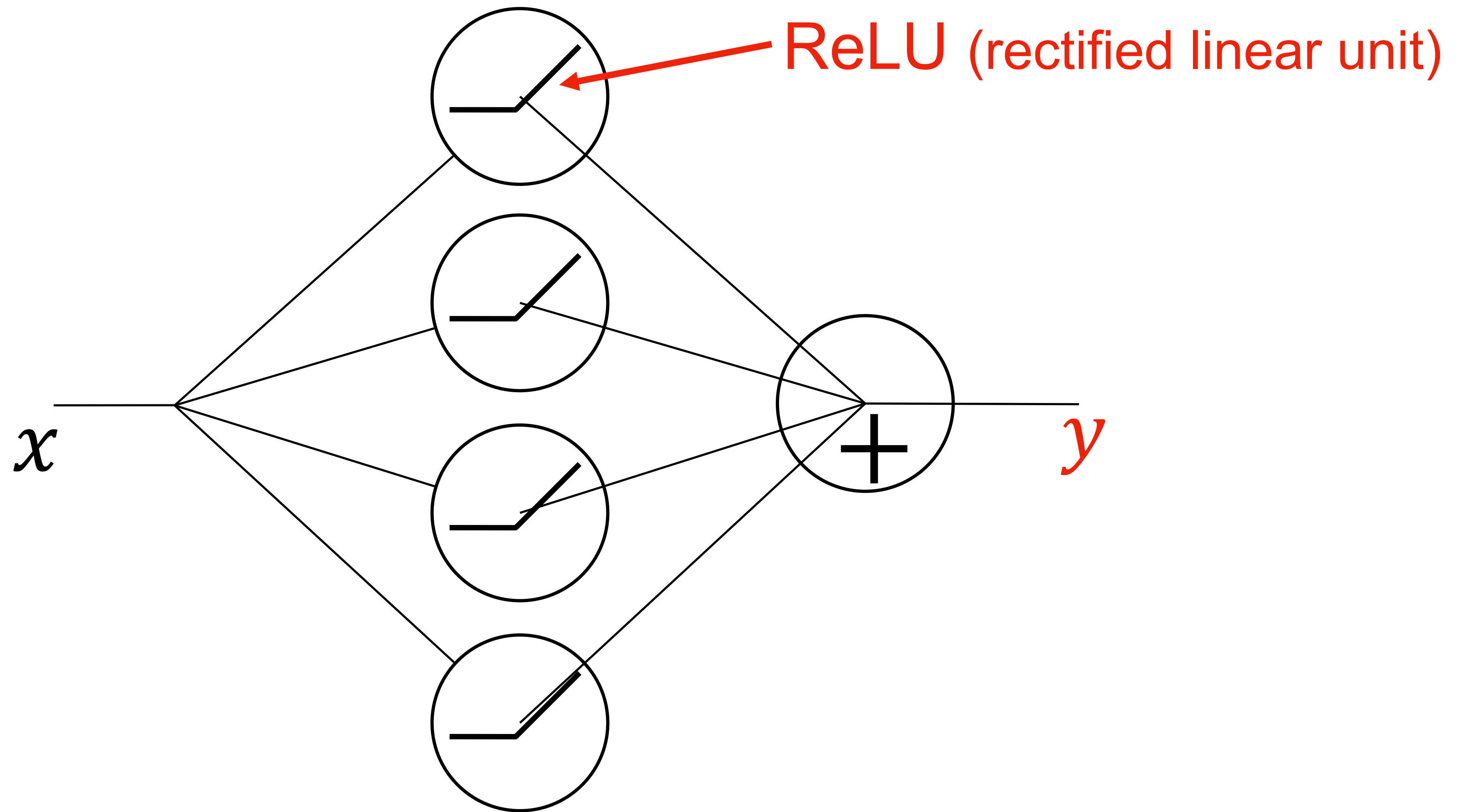


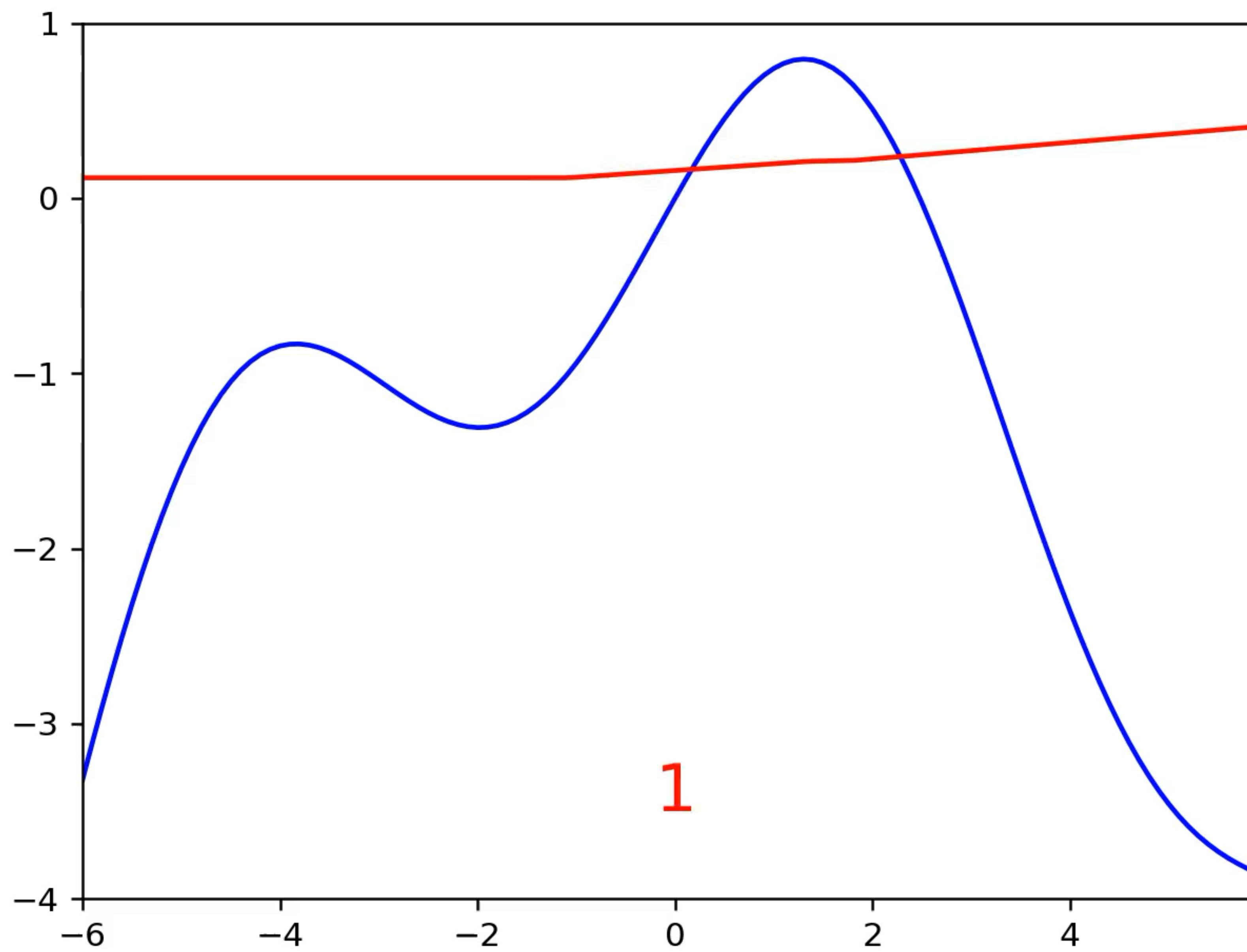
$$P(x_n | x_{n-1}, x_{n-2}, x_{n-3}, x_{n-4}, x_{n-5}, x_{n-6}, x_{n-7}, \dots)$$



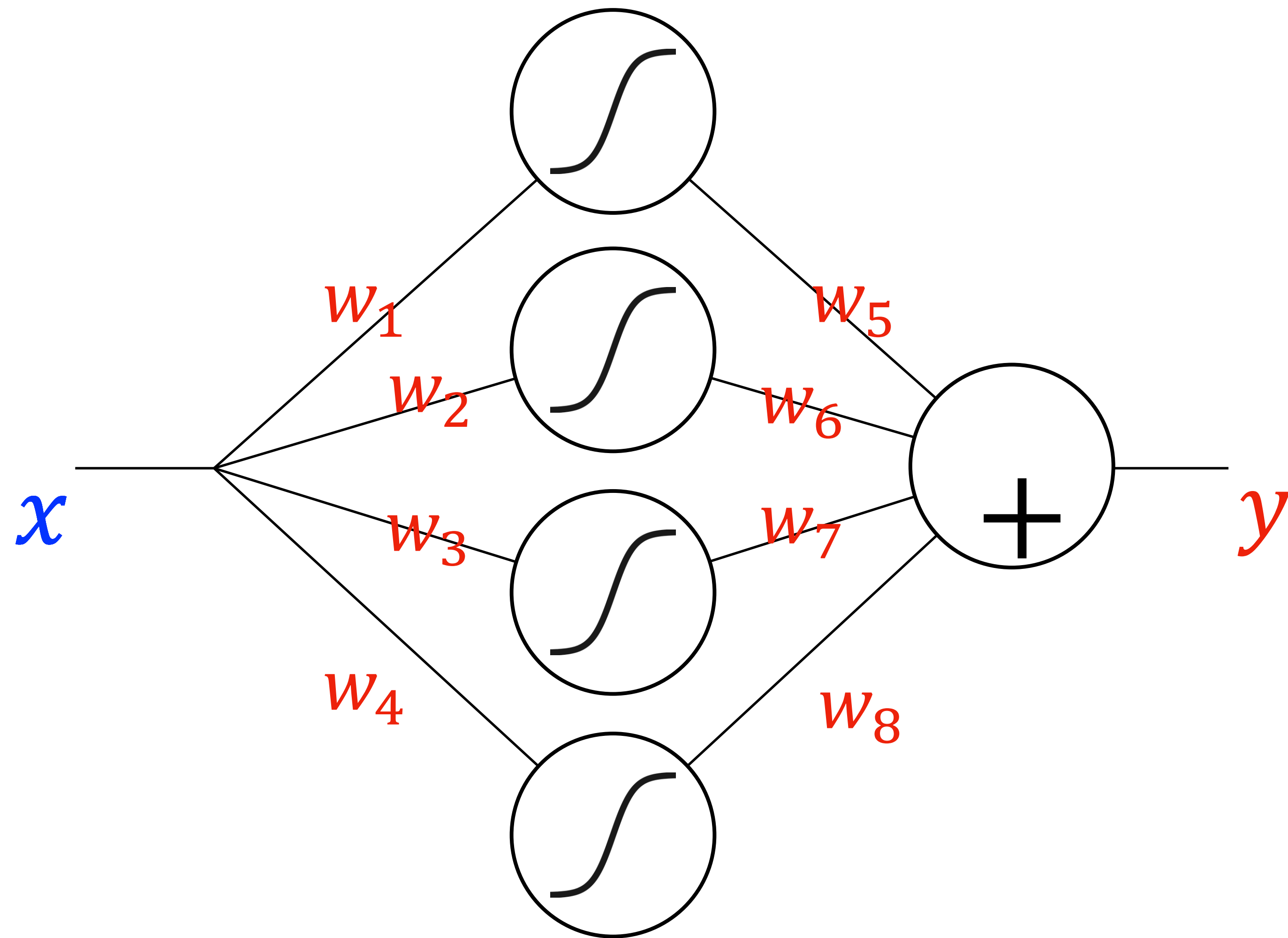


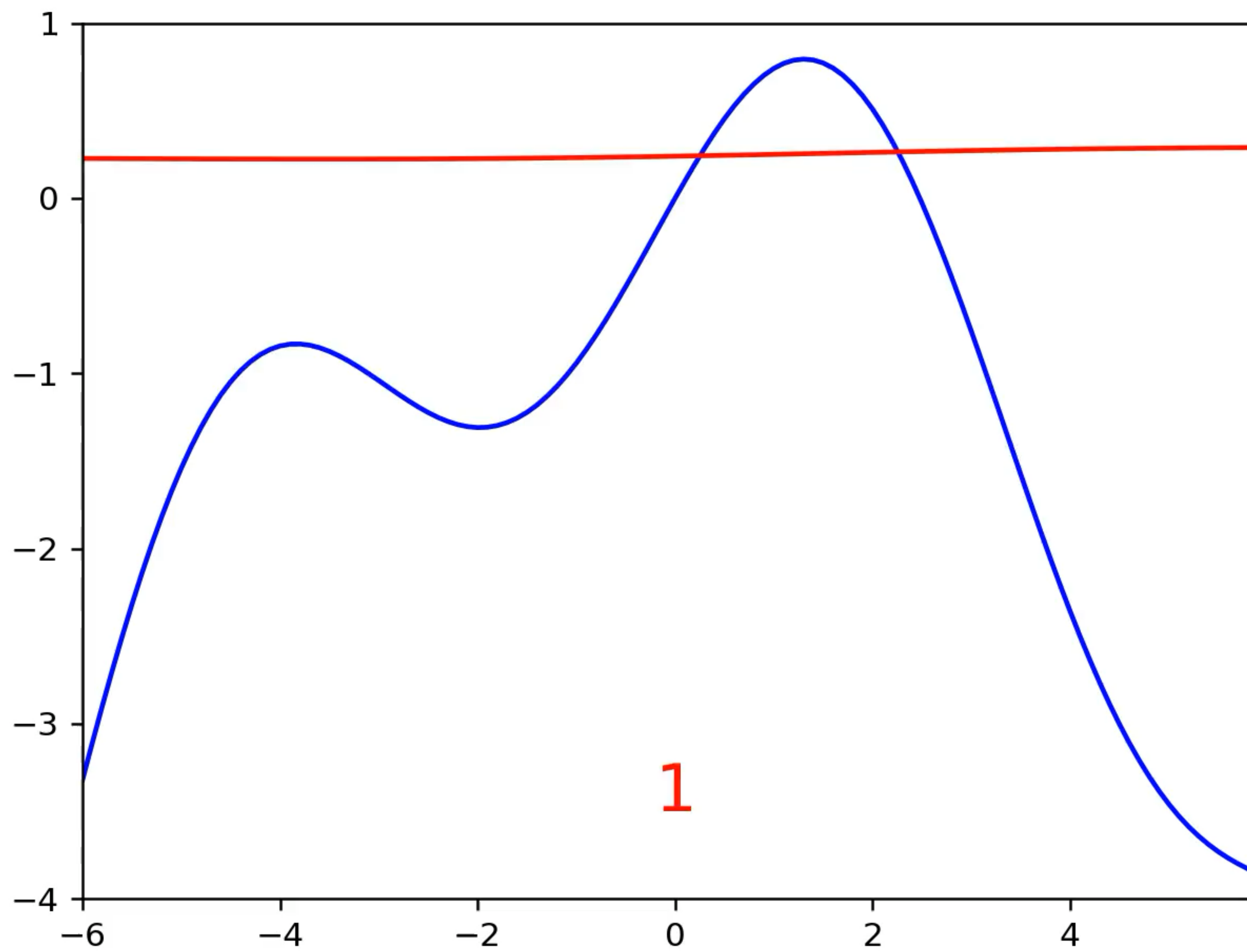






$$P(x_n | x_{n-1}, x_{n-2}, x_{n-3}, x_{n-4}, x_{n-5}, x_{n-6}, x_{n-7}, \dots)$$





$$P(x_n | x_{n-1}, x_{n-2}, x_{n-3}, x_{n-4}, x_{n-5}, x_{n-6}, x_{n-7}, \dots)$$