# Week 6: More Neural Networks

**Matthew Caldwell**

**COMP0088 Introduction to Machine Learning • UCL Computer Science • Autumn 2023**

# Admin

- Pulse surveys, again

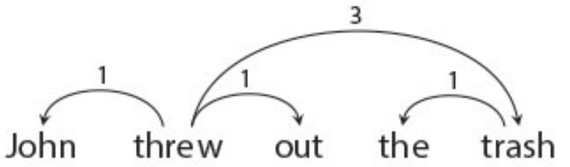
## Week 6 Recap

# Adventures in Space and Time

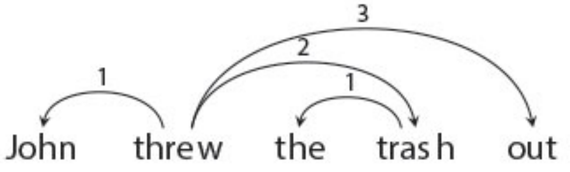
RANDOM
CRAP

# Meerkats

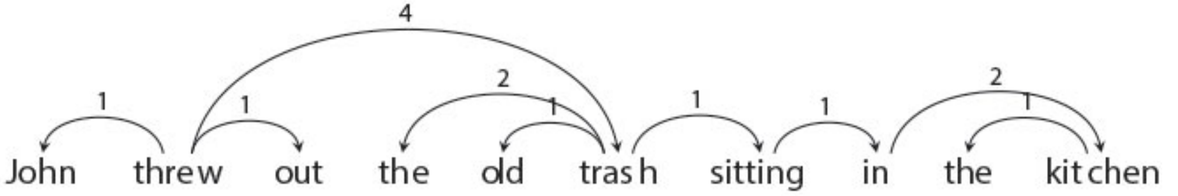
| # | Age | Weight | Sex | Captive | ... |
|---|---|---|---|---|---|
| **1** | 11.8 | 815 | 1 | 0 | |
| **2** | 9.7 | 672 | 1 | 0 | |
| **3** | 8.9 | 446 | 1 | 0 | |
| **4** | 10.8 | 761 | 0 | 0 | |
| **5** | 8.3 | 1035 | 0 | 1 | |
| **6** | 11.7 | 930 | 1 | 1 | |
| **7** | 8.5 | 1027 | 0 | 1 | |
| **8** | 7.6 | 1234 | 0 | 1 | |
| **9** | 15.5 | 1461 | 0 | 1 | |
| **10** | 8.8 | 720 | 1 | 0 | |
| **11** | 12.8 | 1223 | 0 | 1 | |
| **12** | 7.7 | 711 | 1 | 0 | |
| **13** | 7.2 | [illegible] | | | |



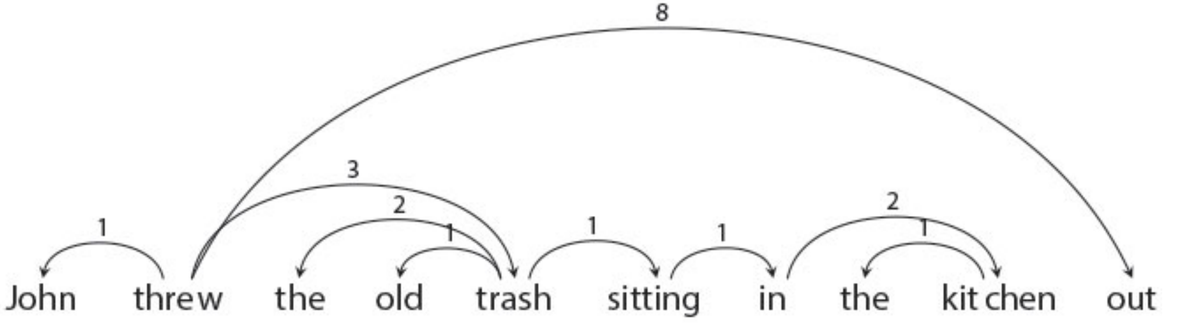

Sentence A: Total dependency length = 6



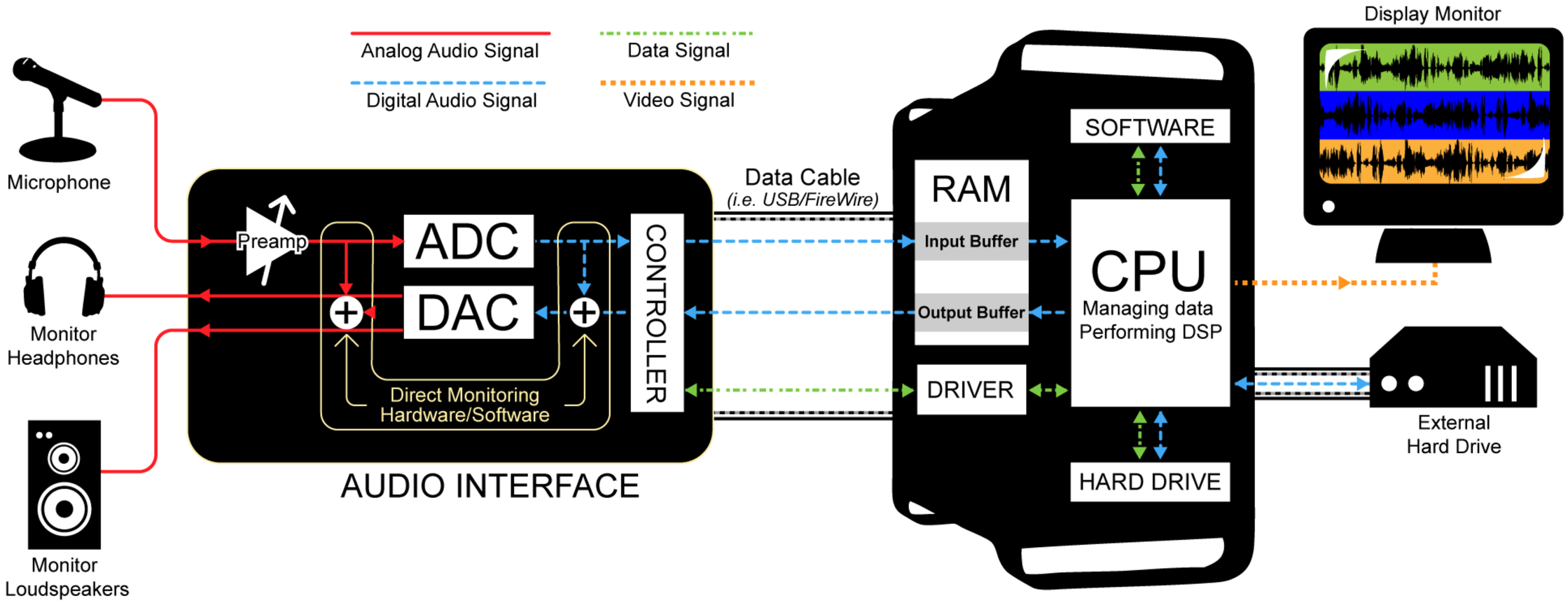

Sentence B: Total dependency length = 7

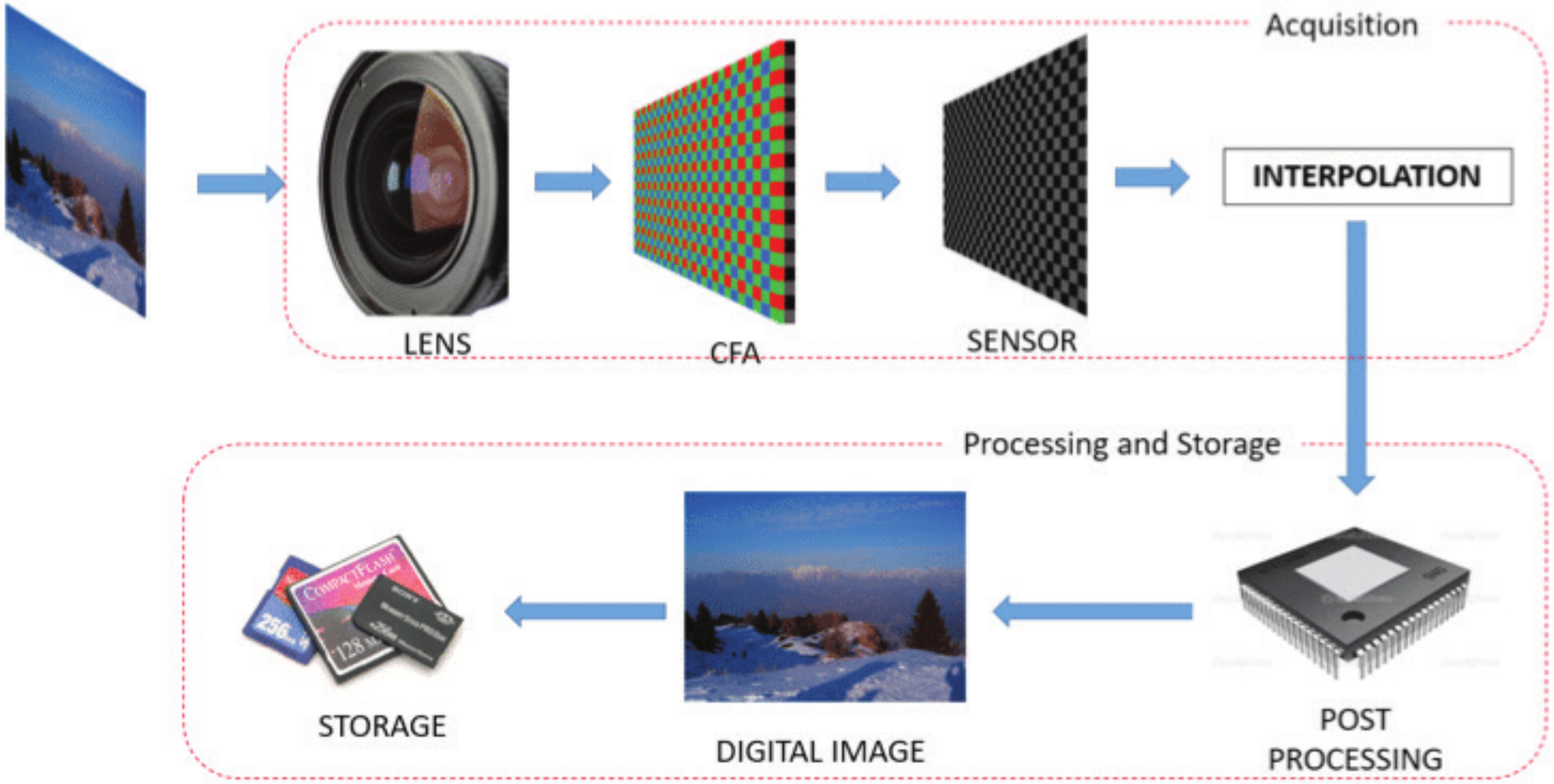



Sentence C: Total dependency length = 14




Sentence D: Total dependency length = 20


Analog Audio Signal
Data Signal
Digital Audio Signal
Video Signal
Microphone
Monitor Headphones
Monitor Loudspeakers
Preamp
ADC
DAC
CONTROLLER
Direct Monitoring Hardware/Software
AUDIO INTERFACE
Data Cable
(i.e. USB/FireWire)
RAM
Input Buffer
Output Buffer
DRIVER
SOFTWARE
CPU
Managing data
Performing DSP
HARD DRIVE
Display Monitor
External Hard Drive

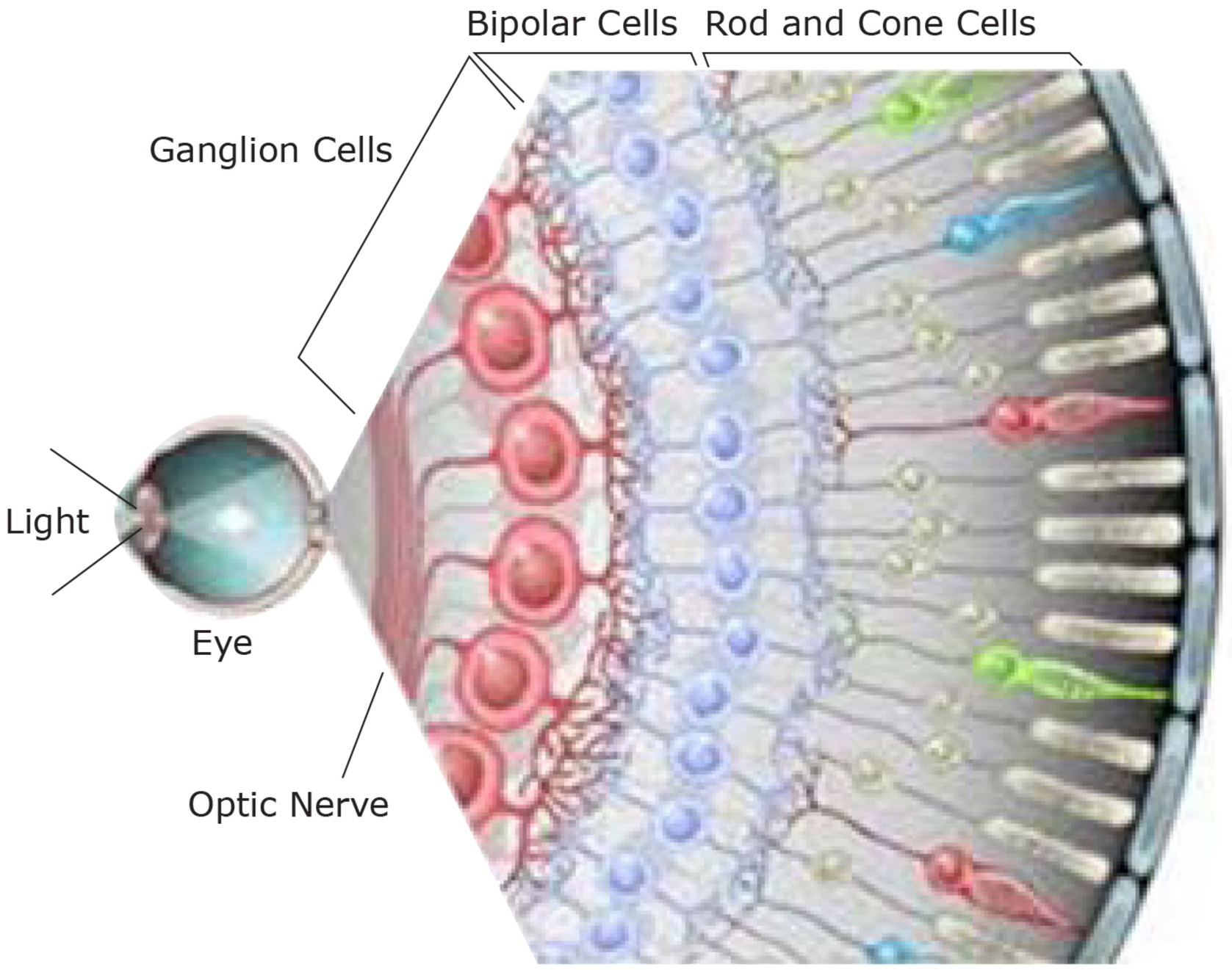

Acquisition
LENS
CFA
SENSOR
INTERPOLATION
Processing and Storage
STORAGE
DIGITAL IMAGE
POST
PROCESSING

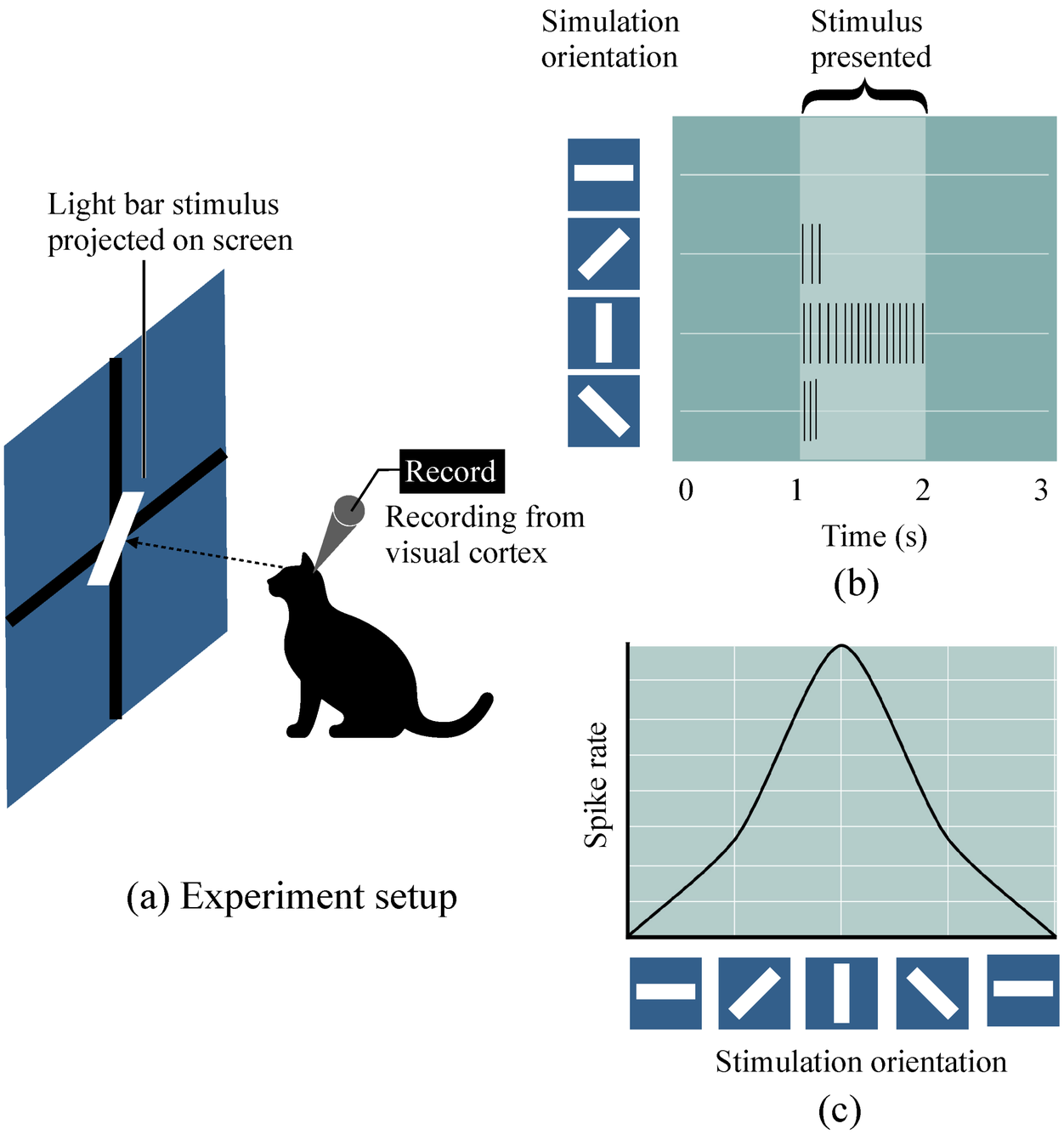
# REFUGEES

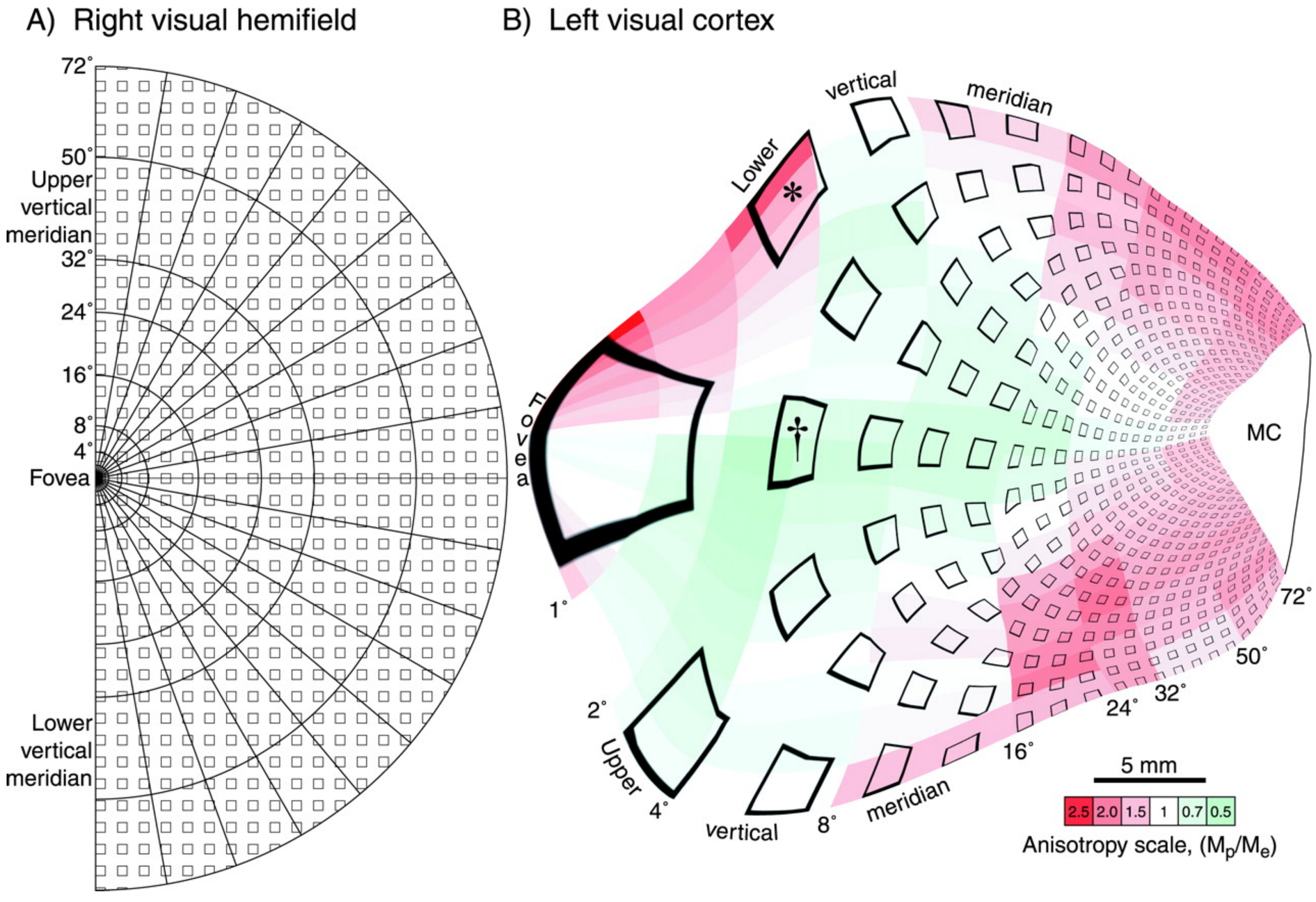
Brian Bilson

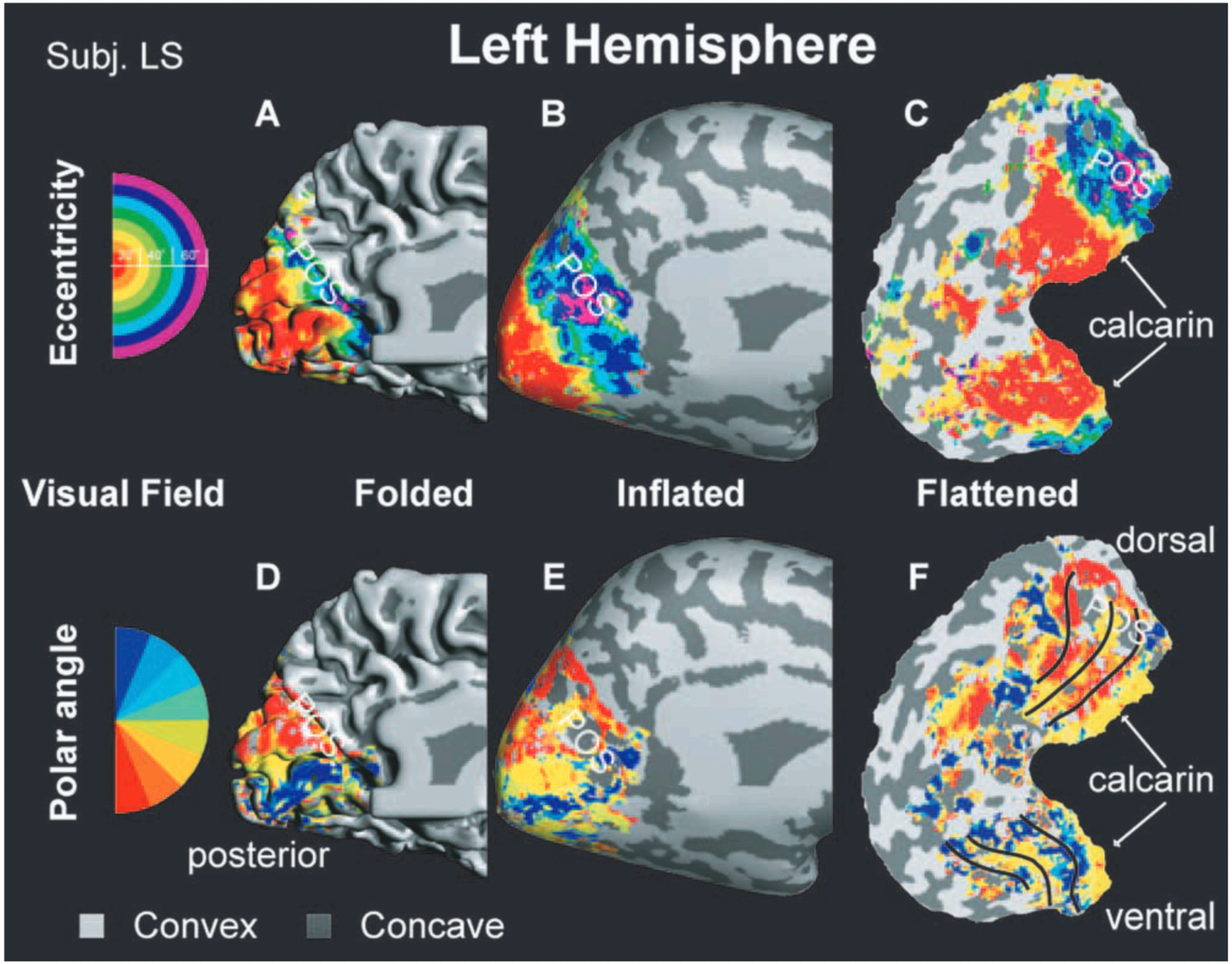
They have no need of our help
So do not tell me
These haggard faces could belong to you or me
Should life have dealt a different hand
We need to see them for who they really are
Chancers and scroungers
Layabouts and loungers
With bombs up their sleeves
Cut-throats and thieves
They are not
Welcome here
We should make them
Go back to where they came from
They cannot
Share our food
Share our homes
Share our countries
Instead let us
Build a wall to keep them out
It is not okay to say
These are people just like us
A place should only belong to those who are born there
Do not be so stupid to think that
The world can be looked at another way

*(now read from bottom to top)*


Bipolar Cells
Rod and Cone Cells
Ganglion Cells
Light
Eye
Optic Nerve


Light bar stimulus
projected on screen
Record
Recording from
visual cortex
(a) Experiment setup
Simulation
orientation
Stimulus
presented
0
1
2
3
Time (s)
(b)
Spike rate
Stimulation orientation
(c)


A) Right visual hemifield
B) Left visual cortex
72°
50°
Upper
vertical
meridian
32°
24°
16°
8°
4°
Fovea
Lower
vertical
meridian
vertical
meridian
Lower
Fovea
MC
1°
2°
Upper
4°
vertical
8°
meridian
16°
24°
32°
50°
72°
5 mm
2.5
2.0
1.5
1
0.7
0.5
Anisotropy scale, ($M_p/M_e$)


Subj. LS
Left Hemisphere
A
B
C
Eccentricity
POS
POS
POS
calcarin
Visual Field
Folded
Inflated
Flattened
dorsal
D
E
F
Polar angle
POS
POS
POS
calcarin
posterior
ventral
Convex
Concave

$$(f \otimes g)(t) = \int_{-\infty}^{\infty} f(s)g(t-s)\mathrm{d}s$$

wrong!

$$(f \otimes g)(t) = \int_{-\infty}^{\infty} f(t) g(t - s) \mathrm{d}s$$

$$(f \otimes g)(t) = \int_{-\infty}^{\infty} f(s)g(t-s)\mathrm{d}s$$

**“Convolution”**

$$(f \otimes g)(t) = \int_{-\infty}^{\infty} f(s)g(t+s)\mathrm{d}s$$

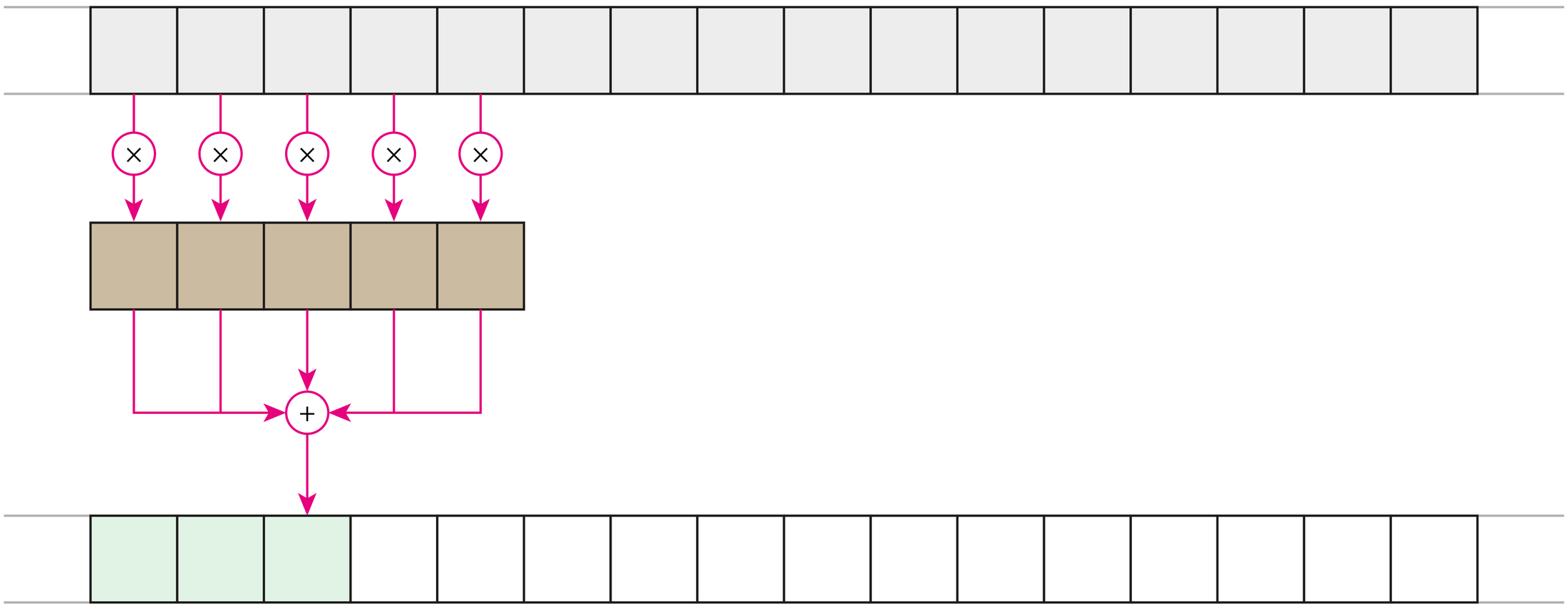
**“Cross-correlation”**

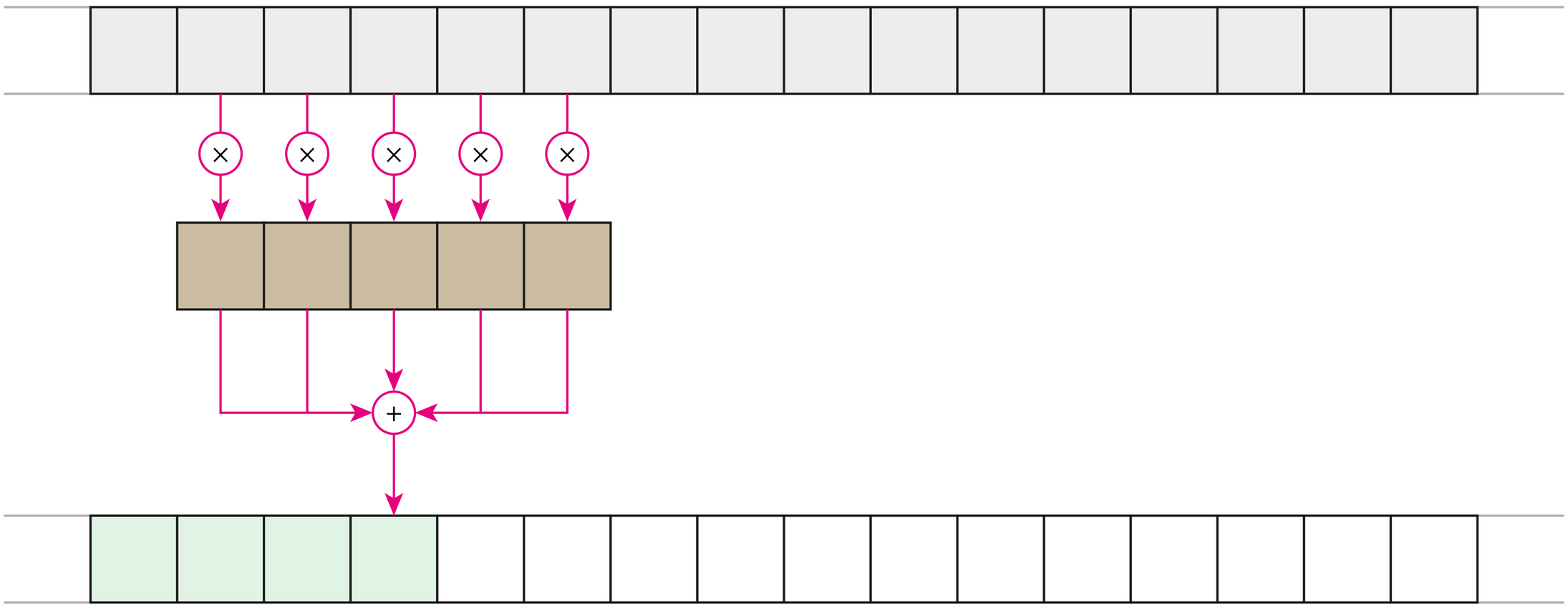
$$(\mathbf{f} \otimes \mathbf{g})_t = \sum_{s=-\infty}^{\infty} f_s g_{t+s}$$

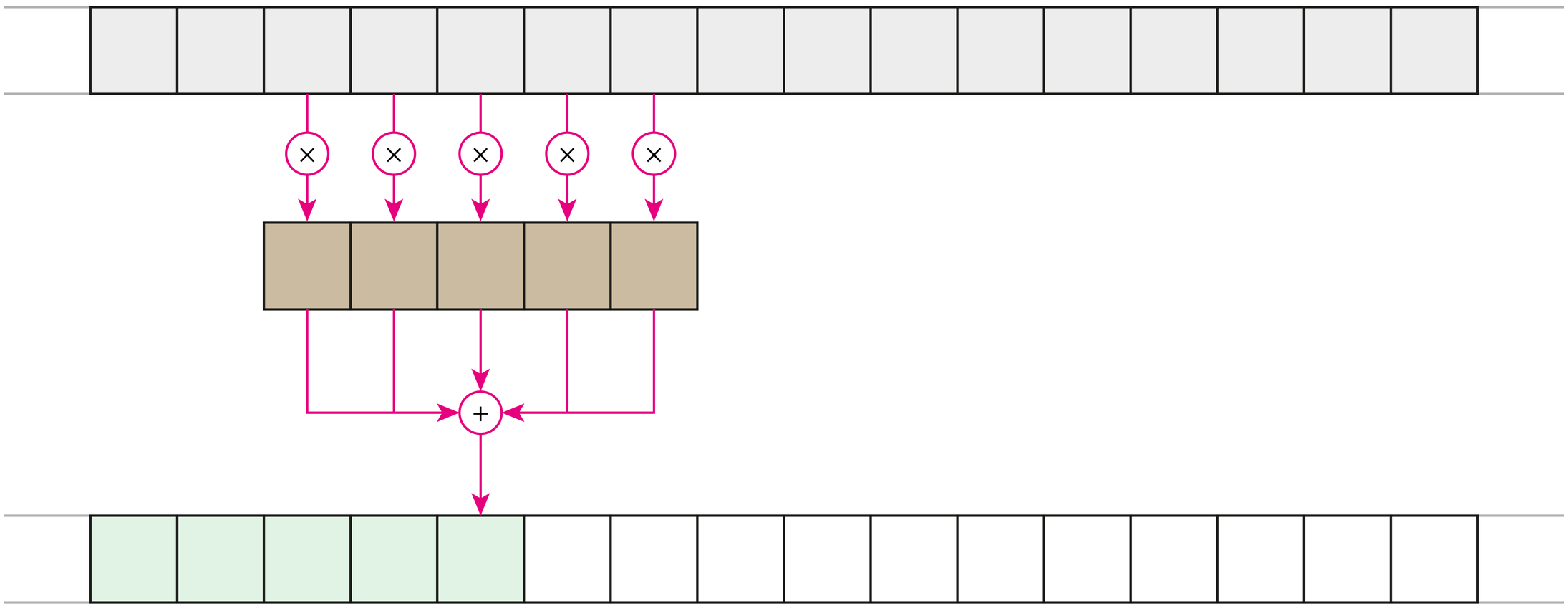
$$(\mathbf{f} \otimes \mathbf{g})_t = \sum_{s=1}^{n-k+1} f_s g_{t+s}$$

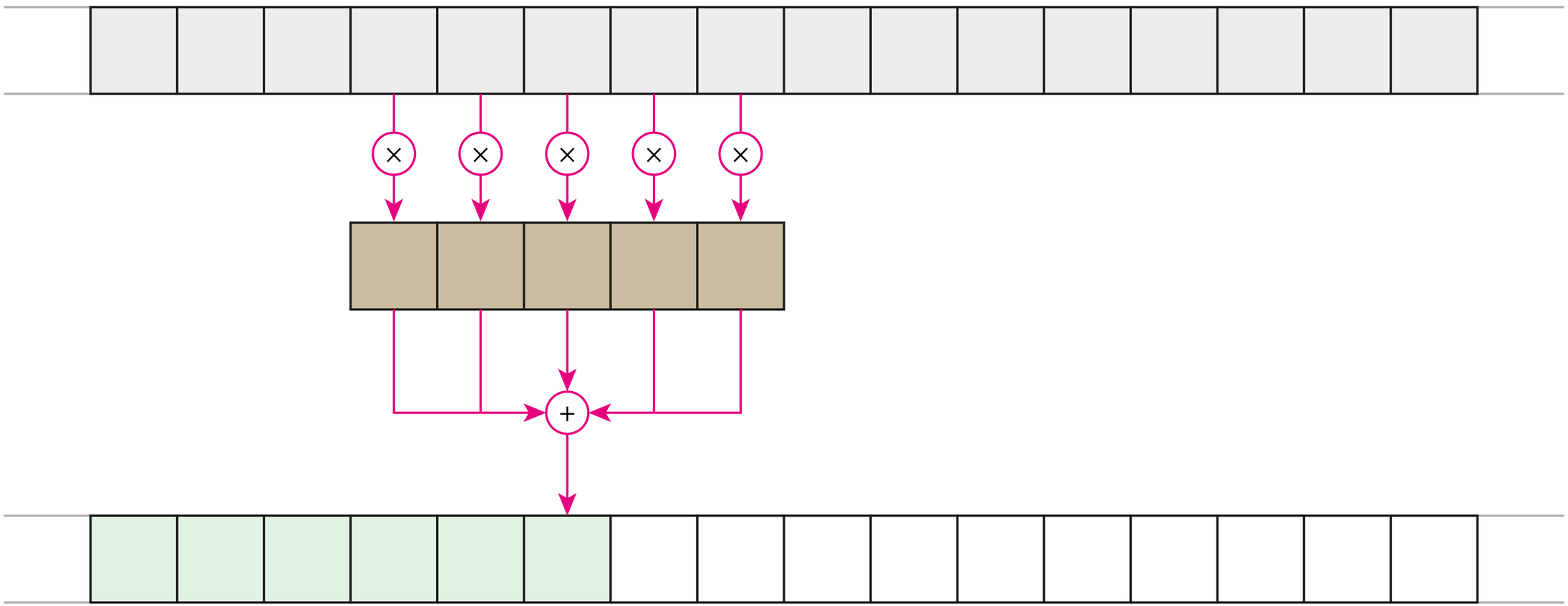
$$(\mathbf{f} \otimes \mathbf{g})_t = \mathbf{f}_{[t,t+k-1]} \cdot \mathbf{g}$$

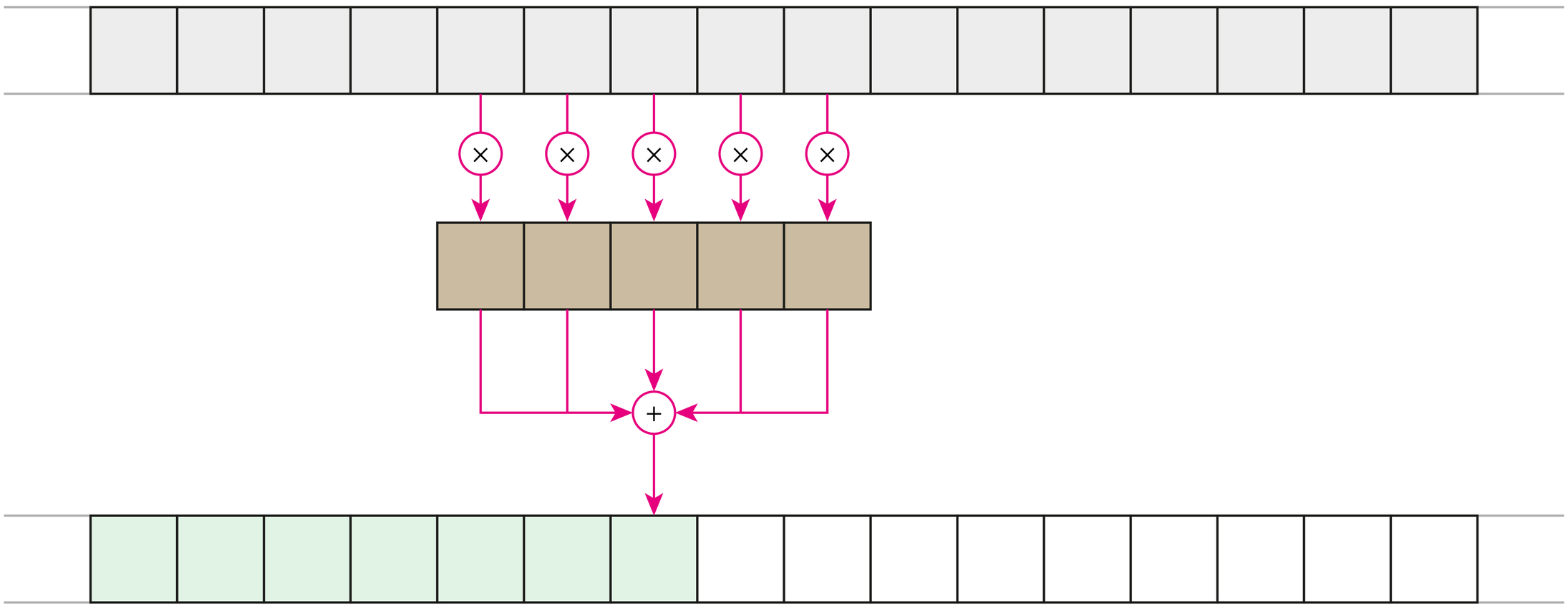
# Testify!

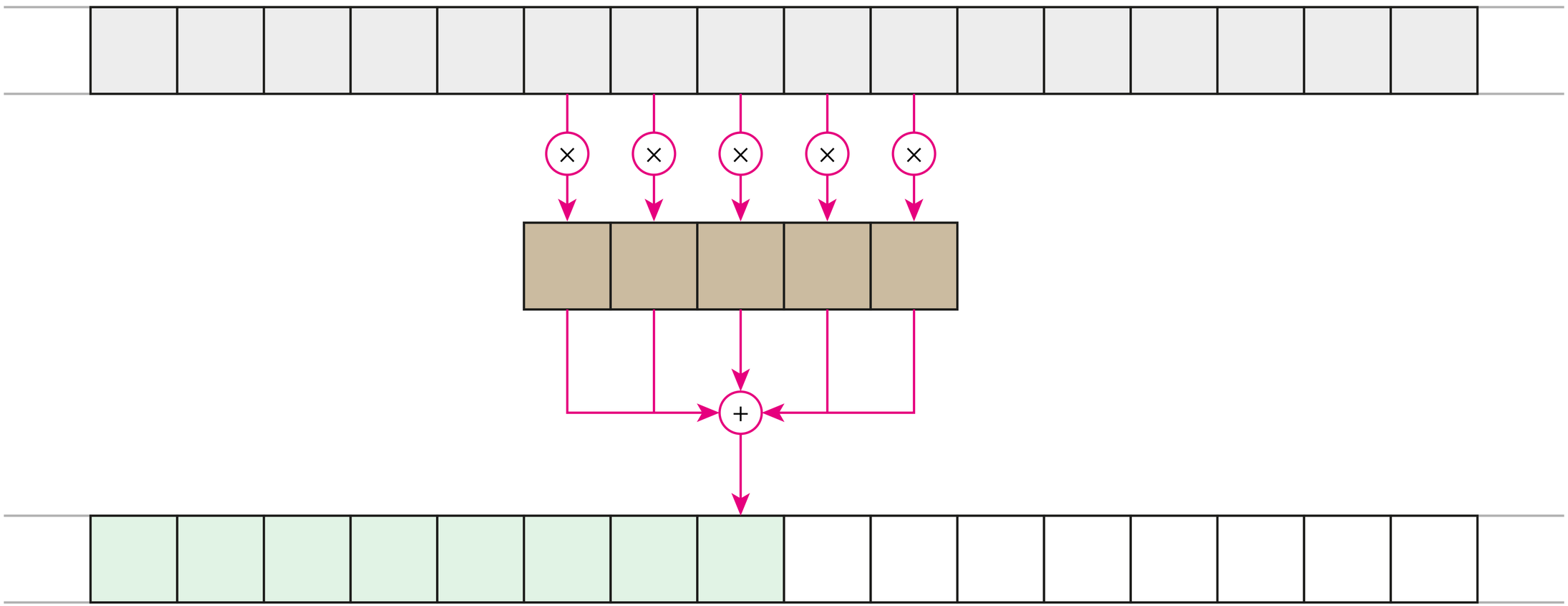


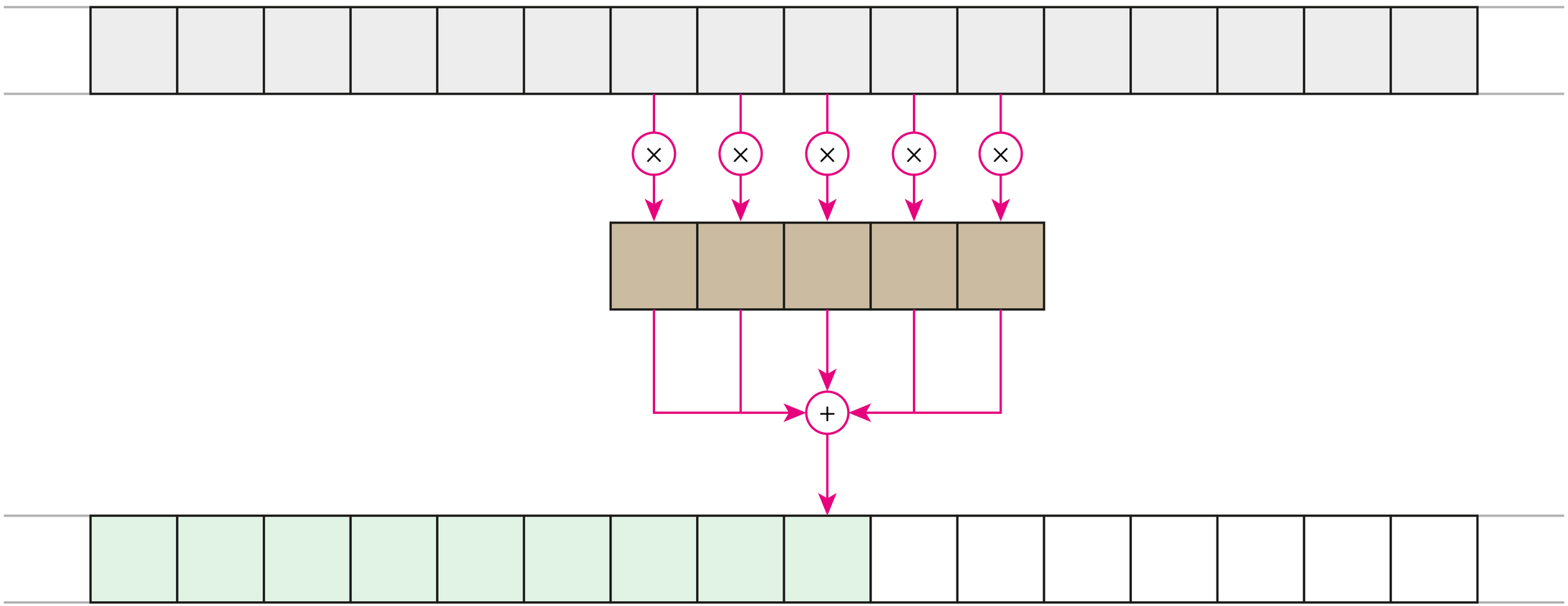


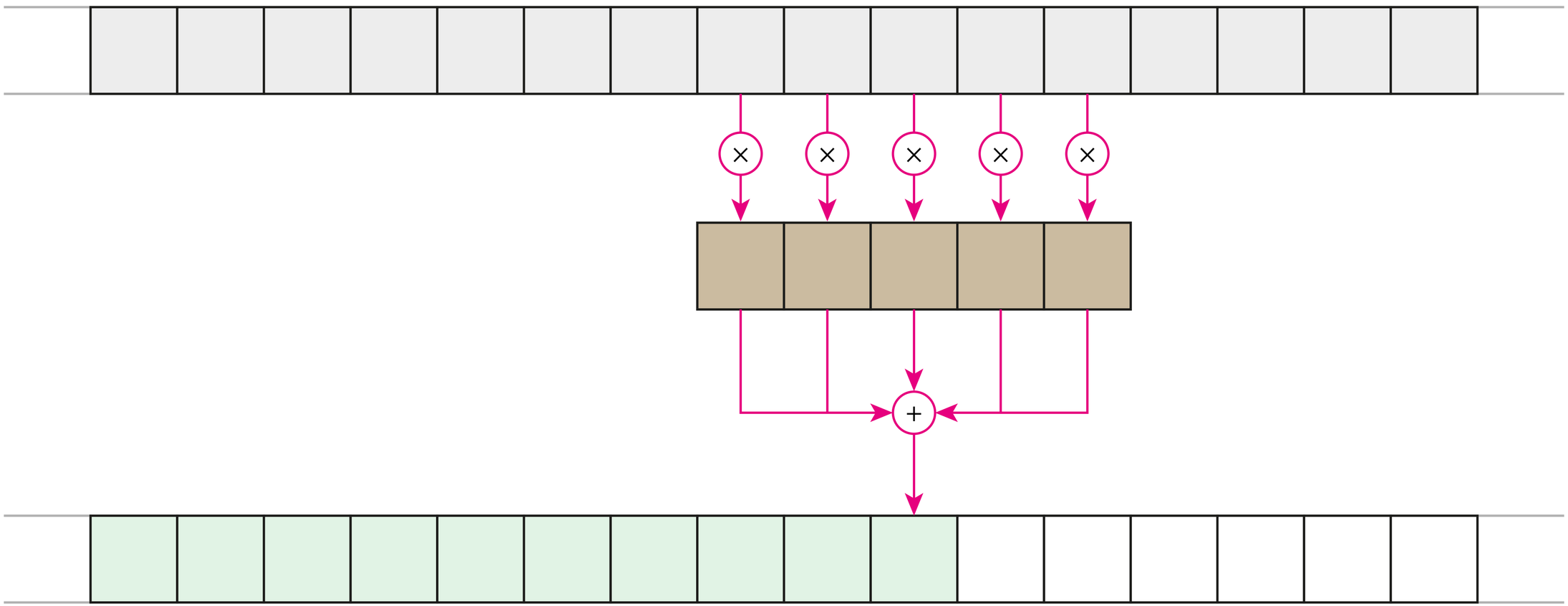


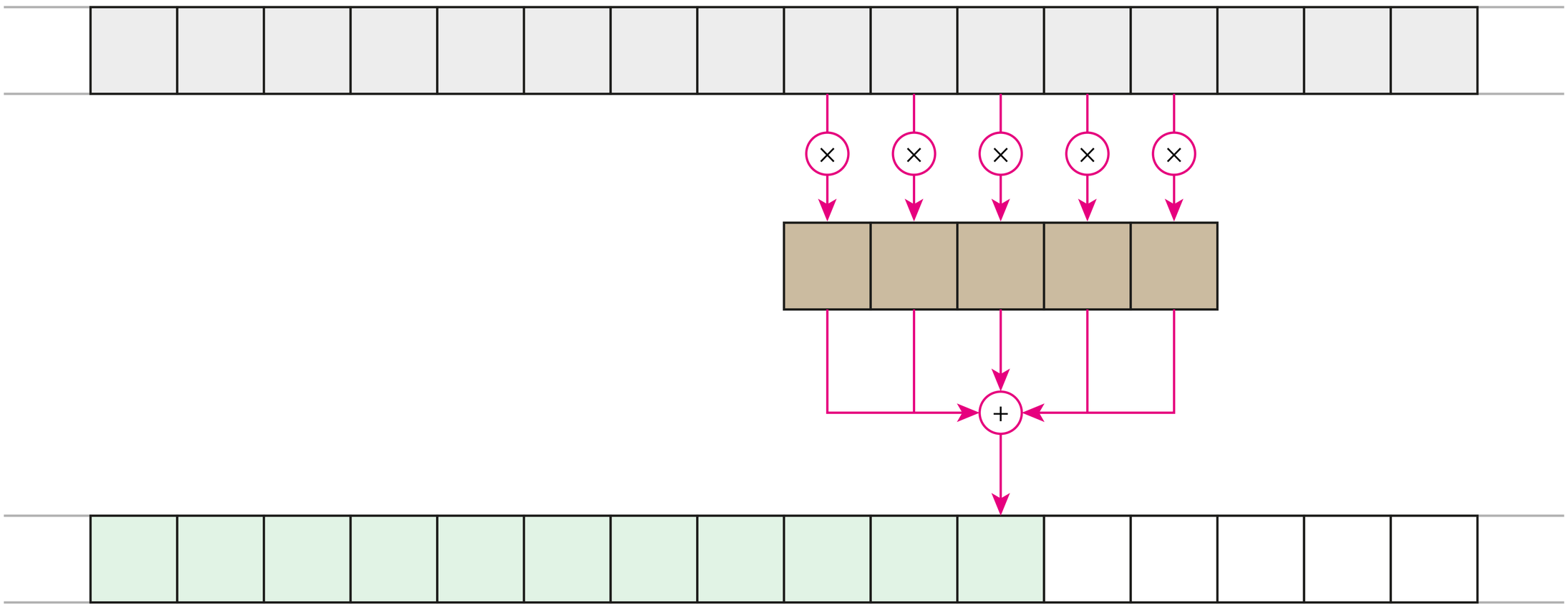


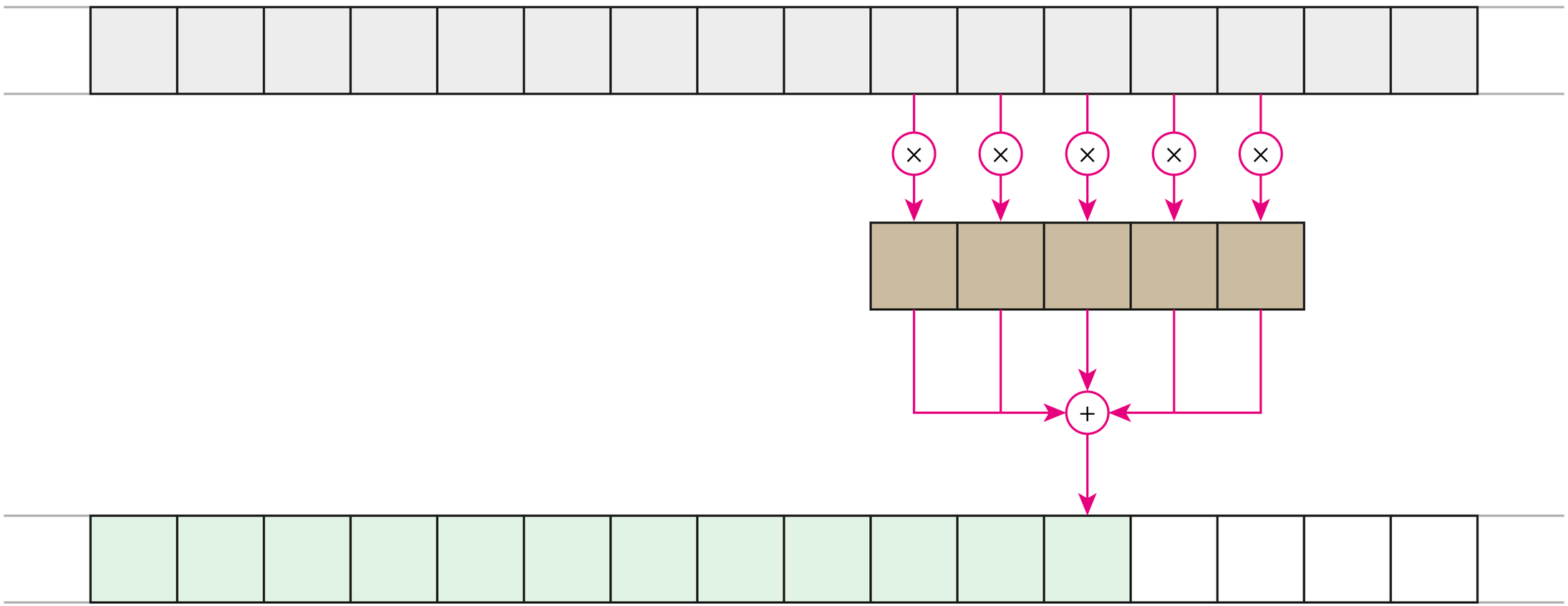


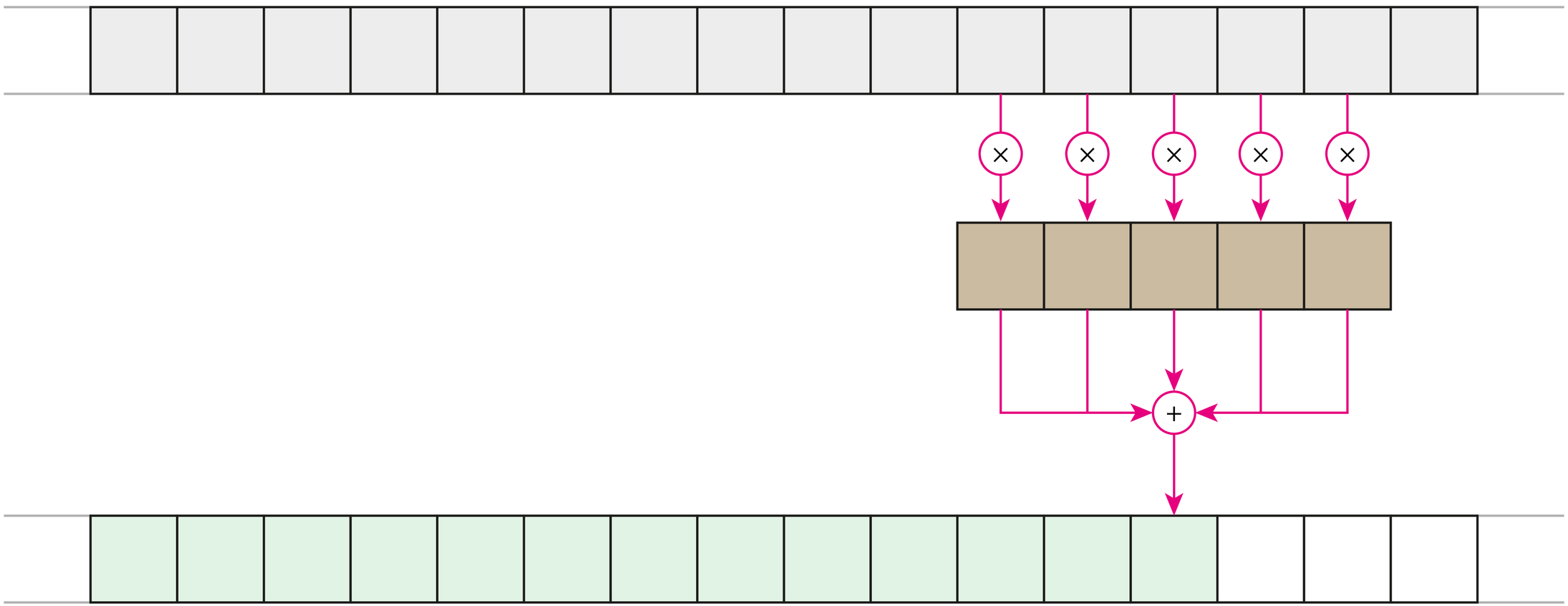


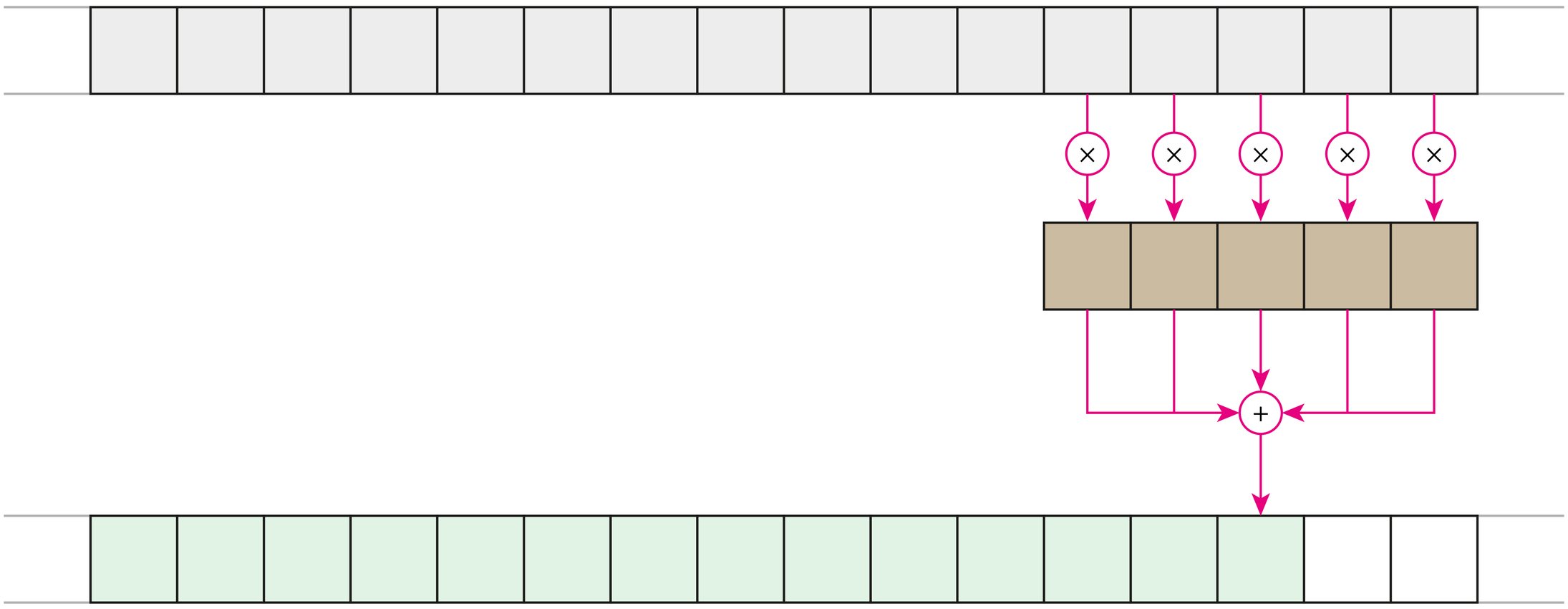


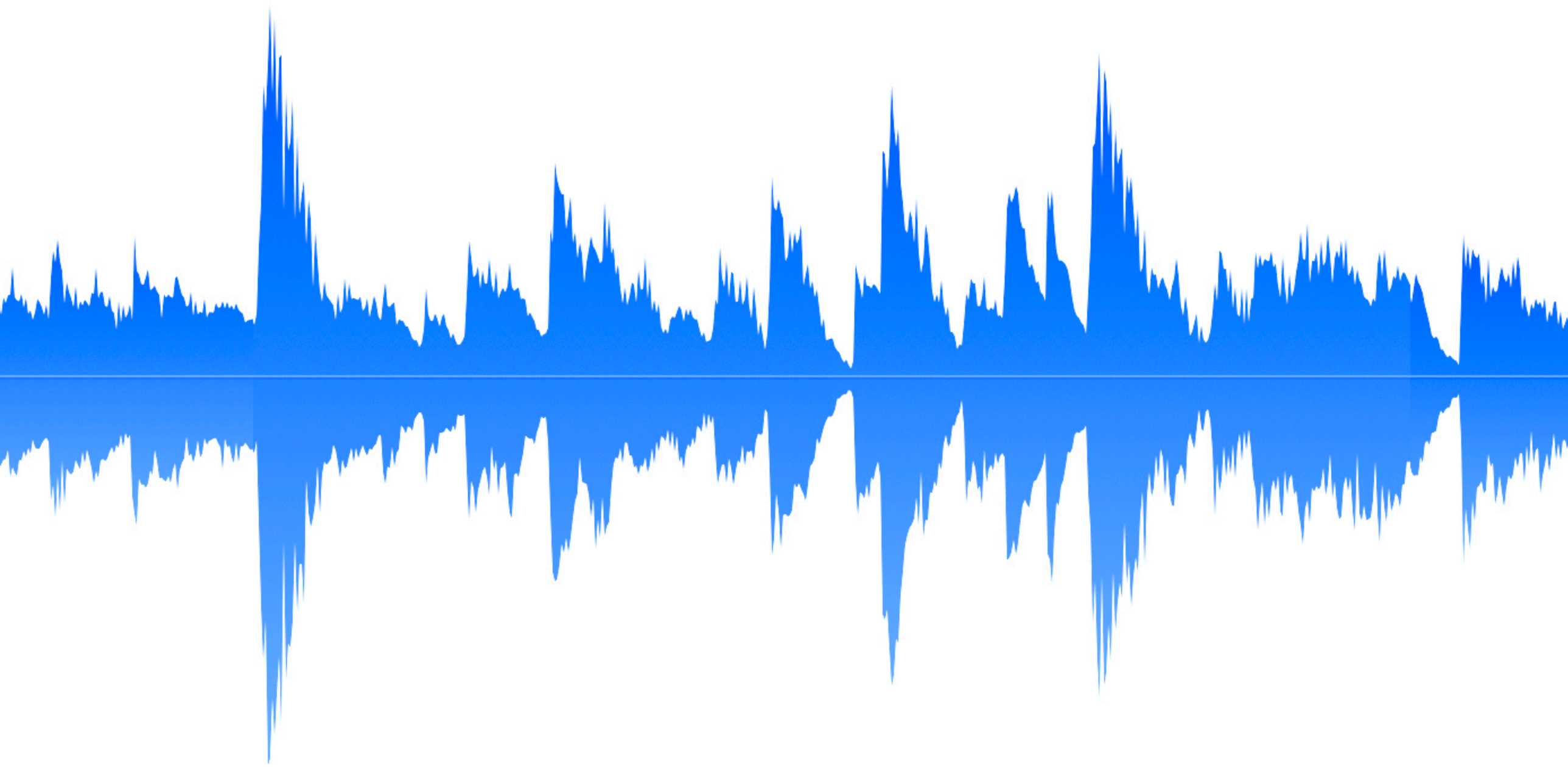










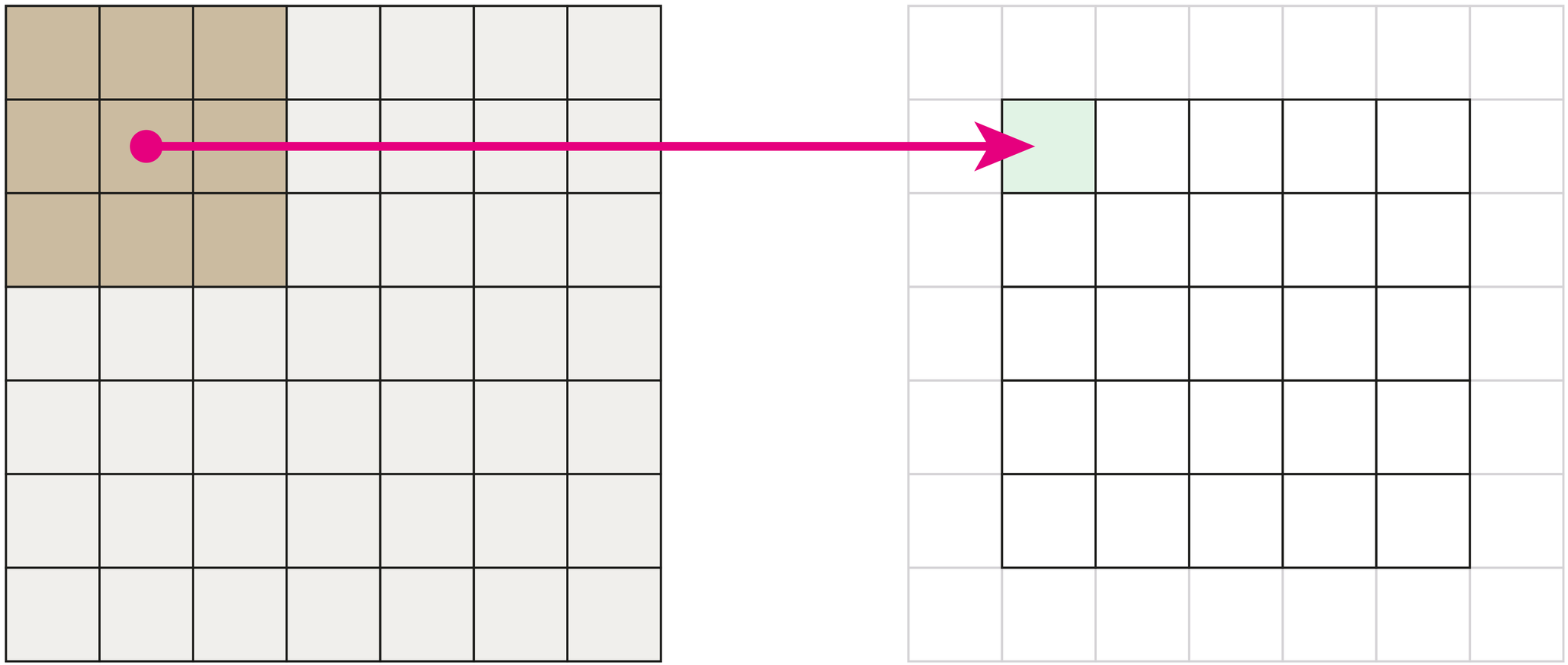


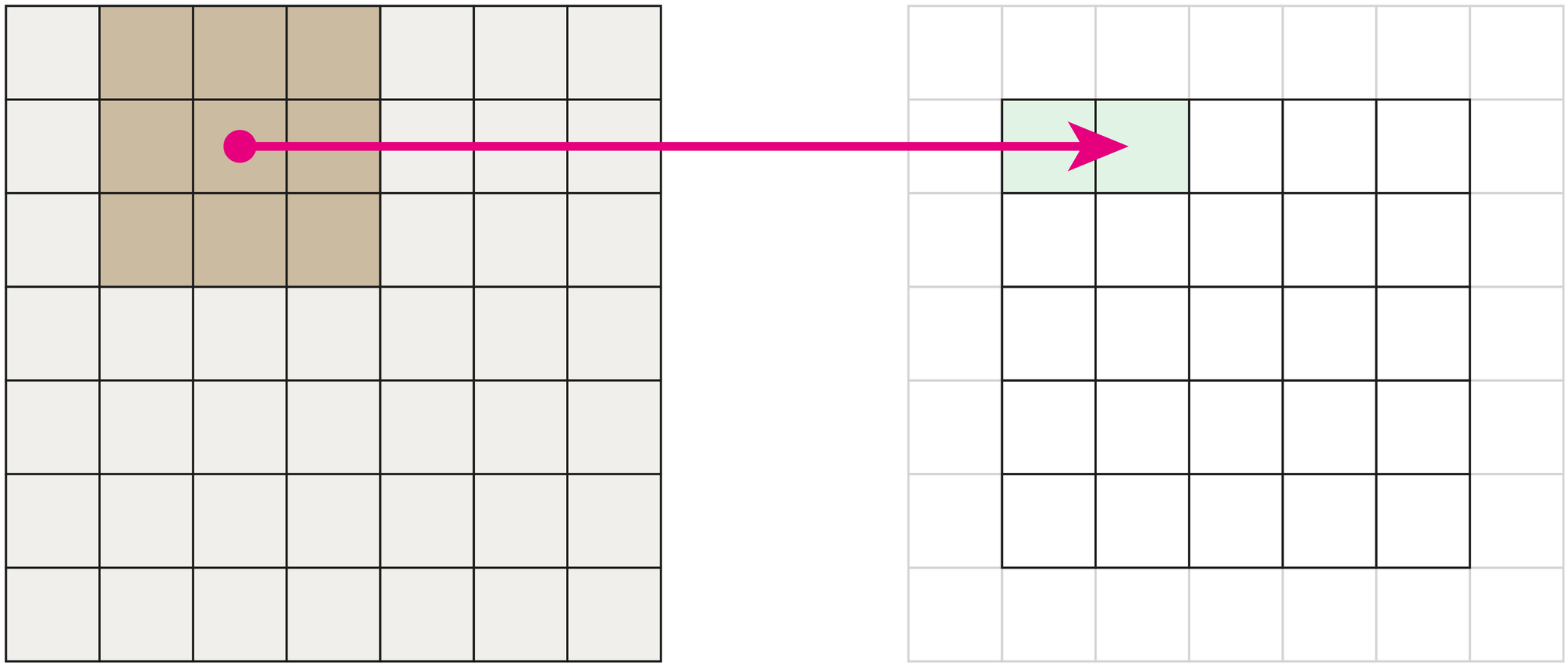
# Original

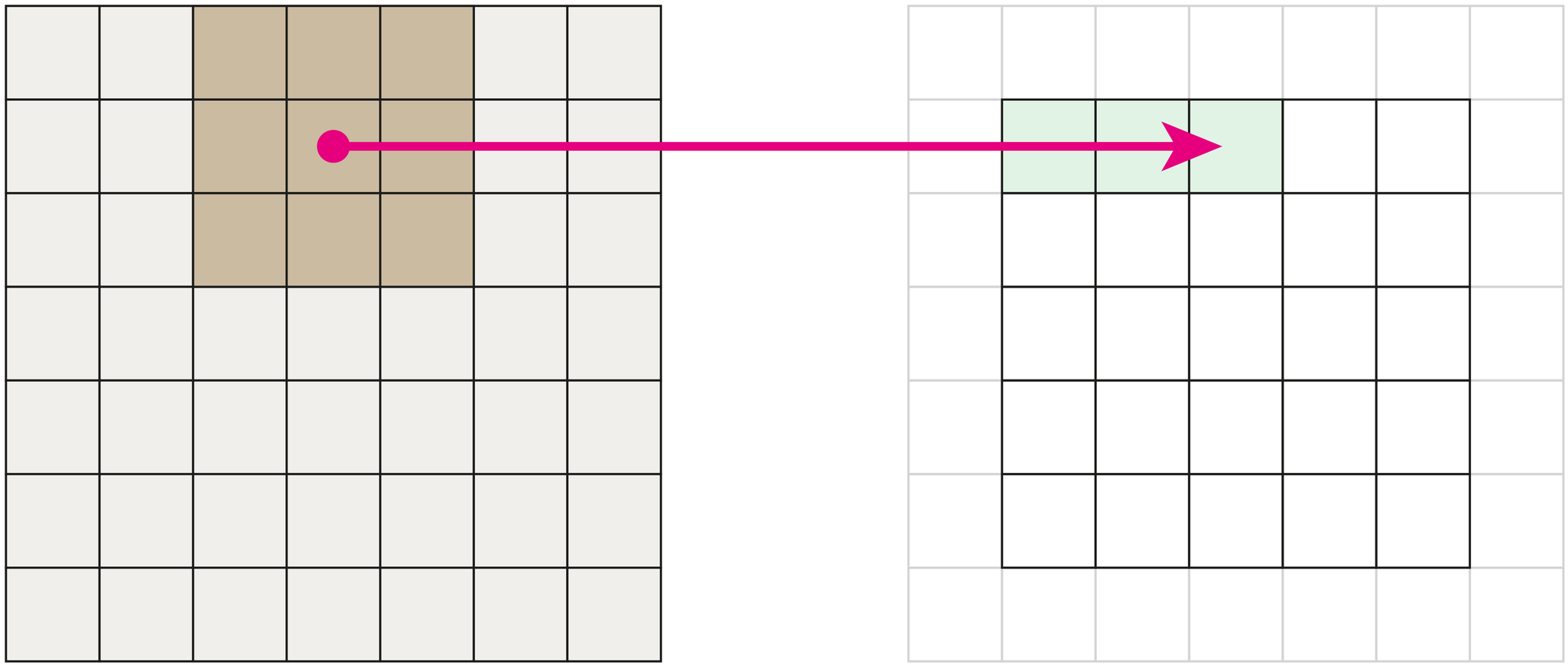
# High Pass Filter*

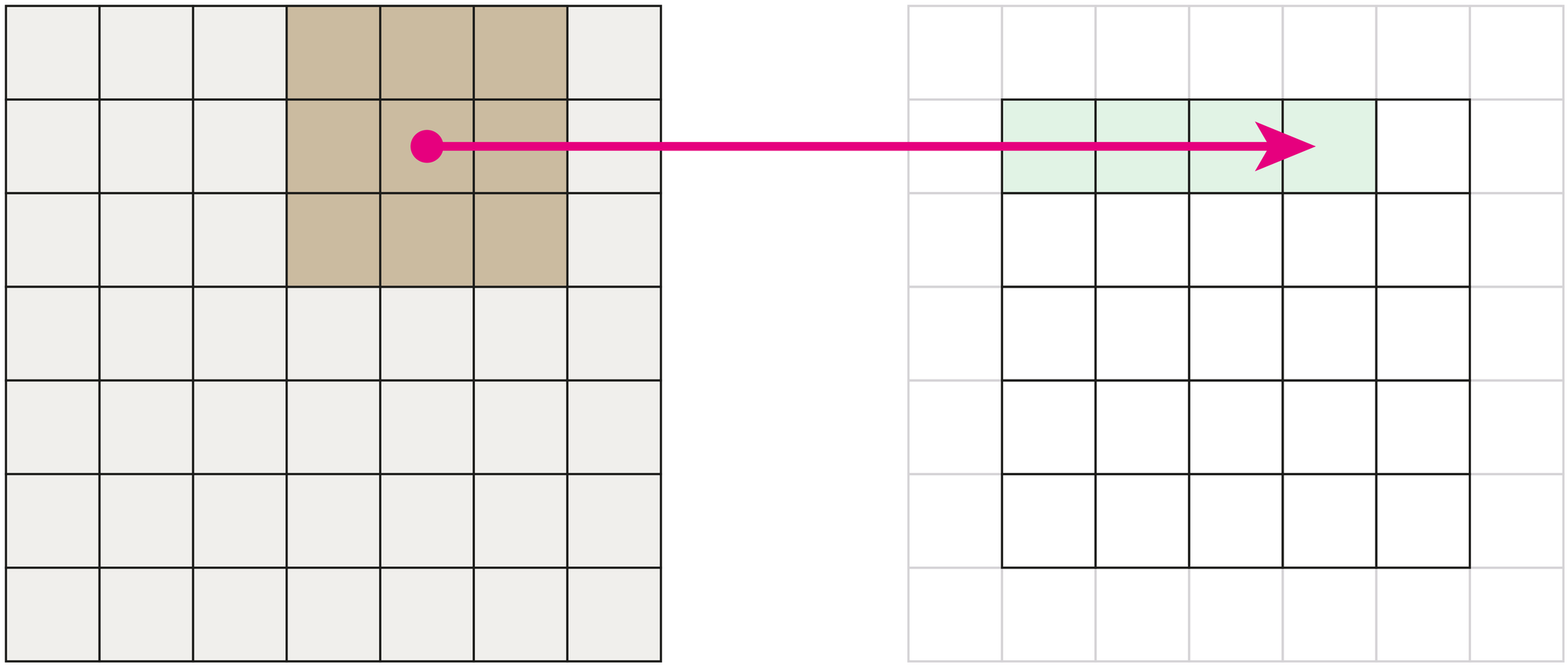
# Impulse Response

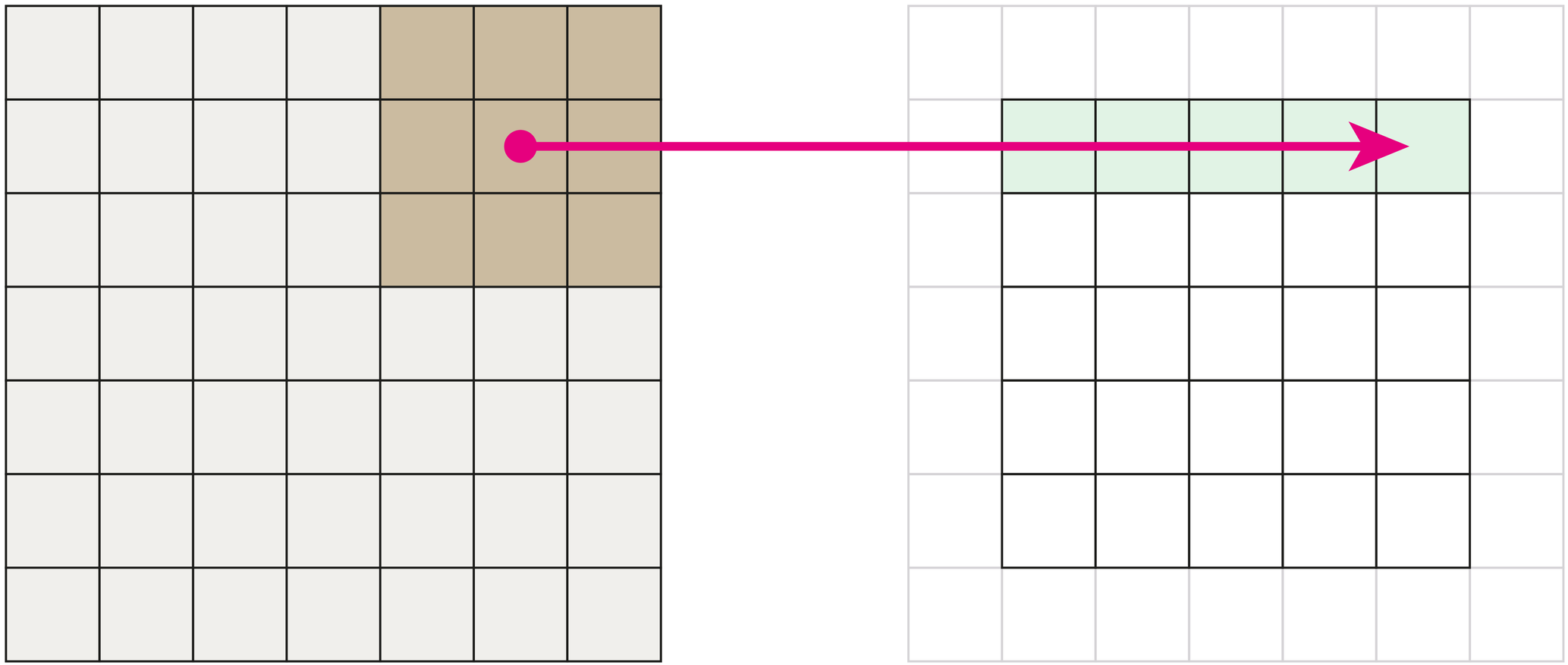
# Convolution Reverb

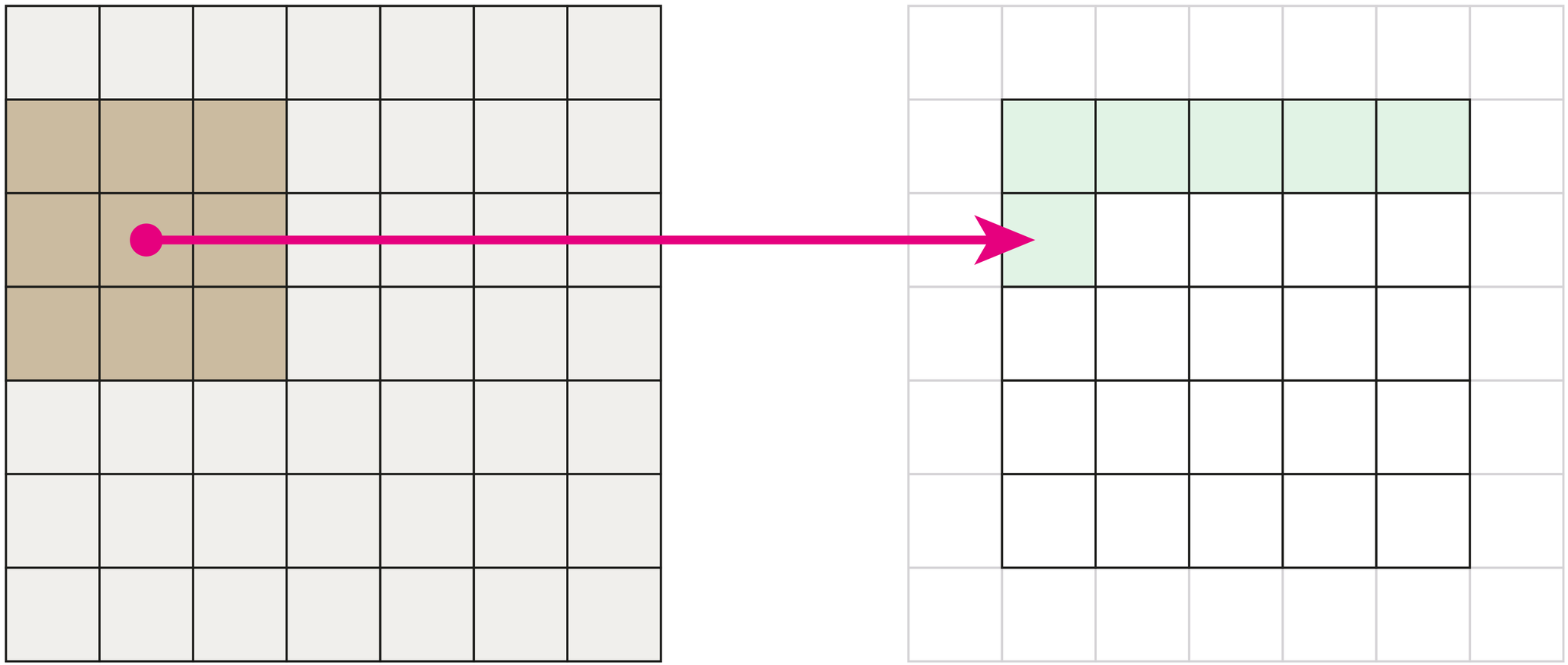


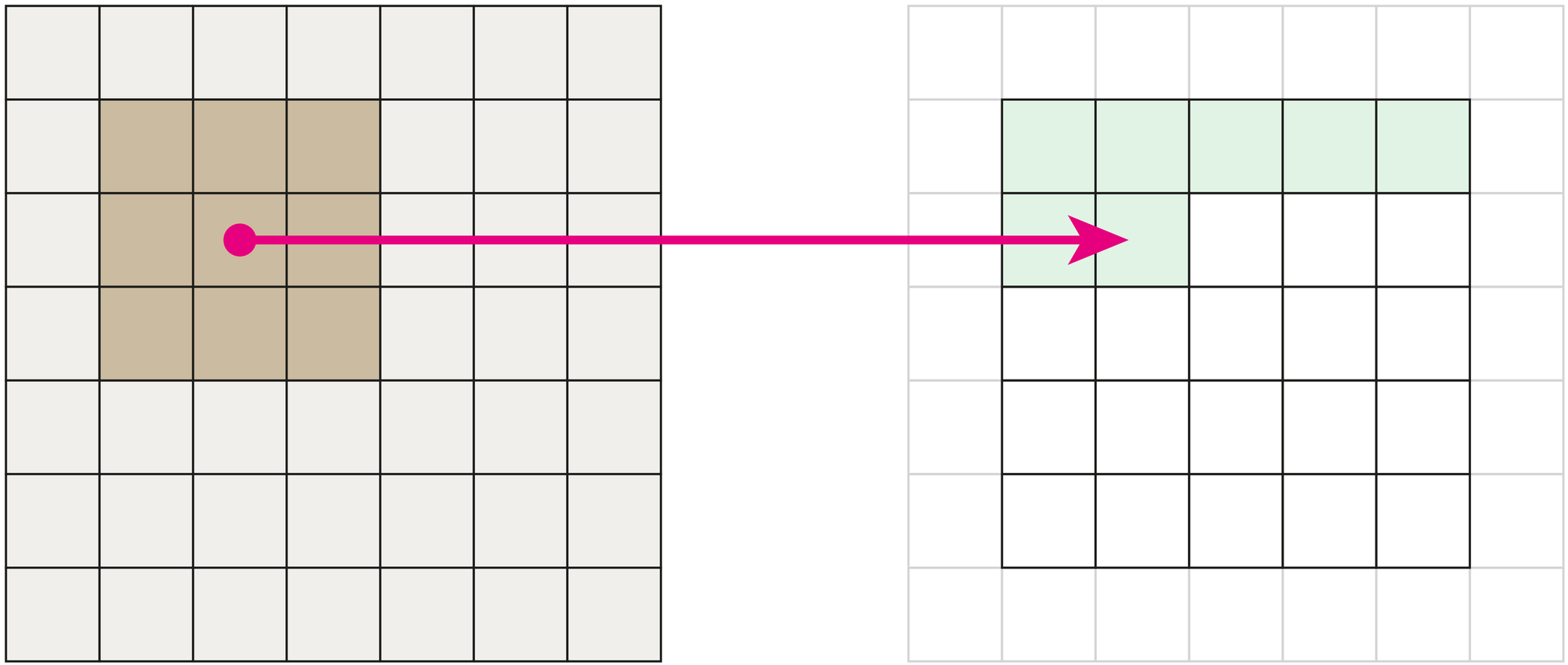


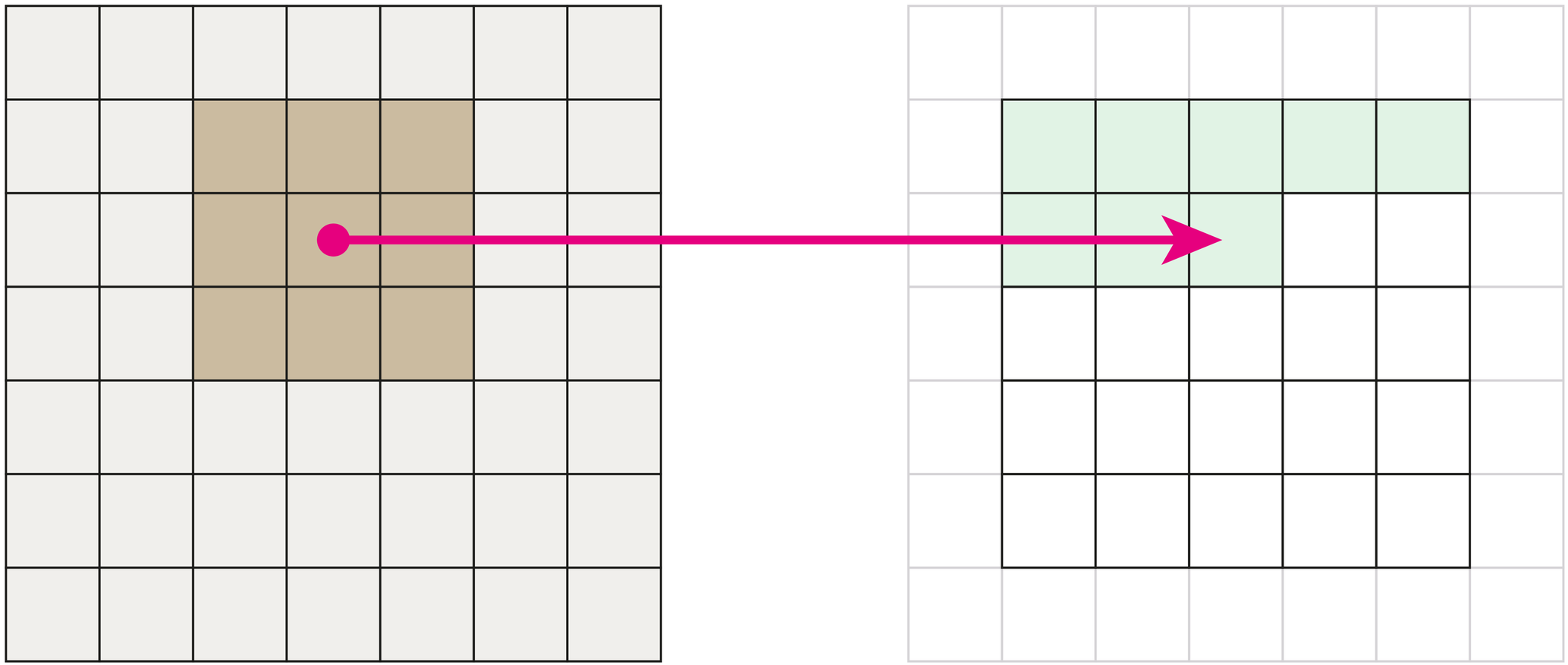


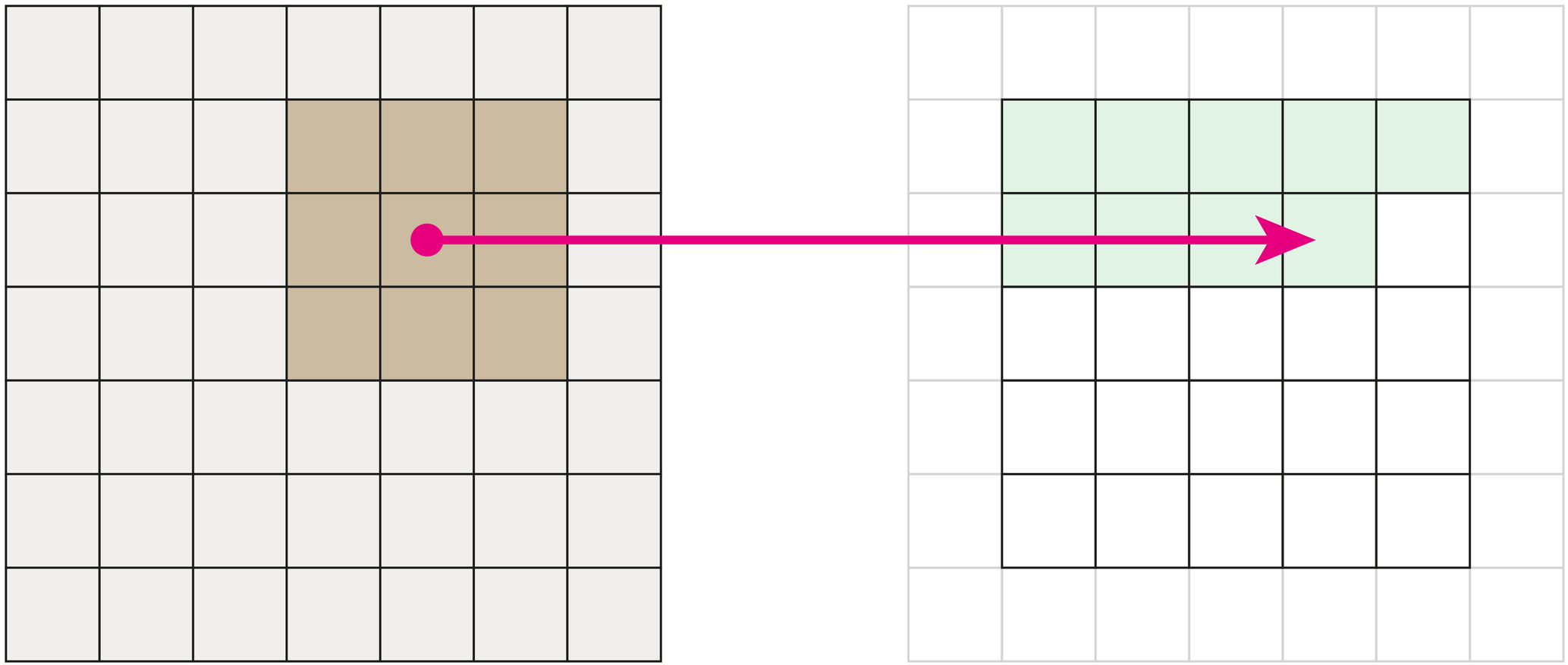


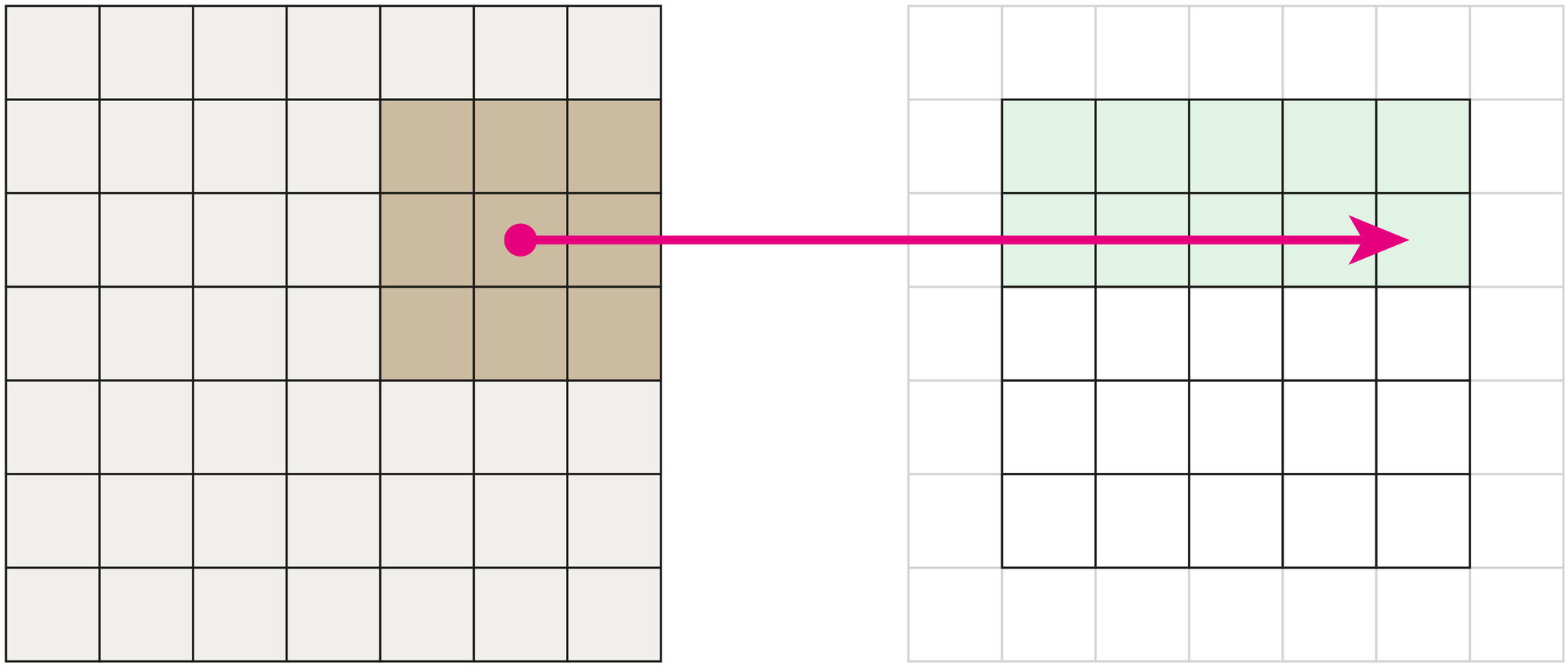


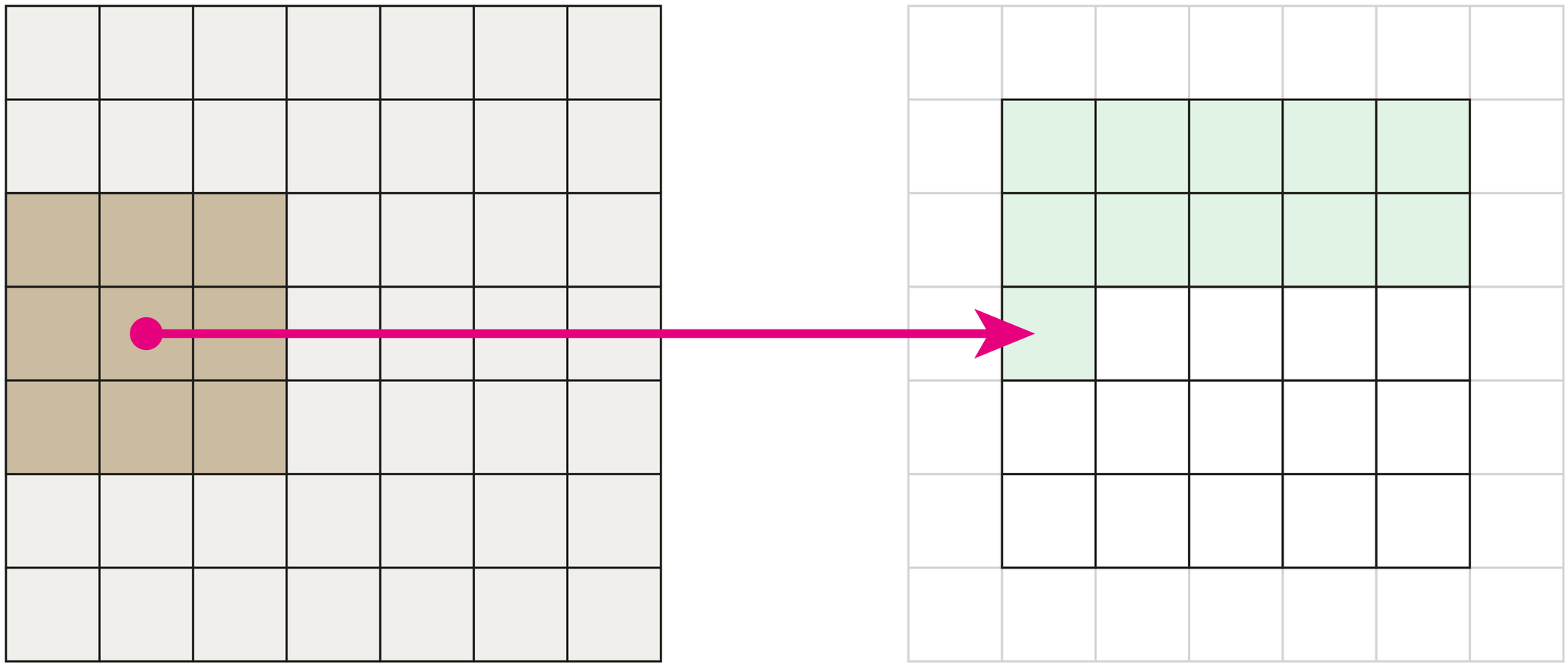


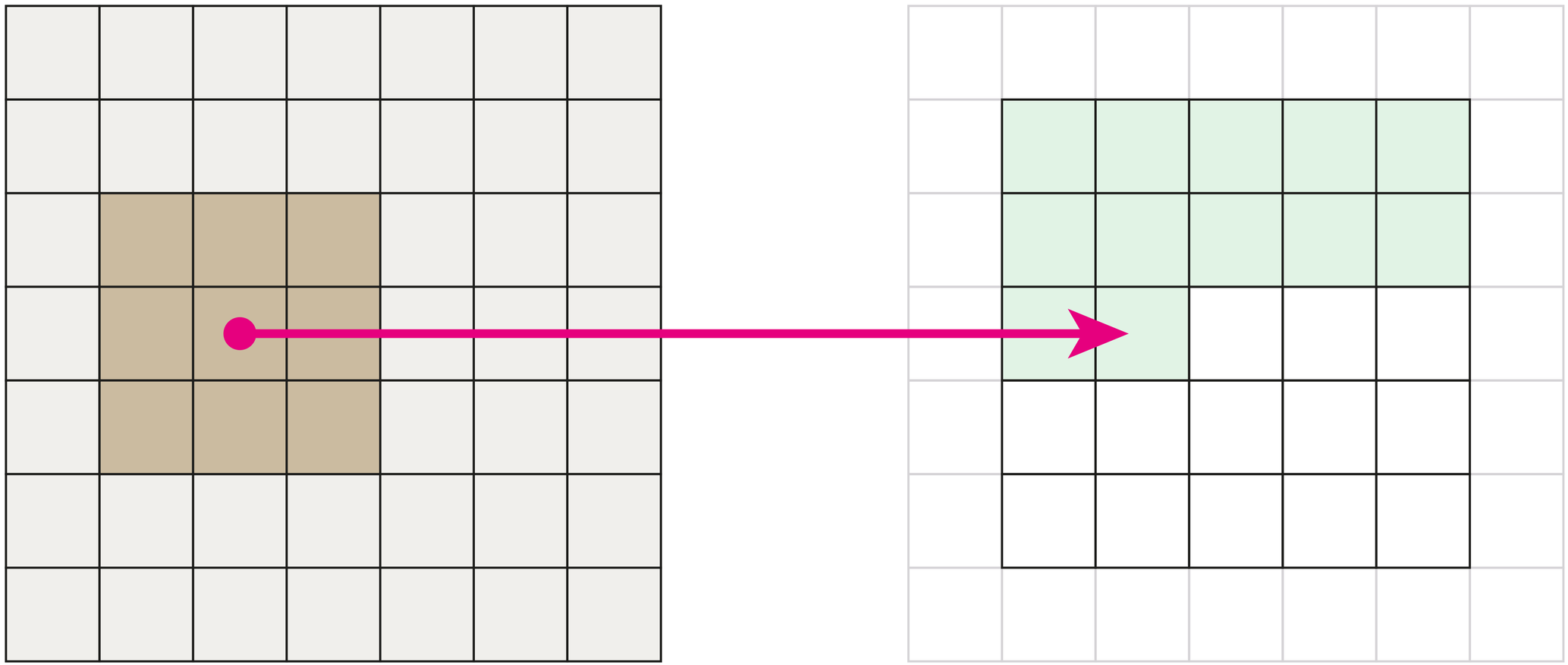


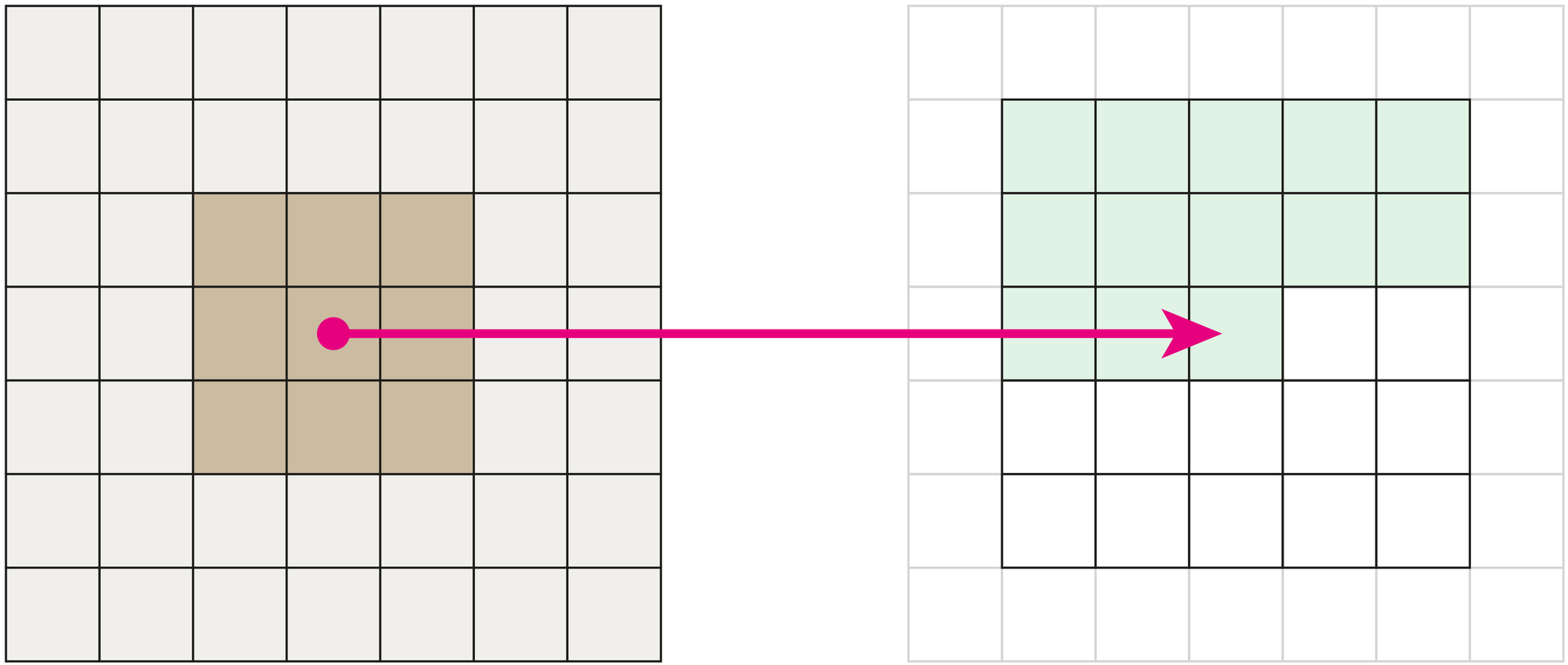






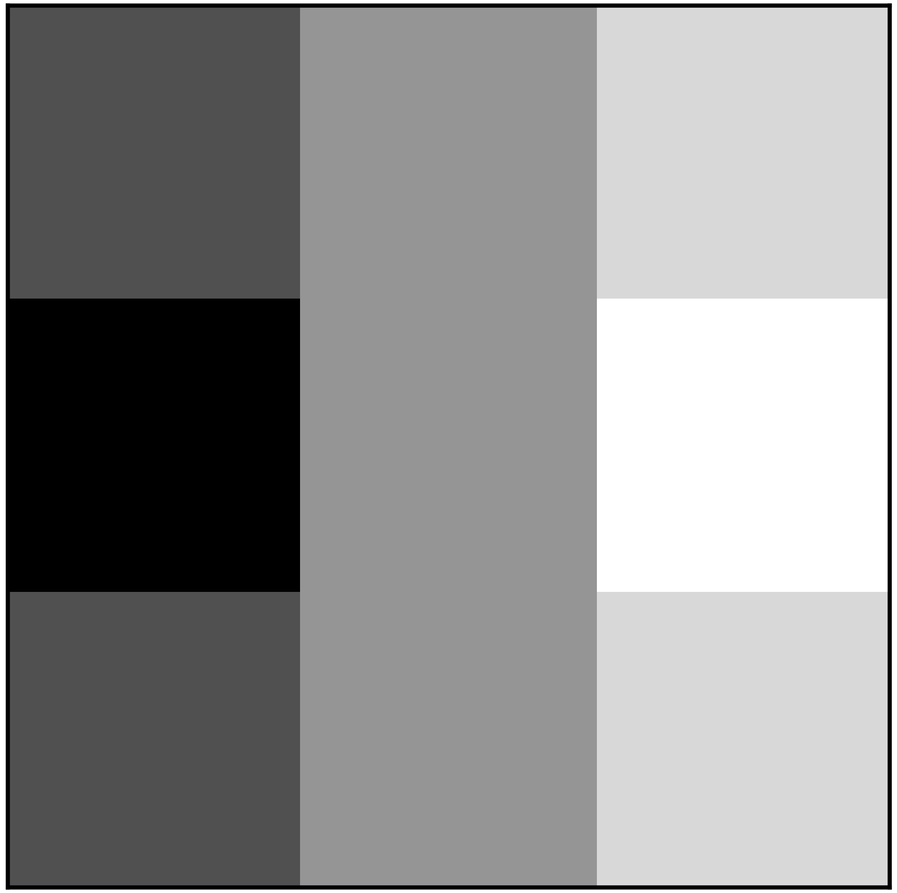


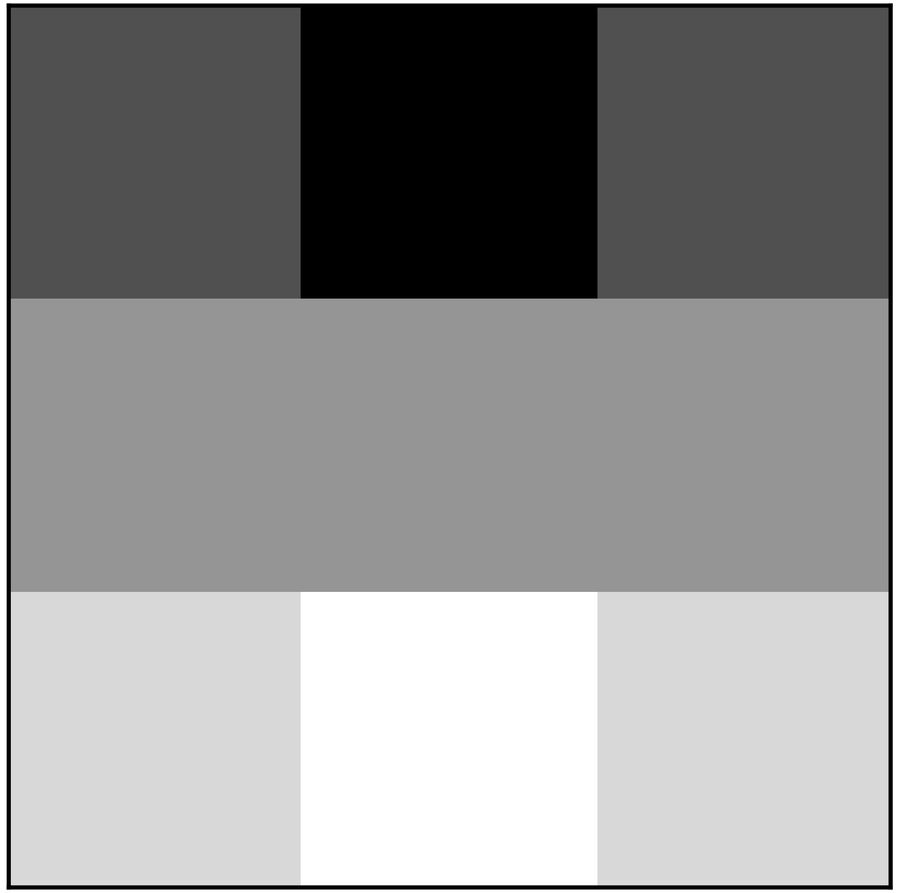


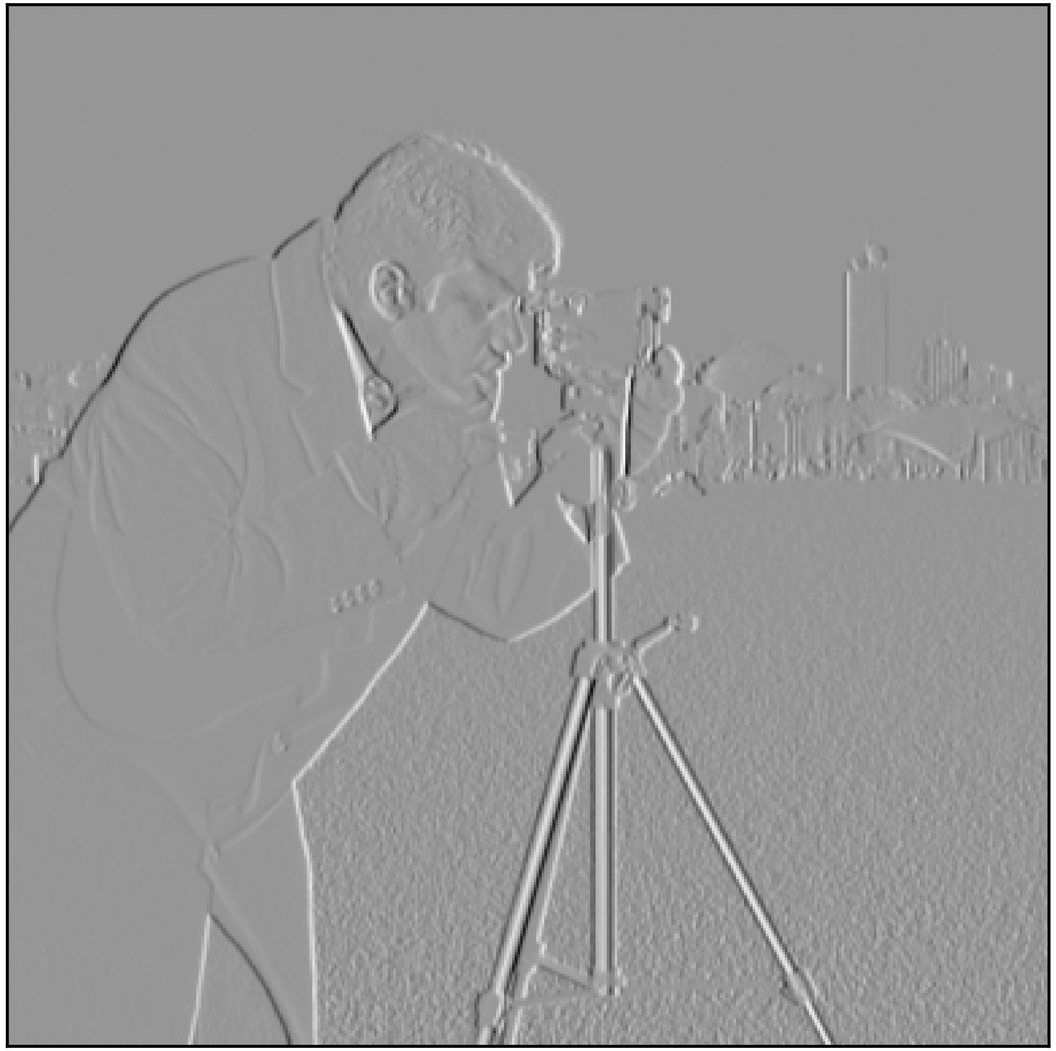


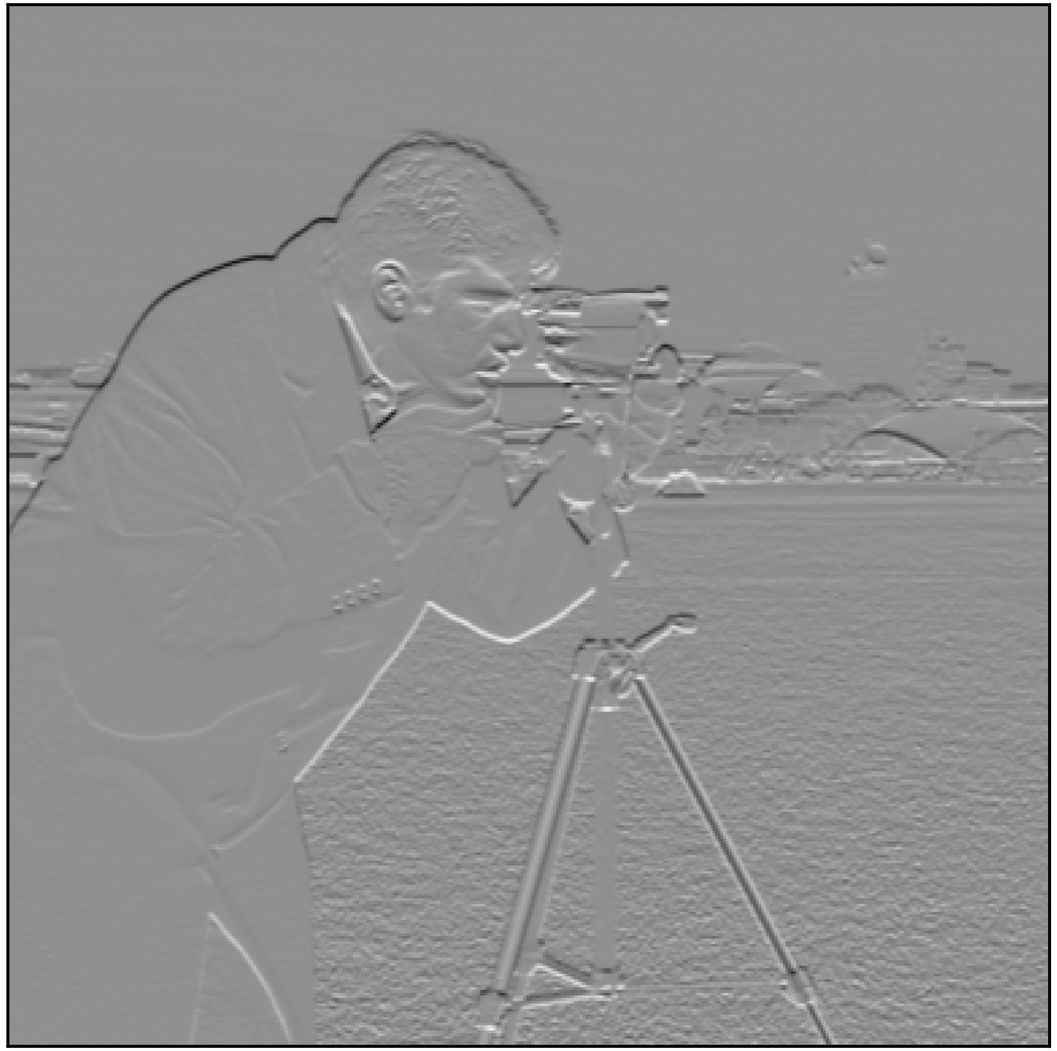
$$\sum_{i}^{k}\sum_{j}^{k} f_{s+i-1,t+j-1} \times g_{i,j}$$

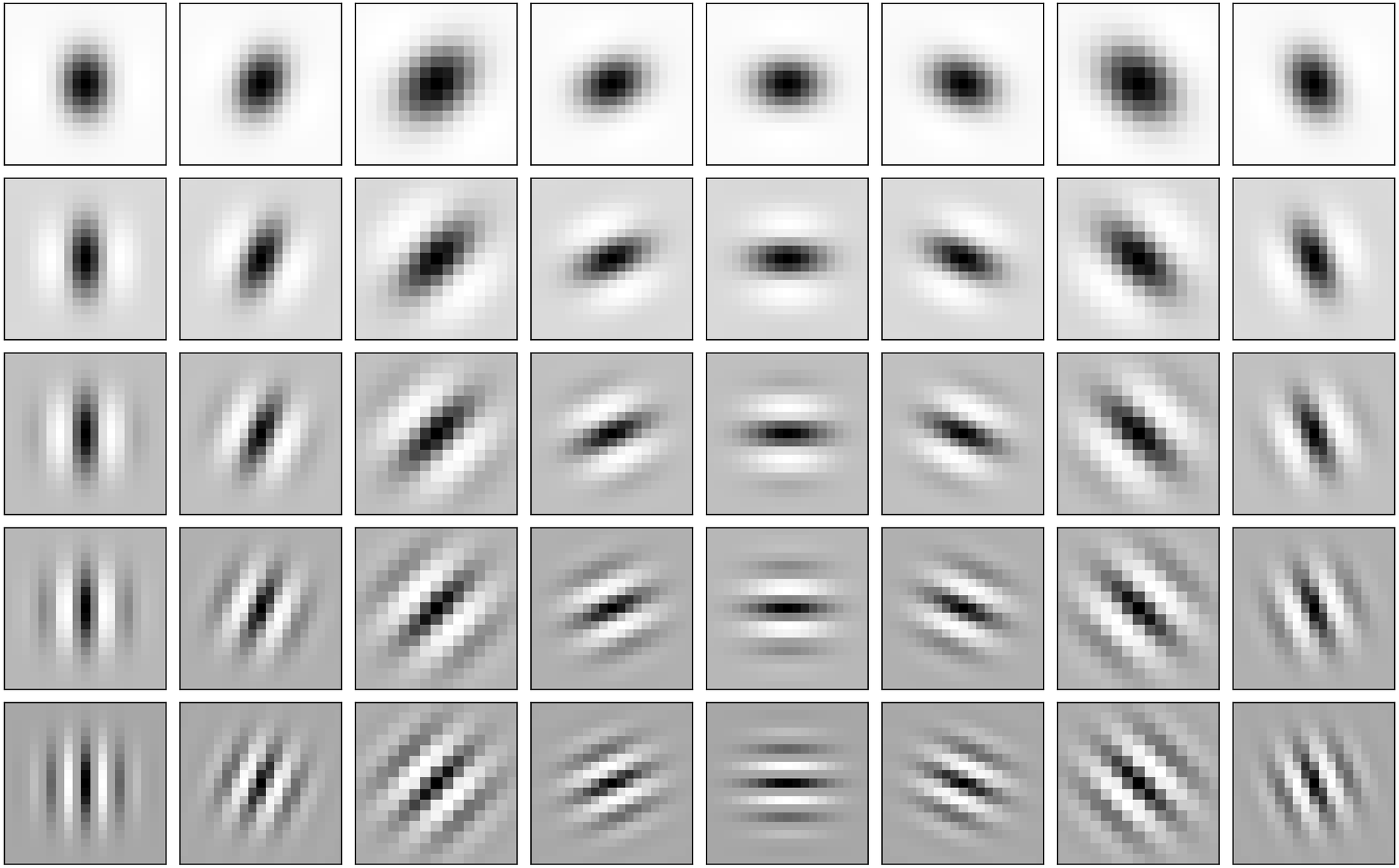
$$\mathbf{f}_{[\ldots]} \cdot \mathbf{g}$$

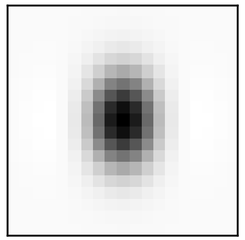


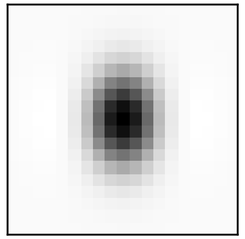


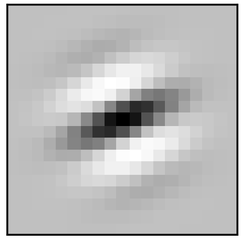


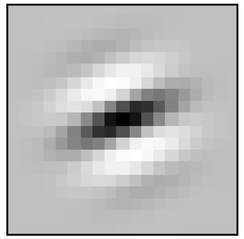


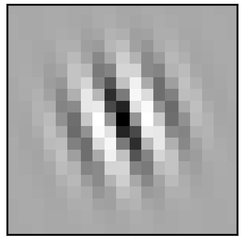


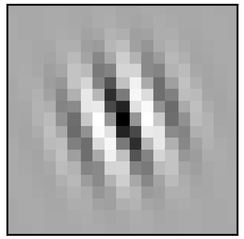


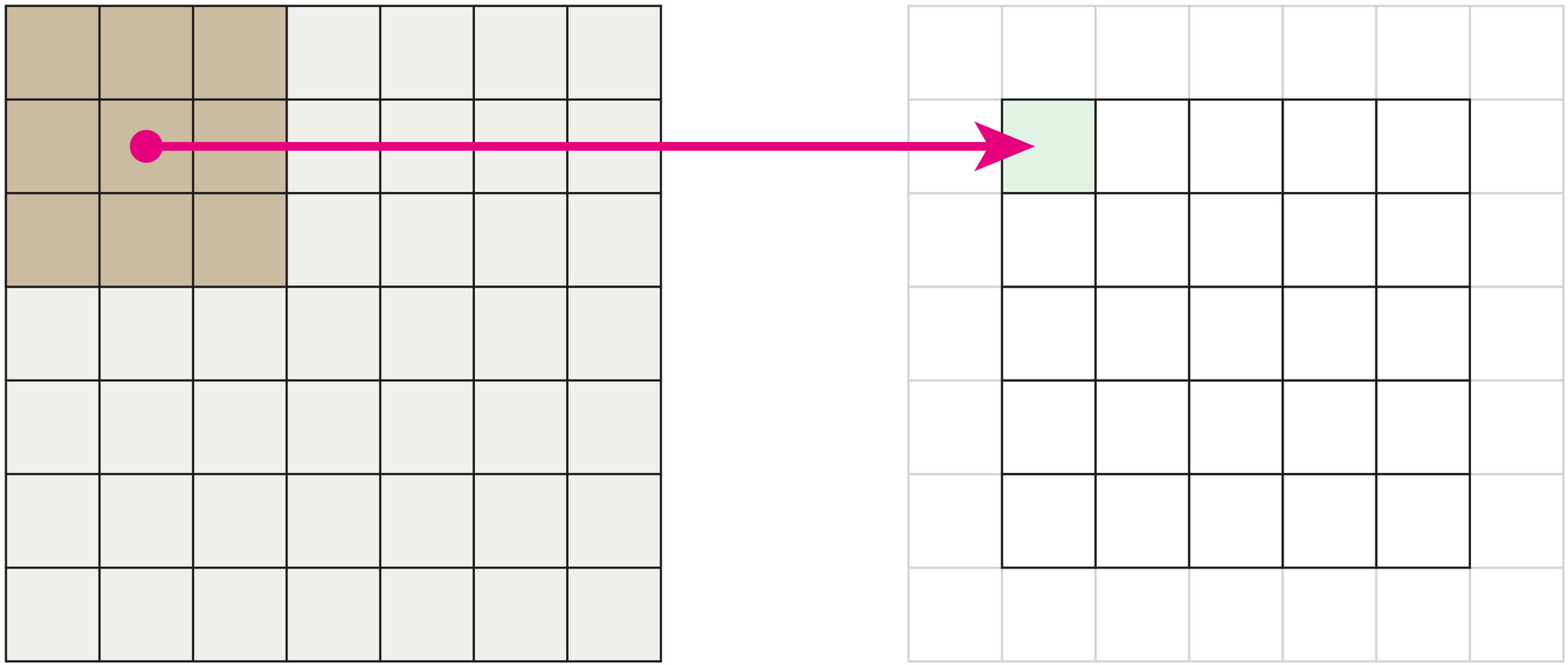


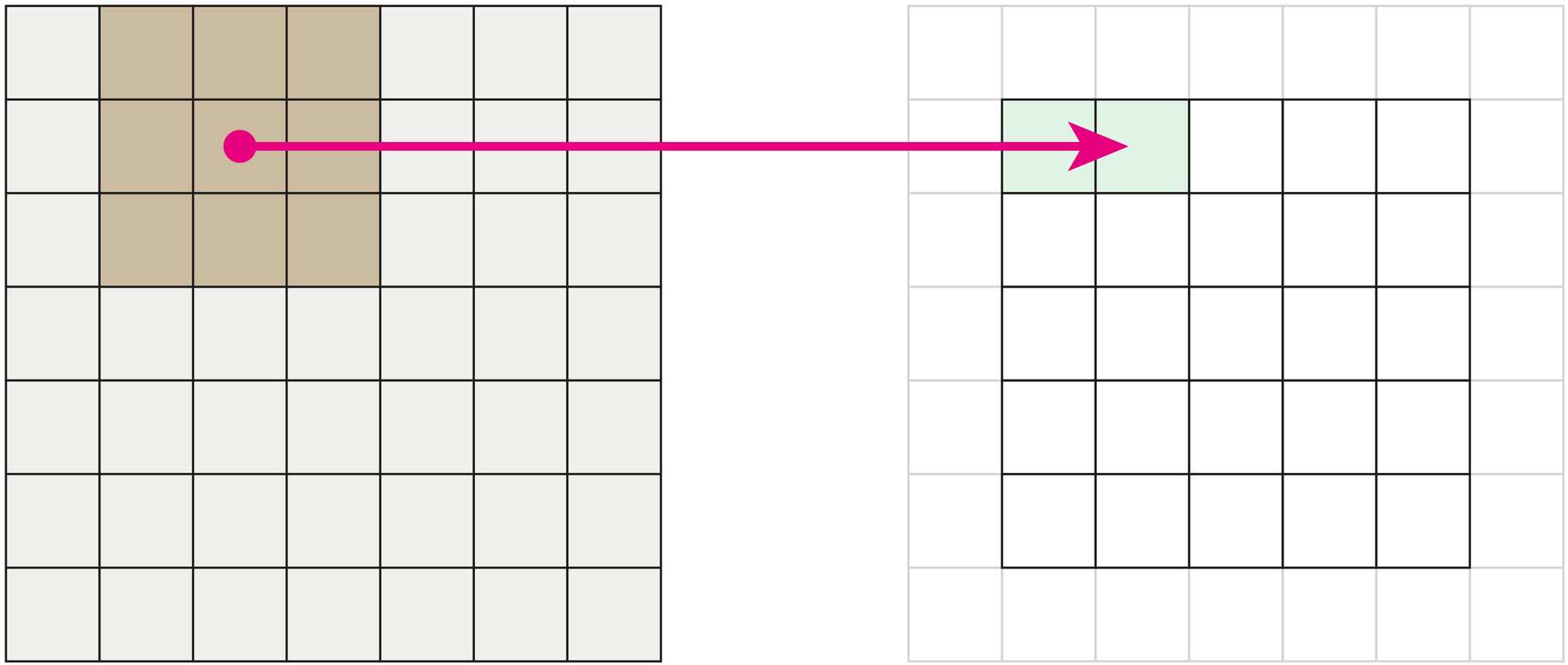


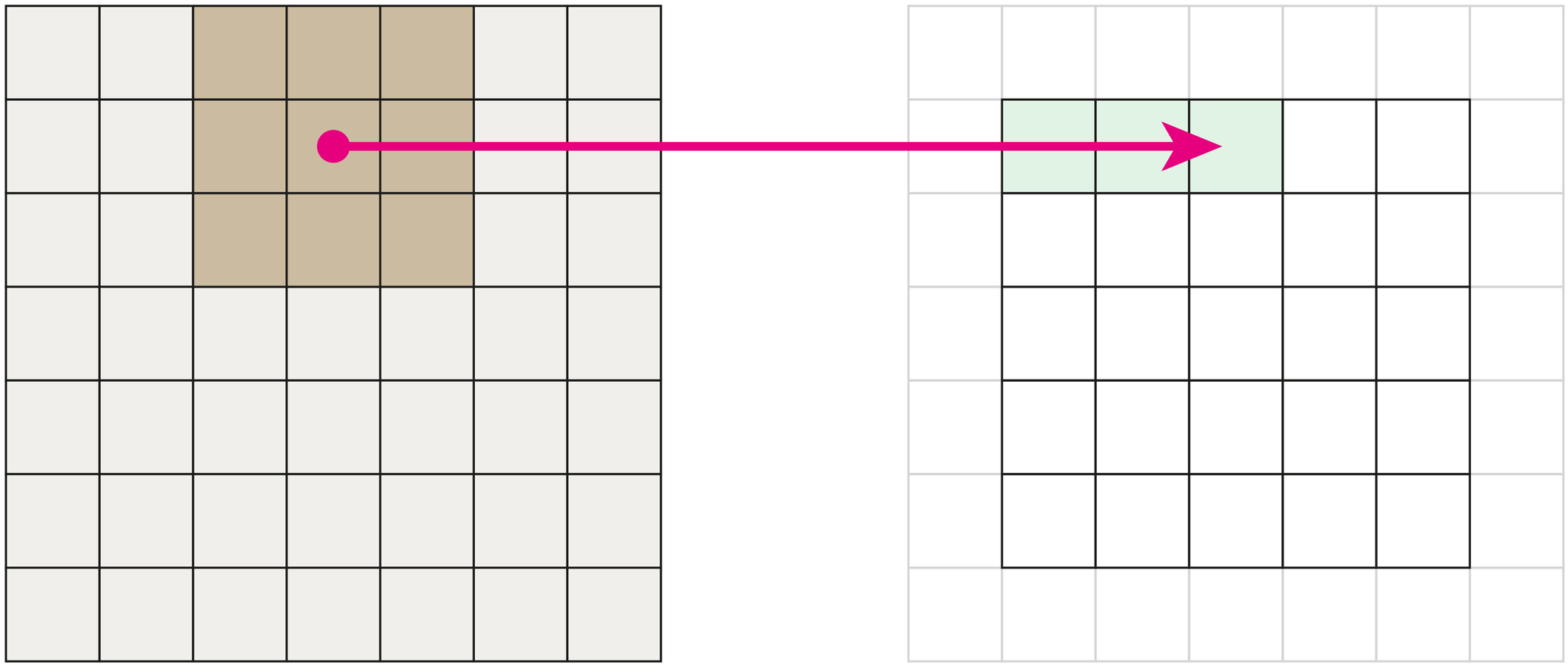


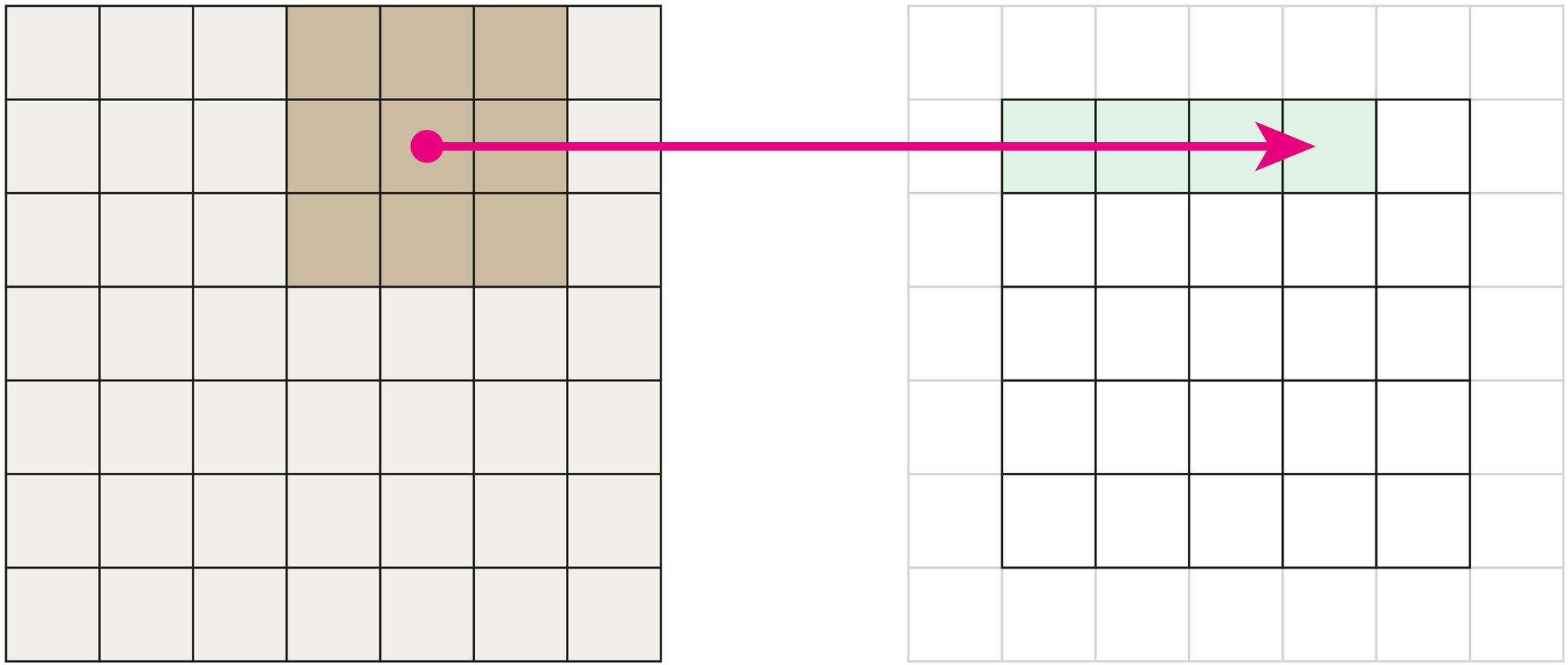


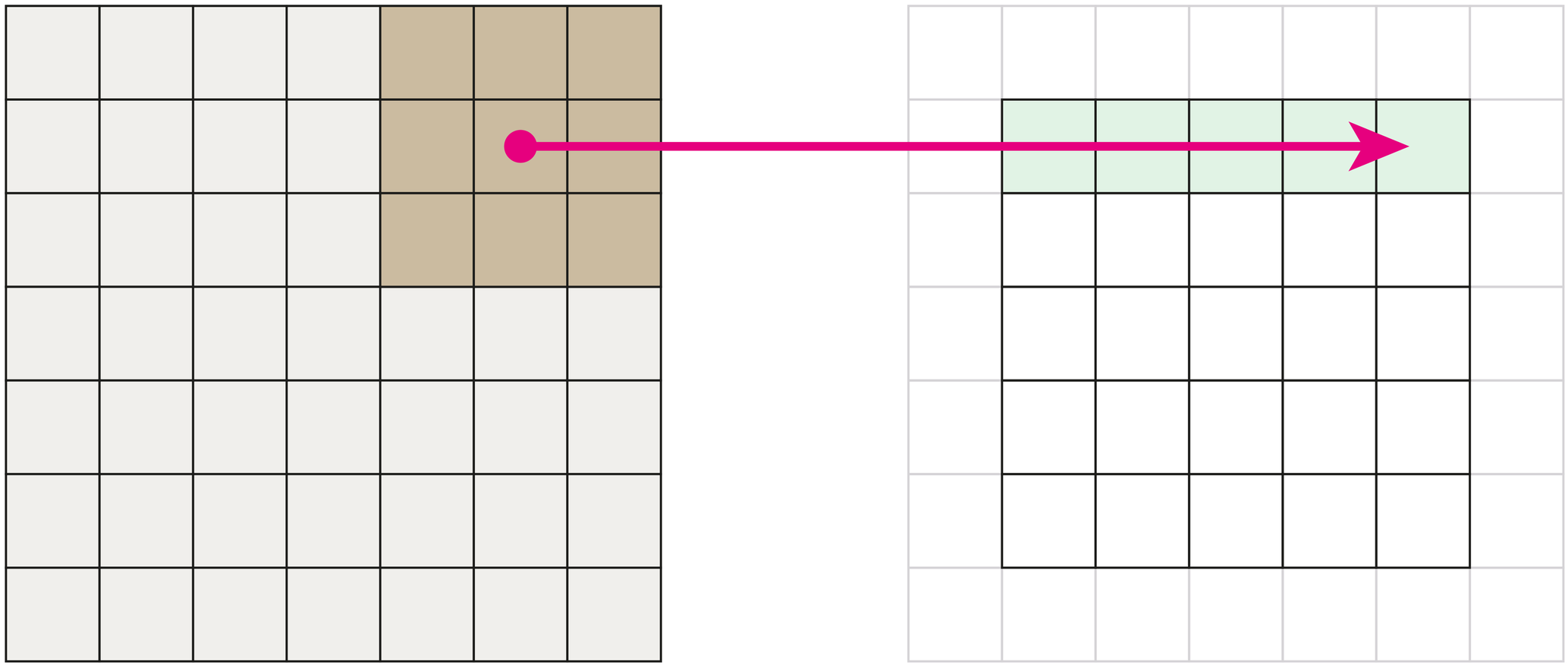


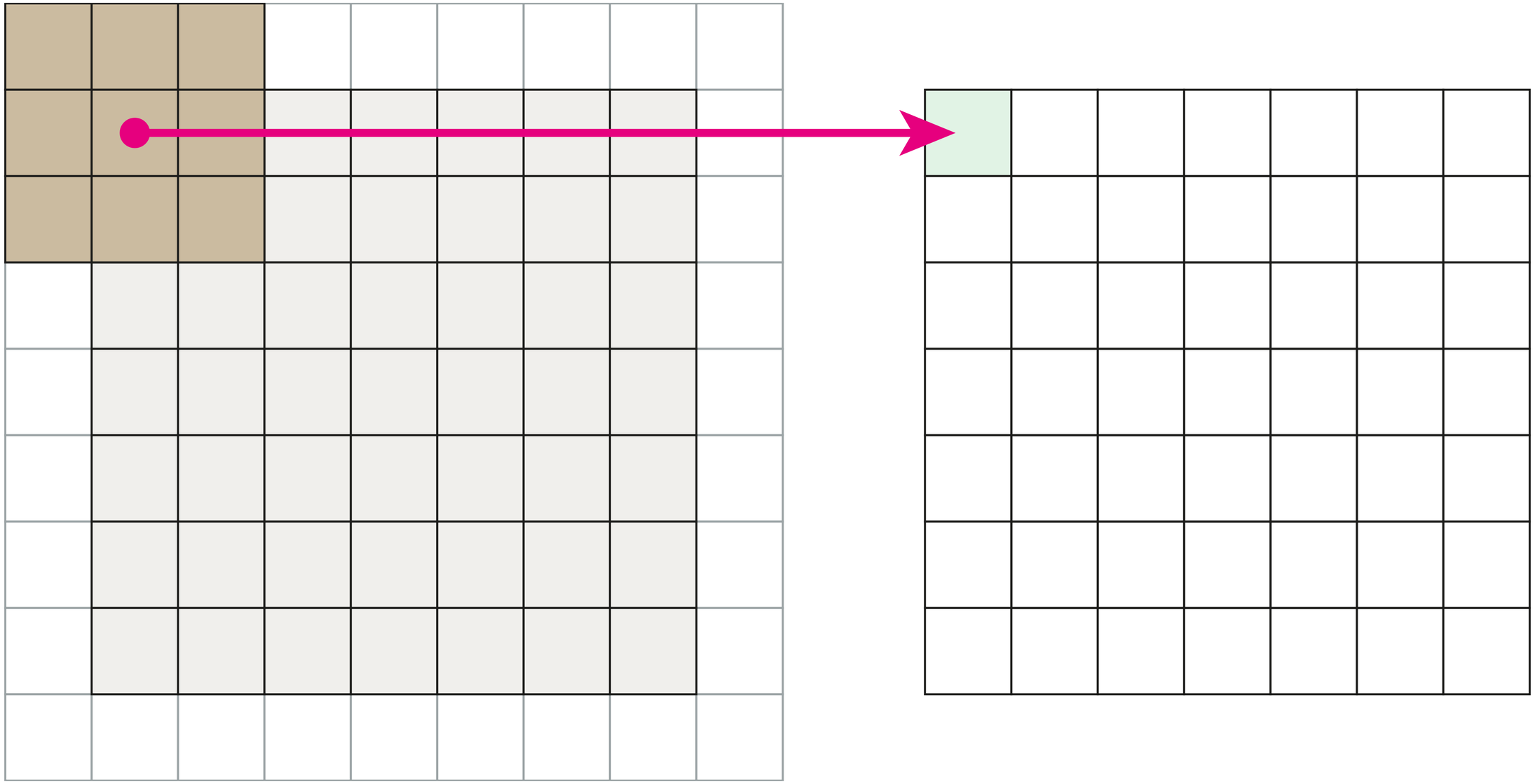


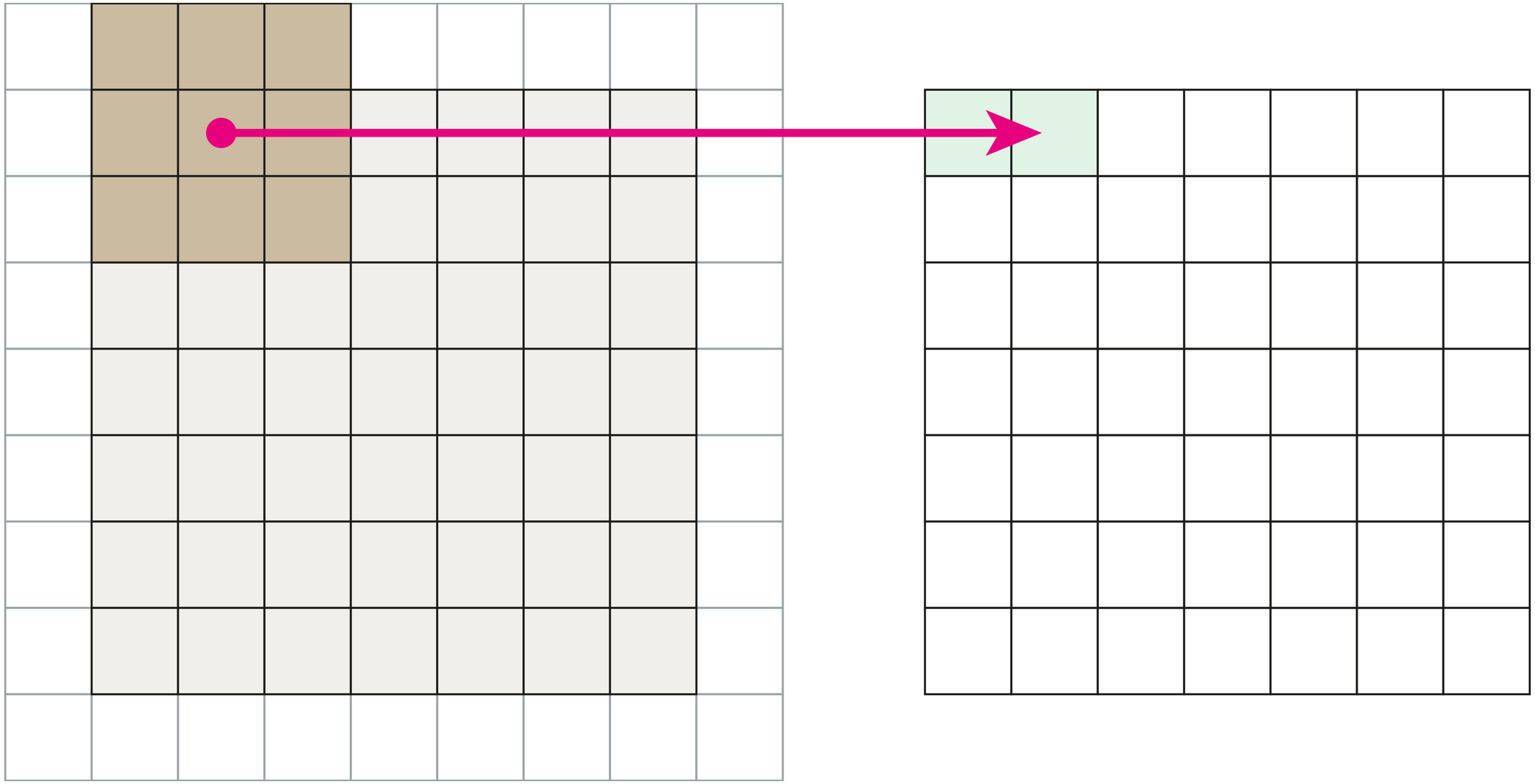


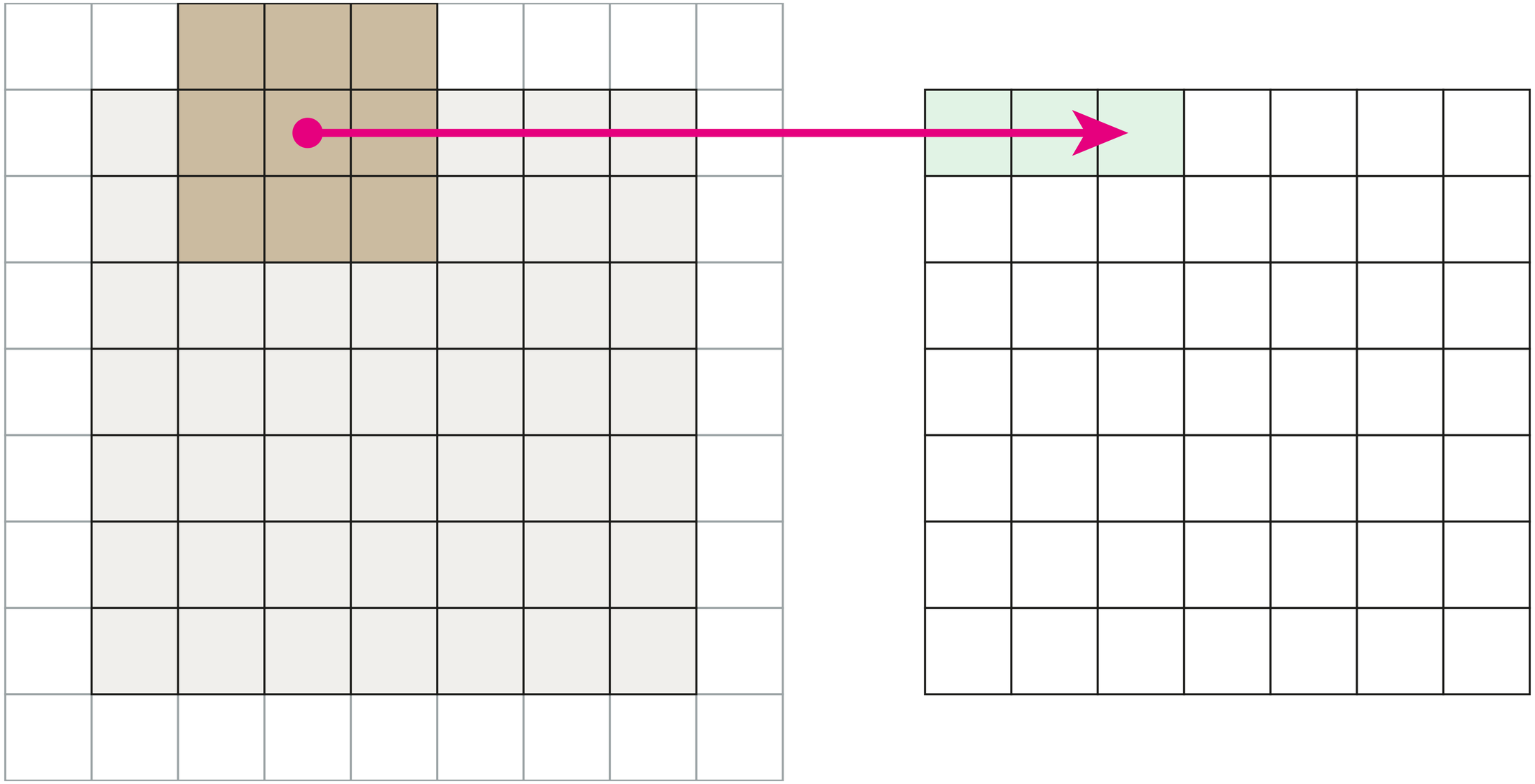


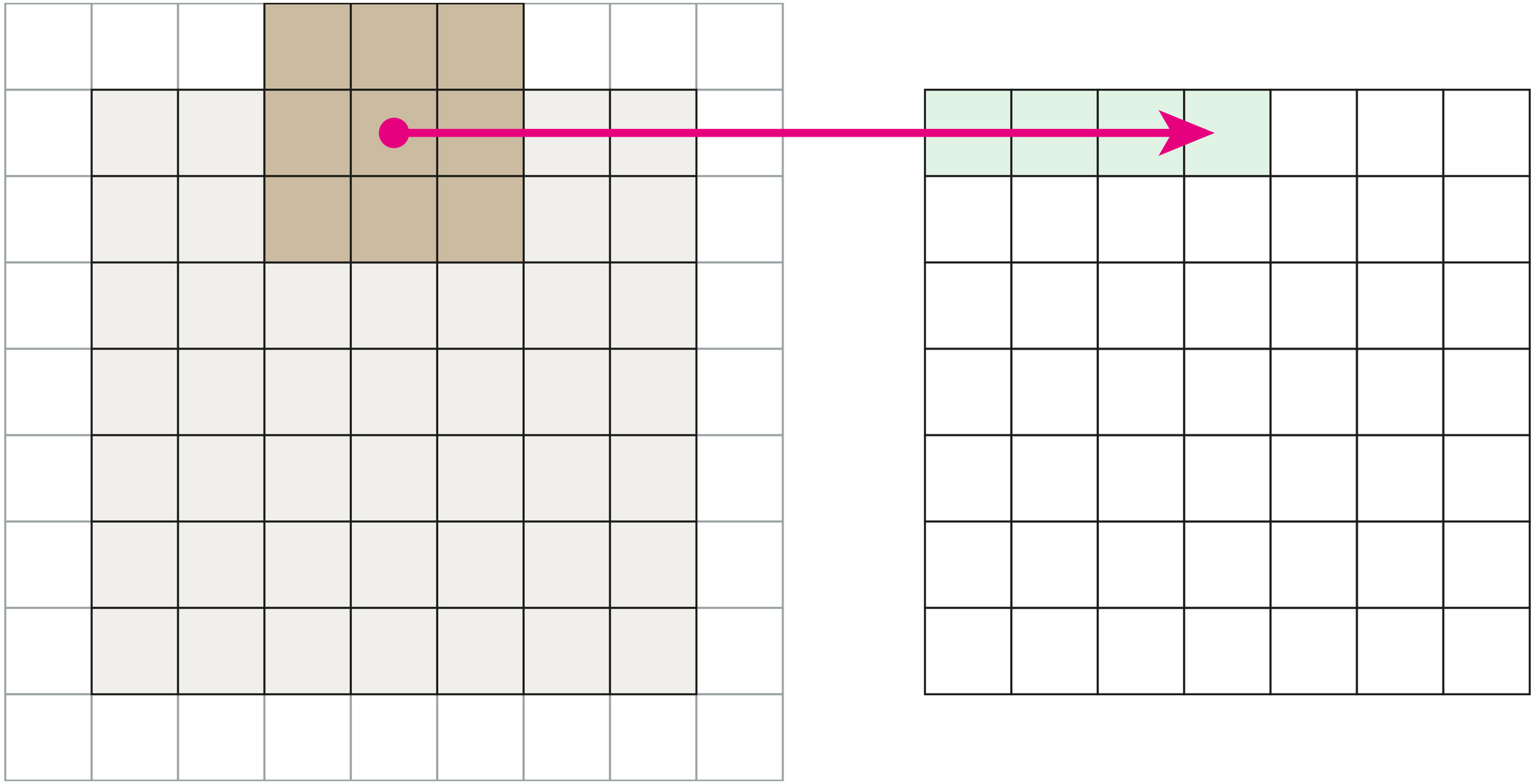


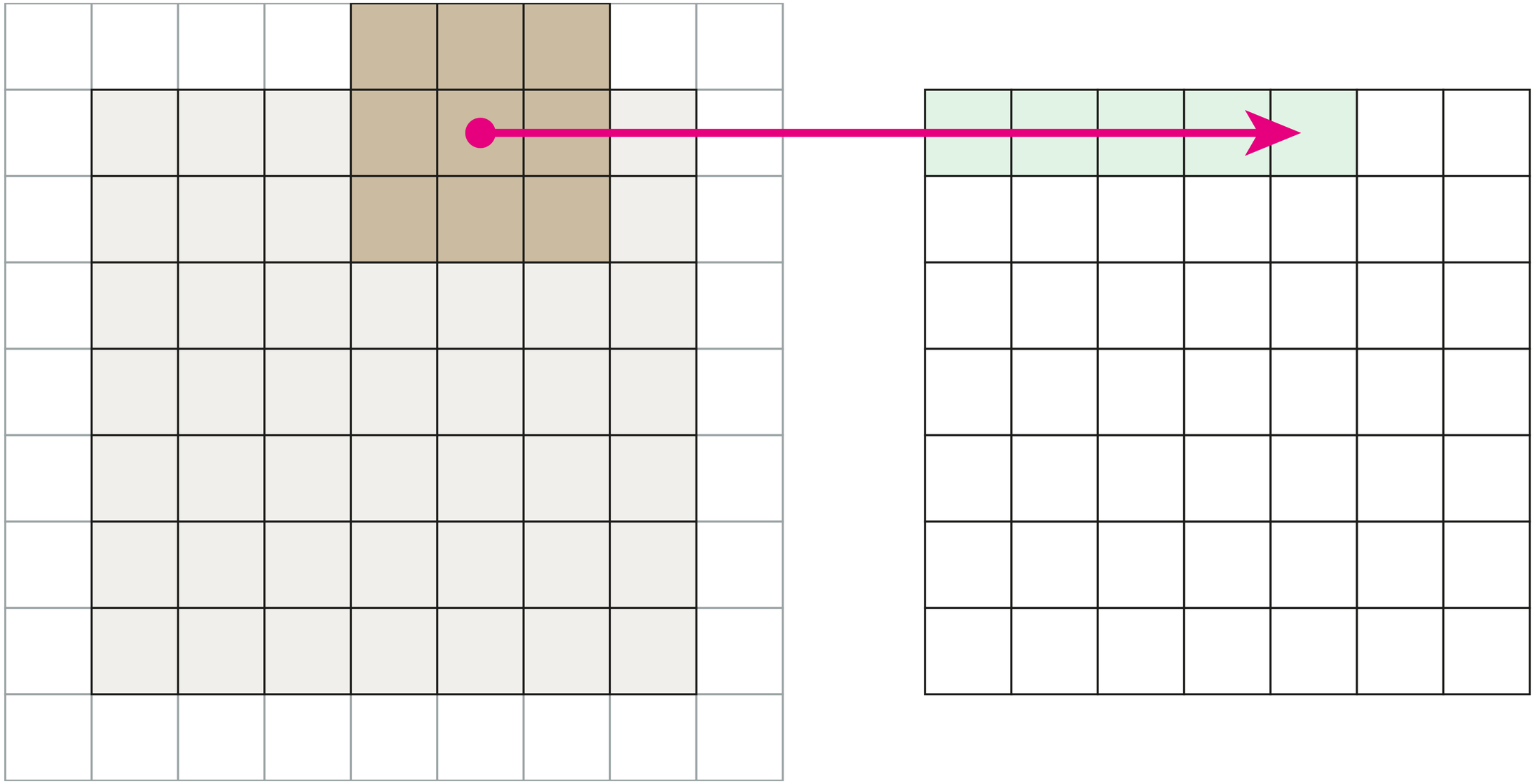


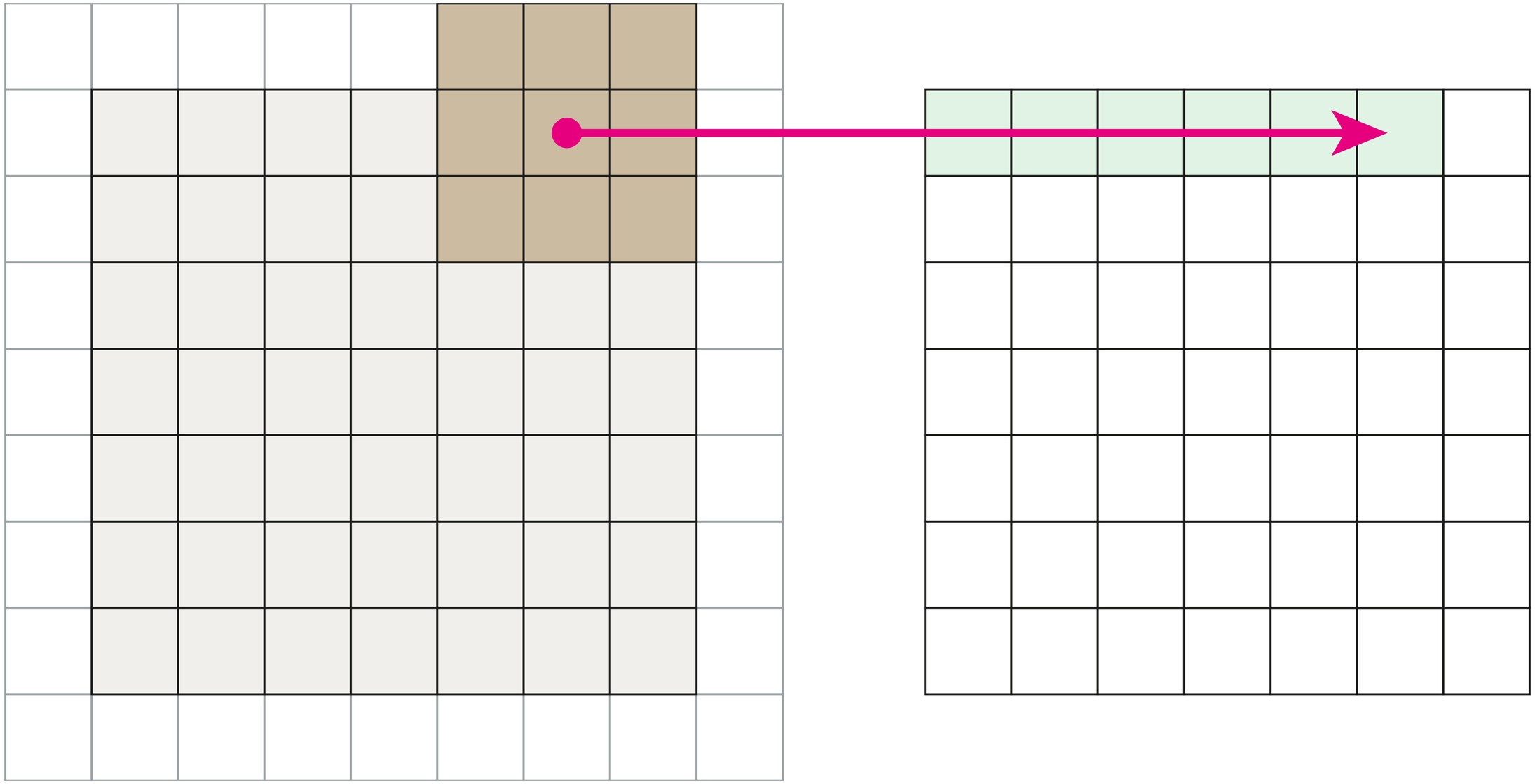


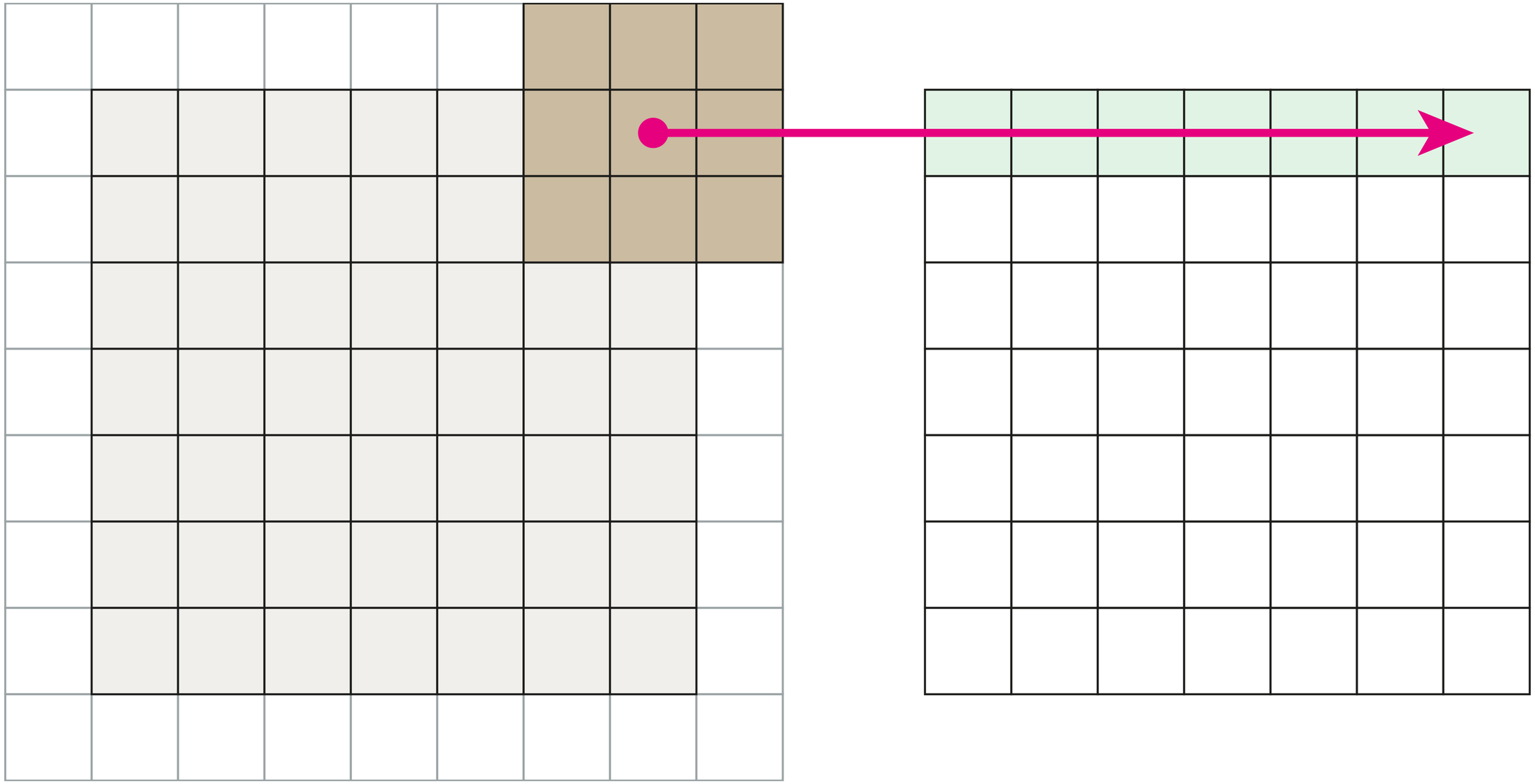


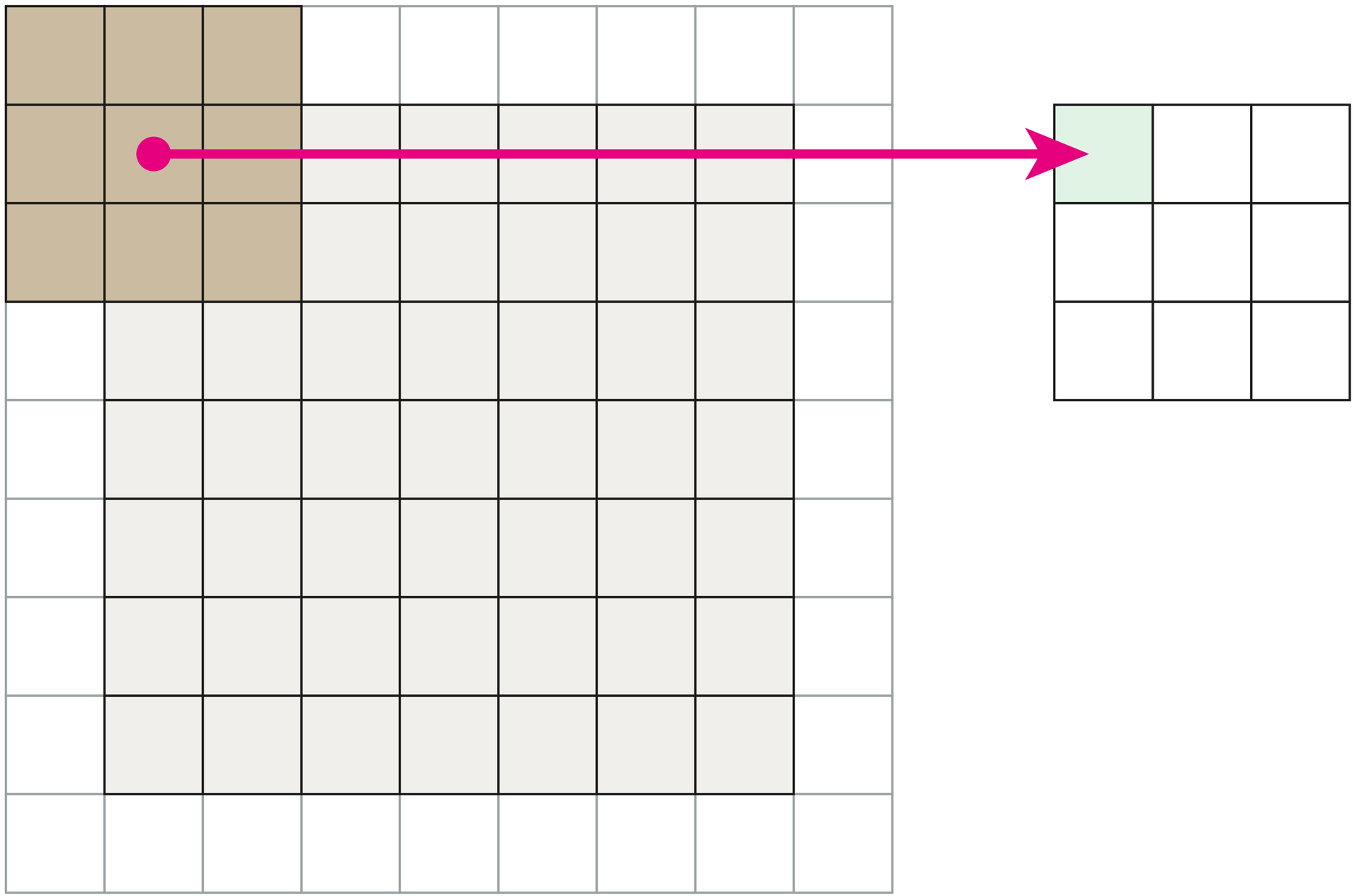


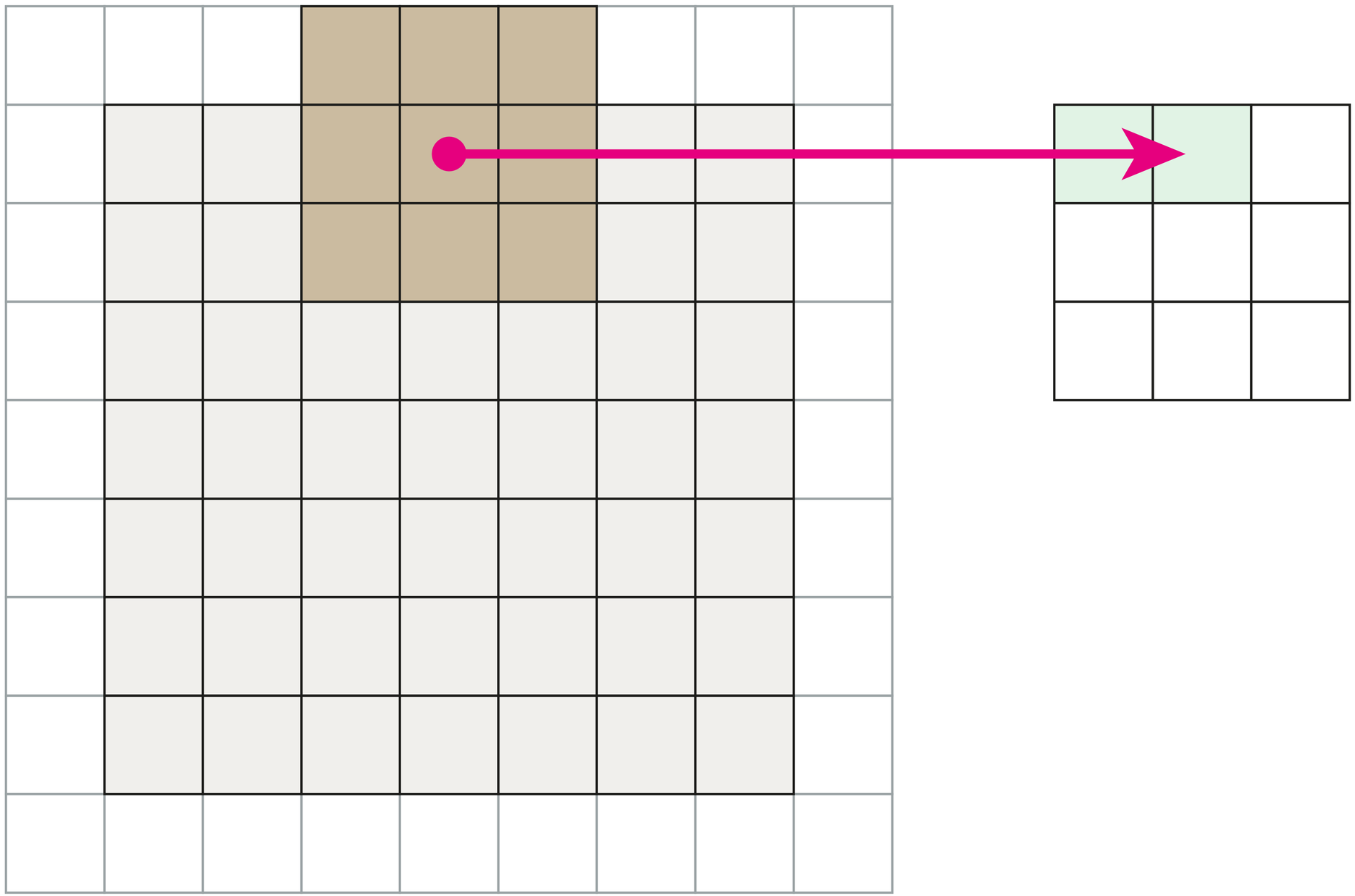


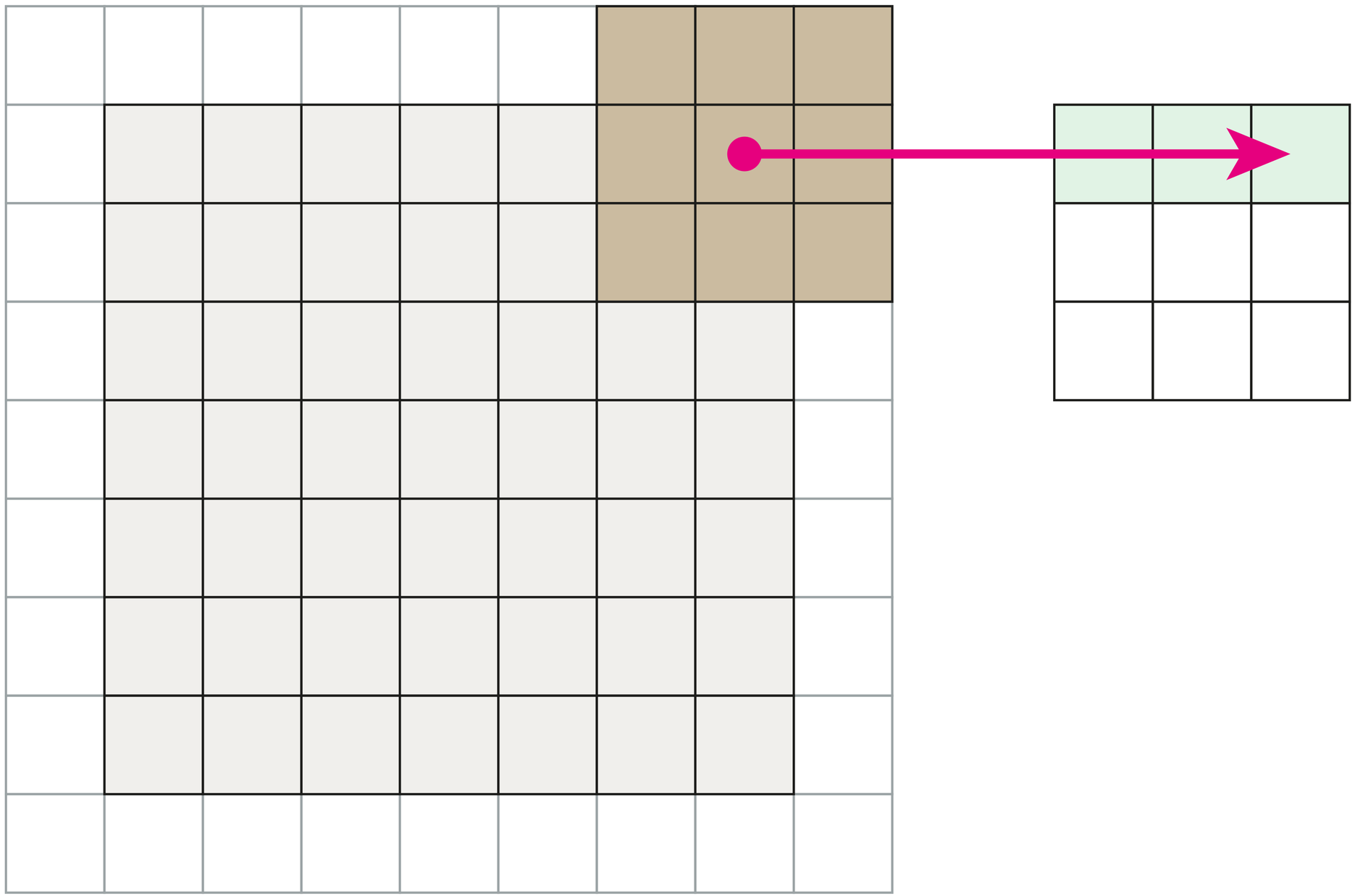


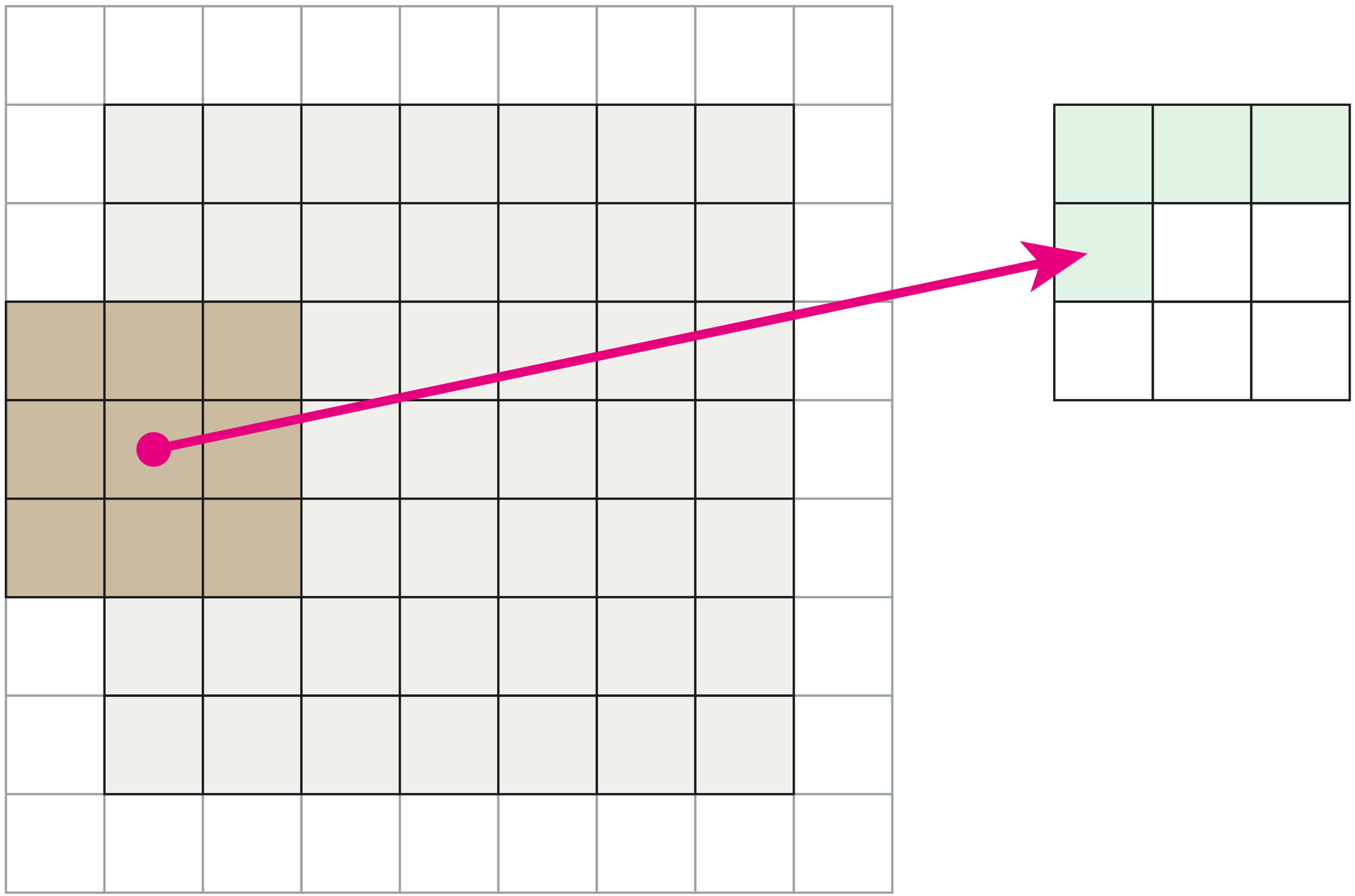


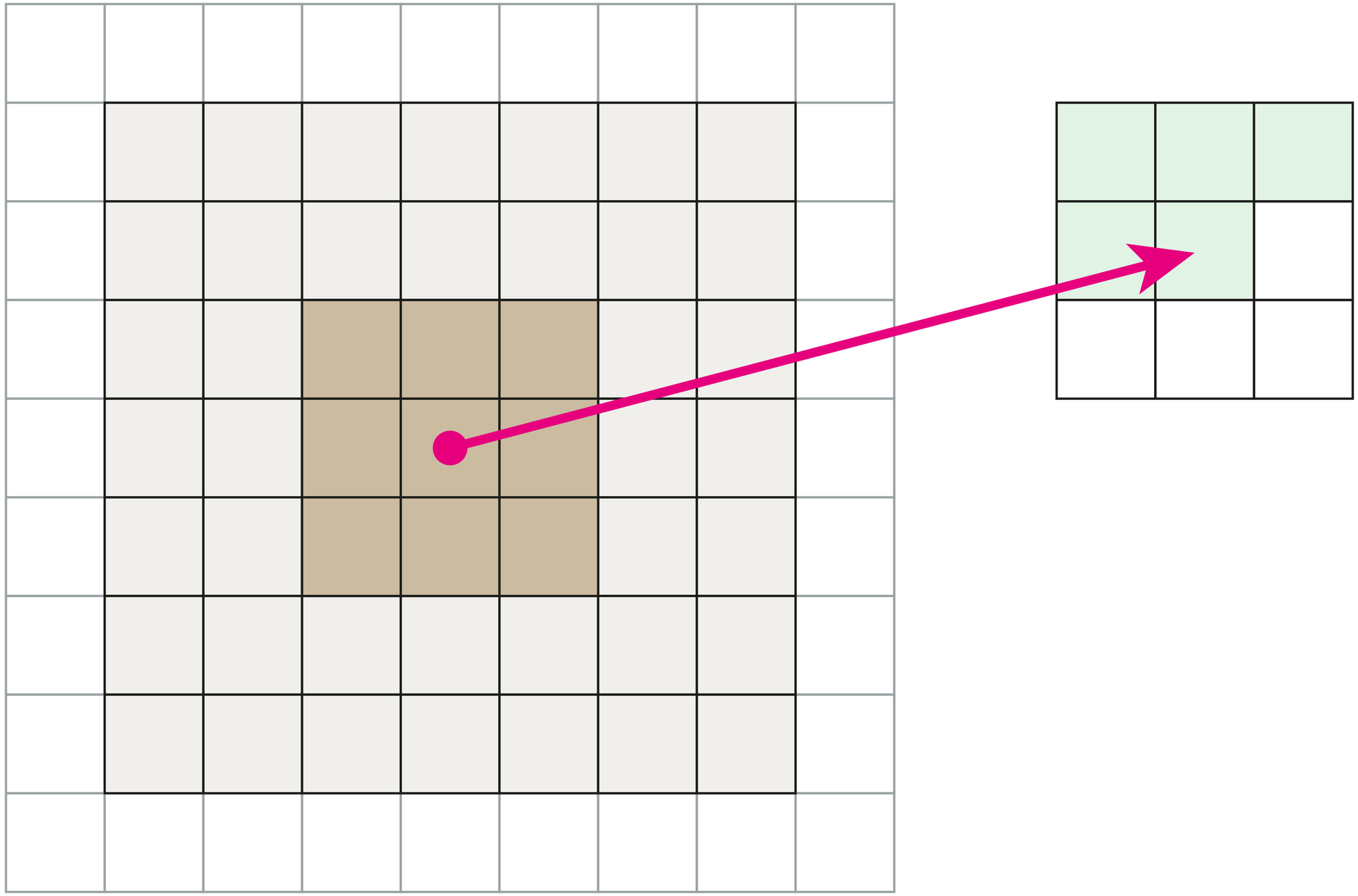


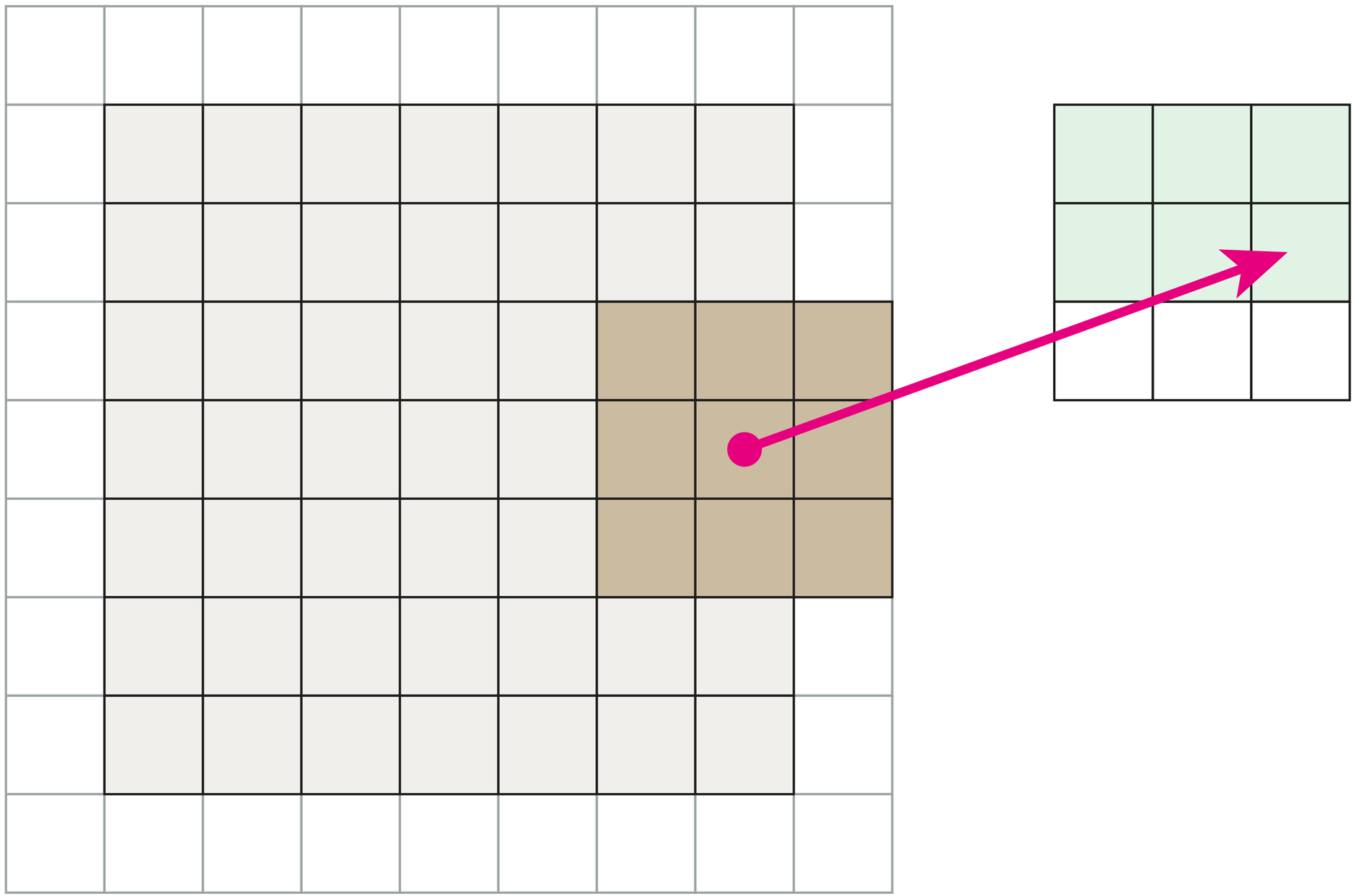


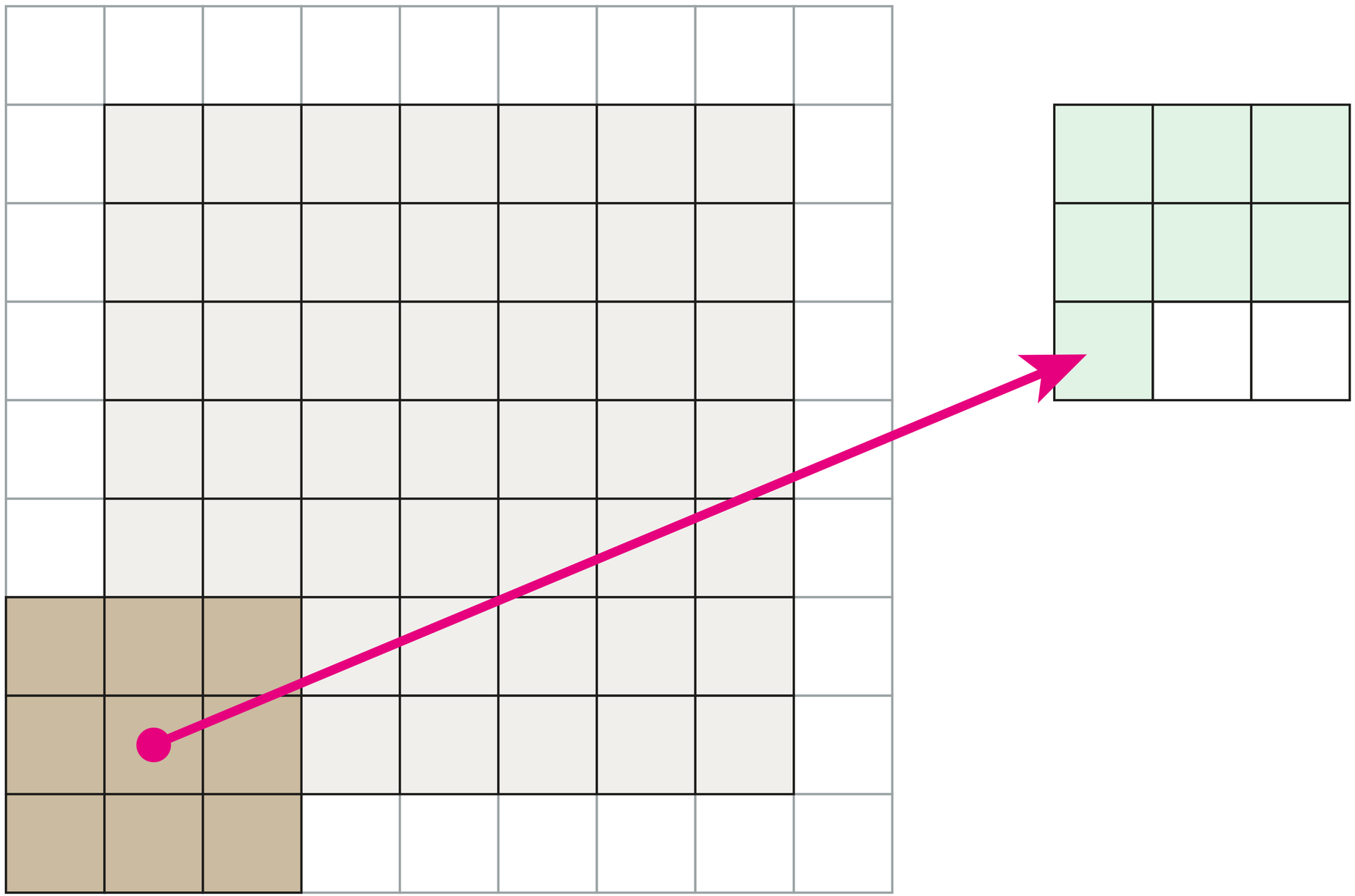


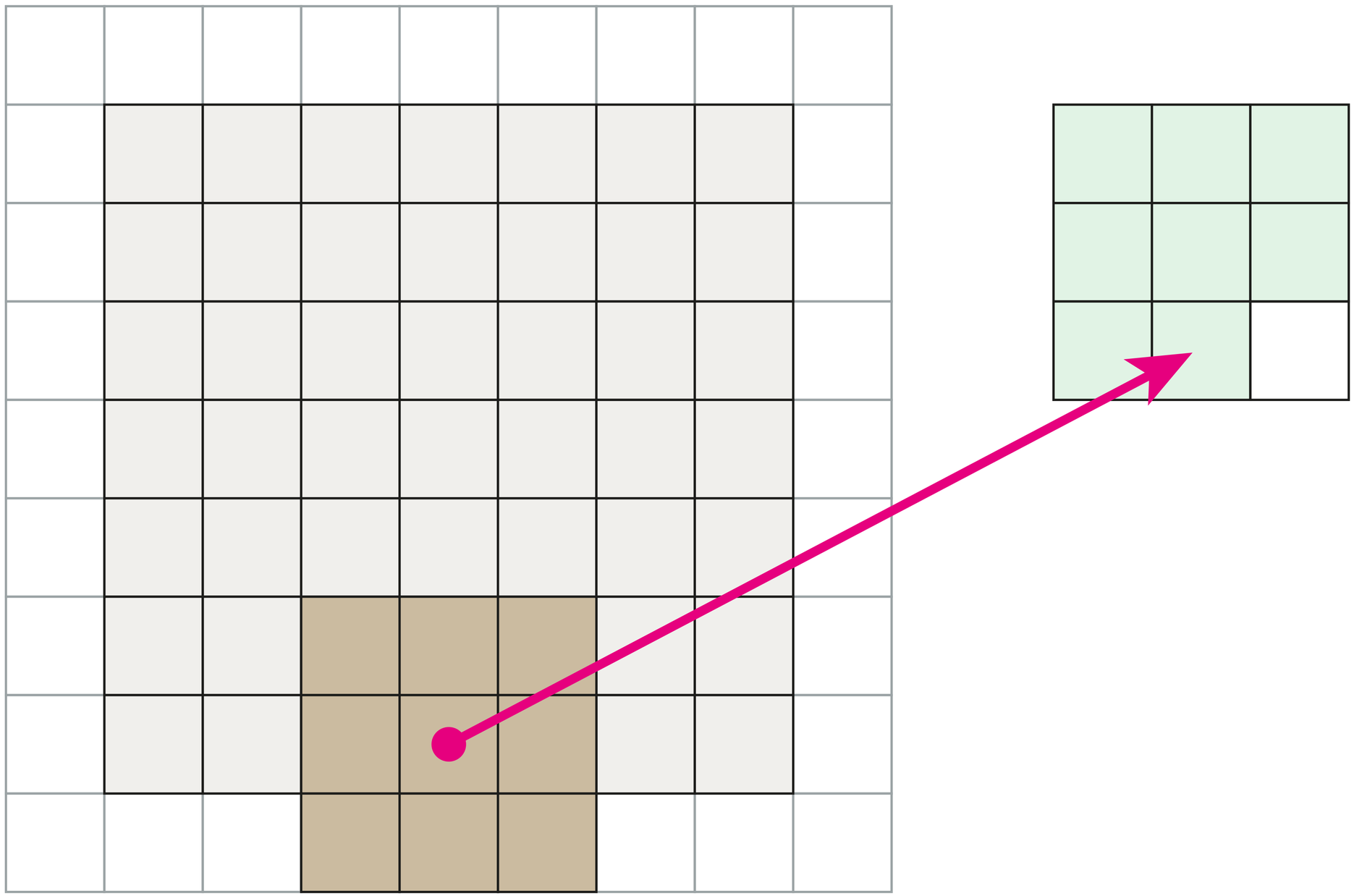


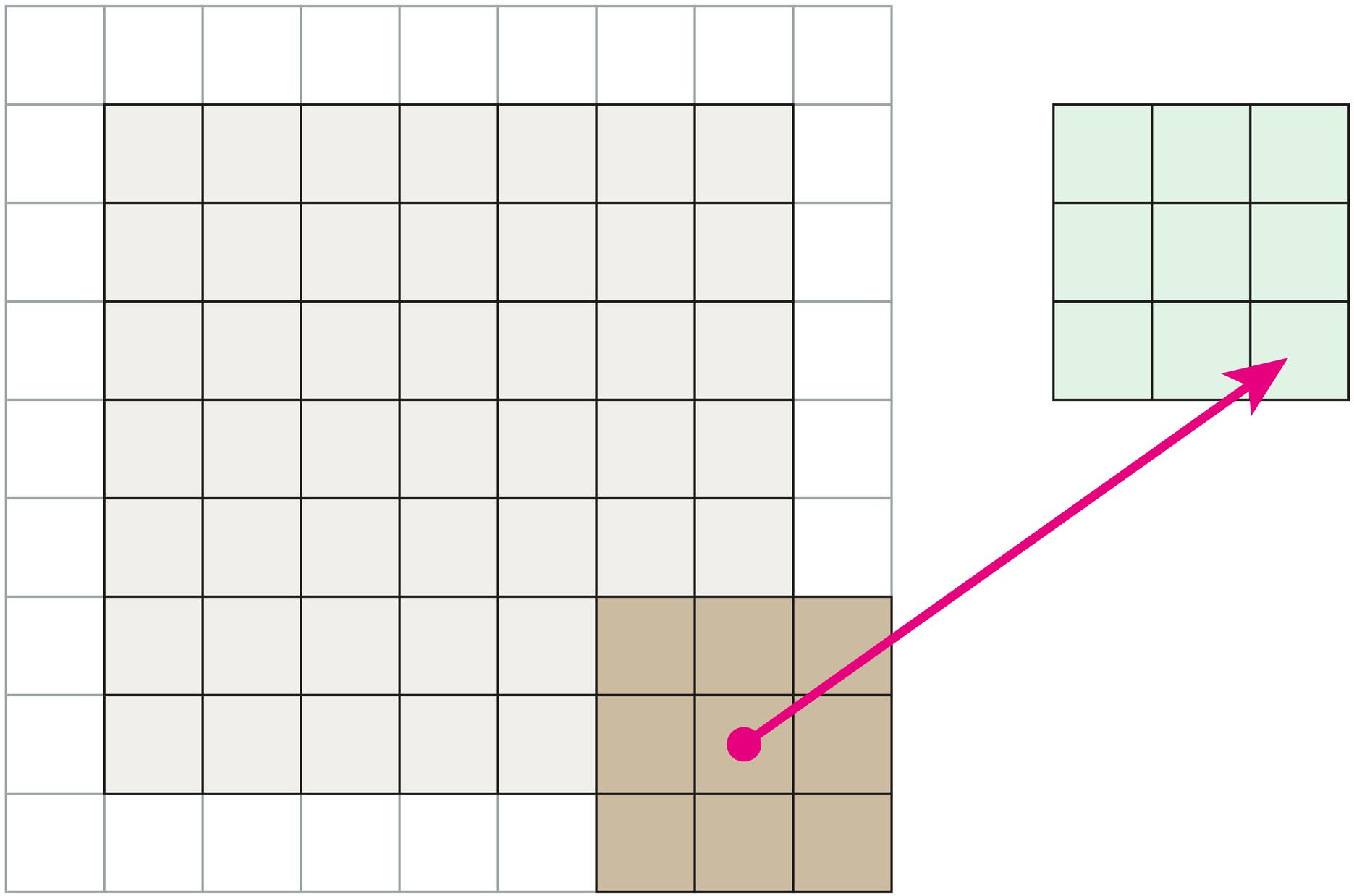


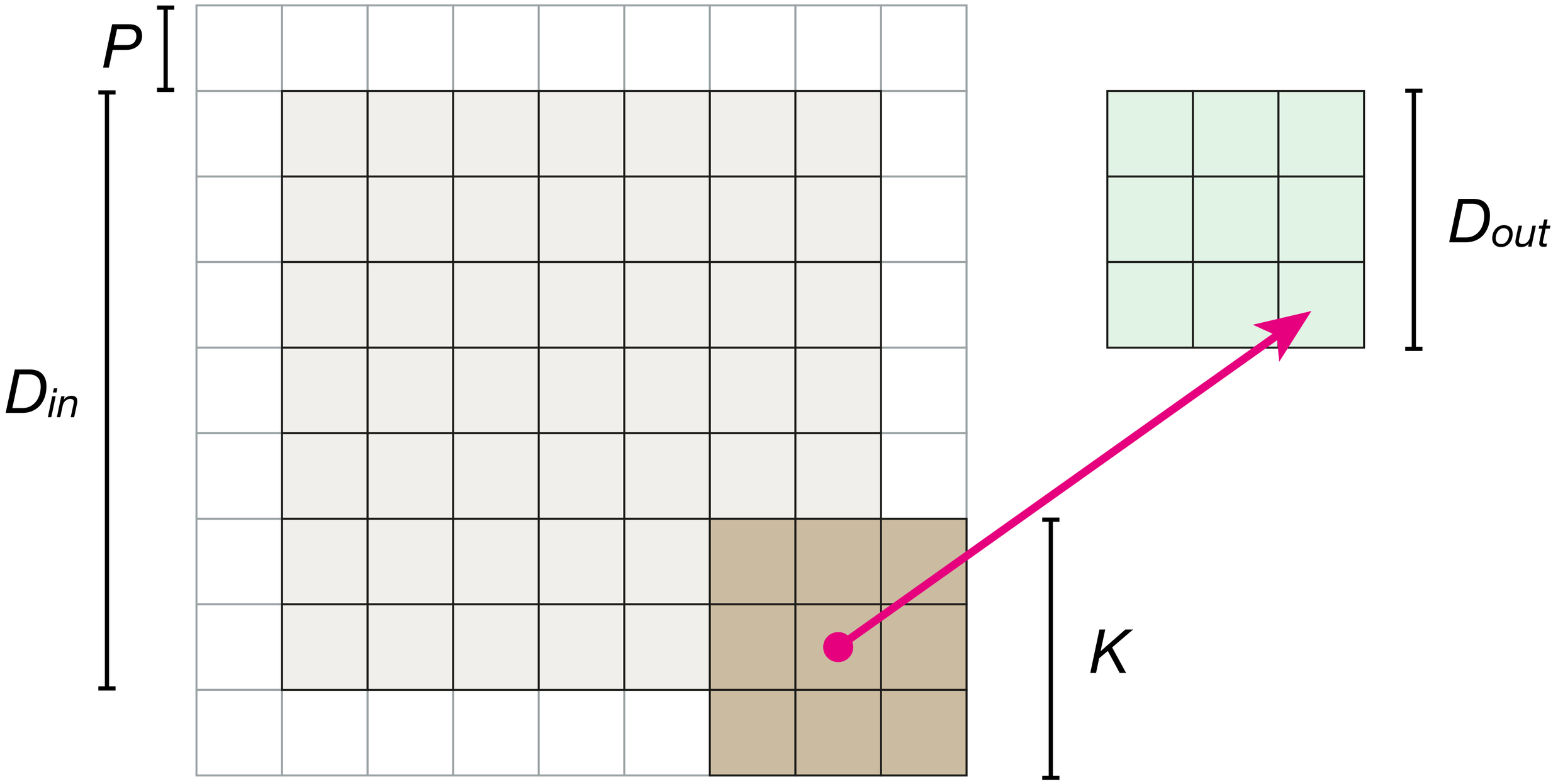


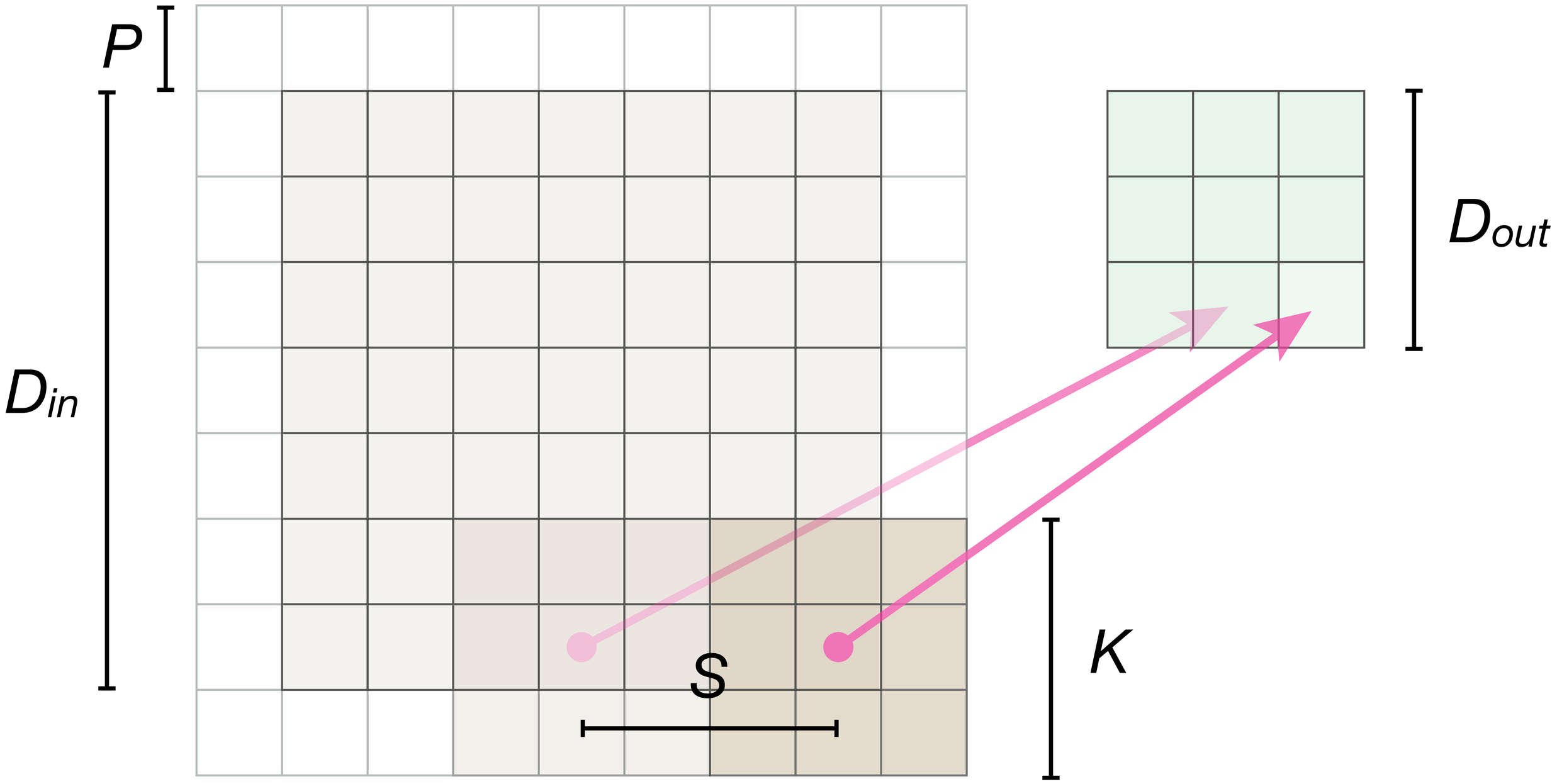




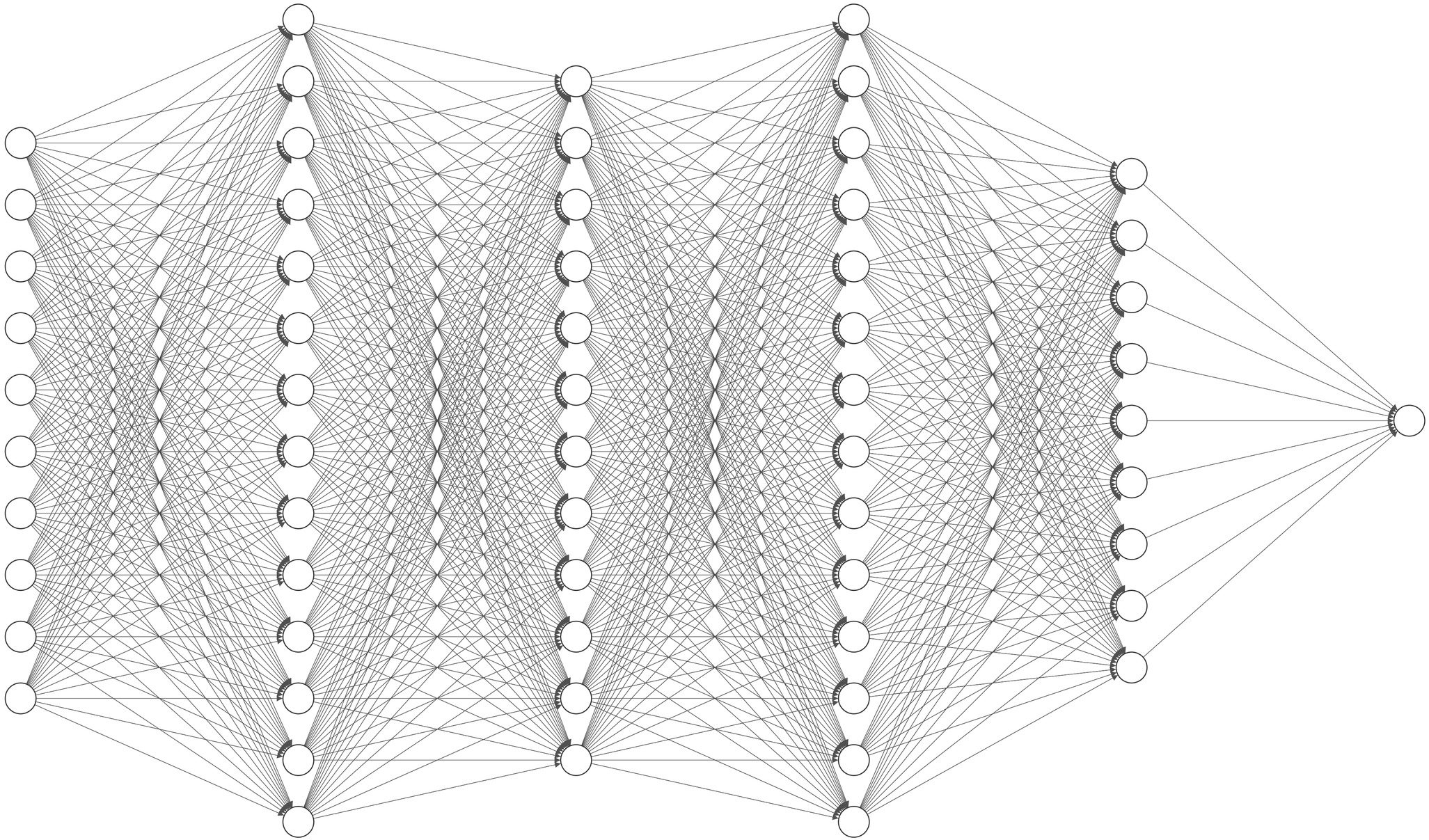




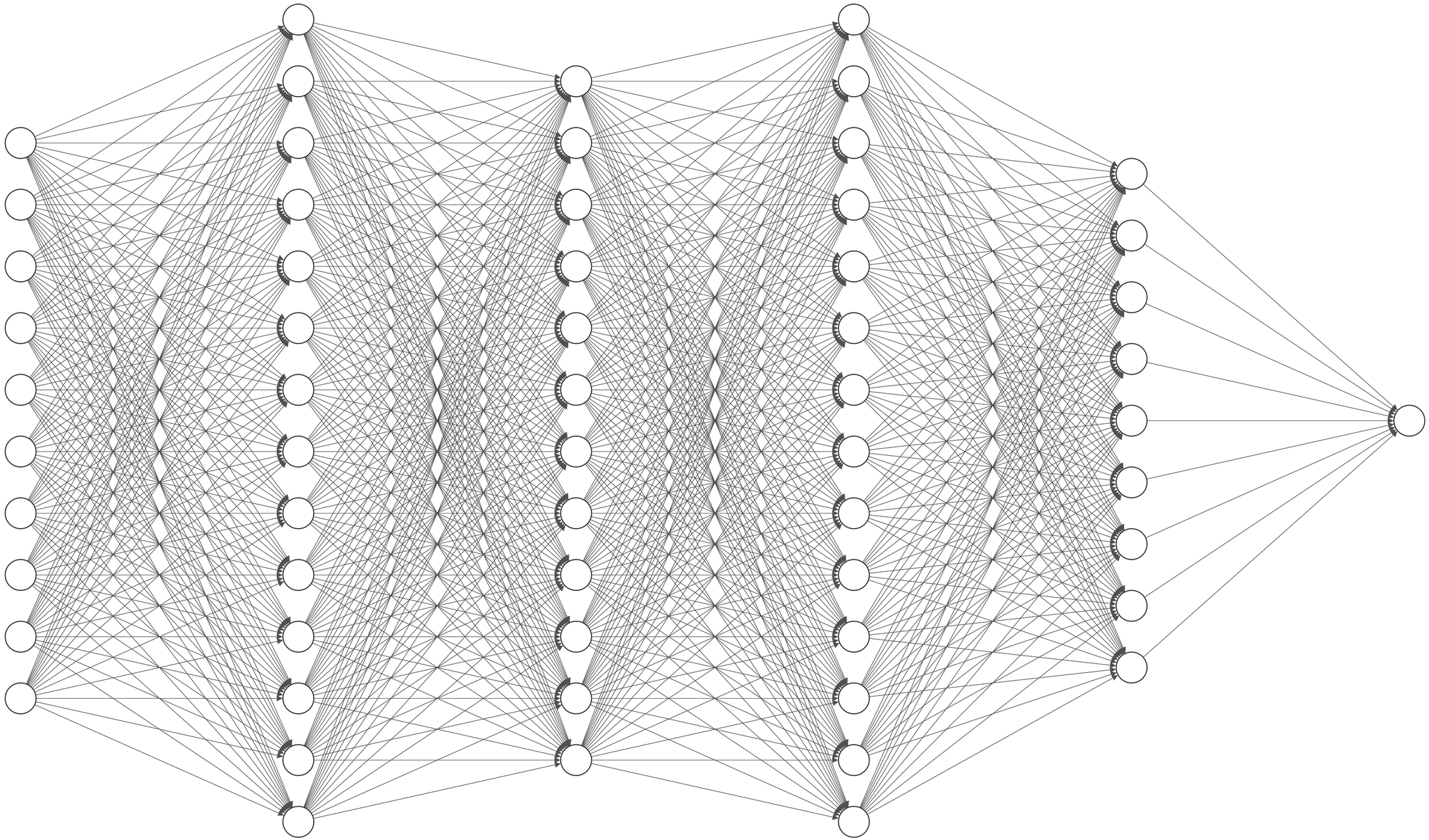

P
Din
Dout
K

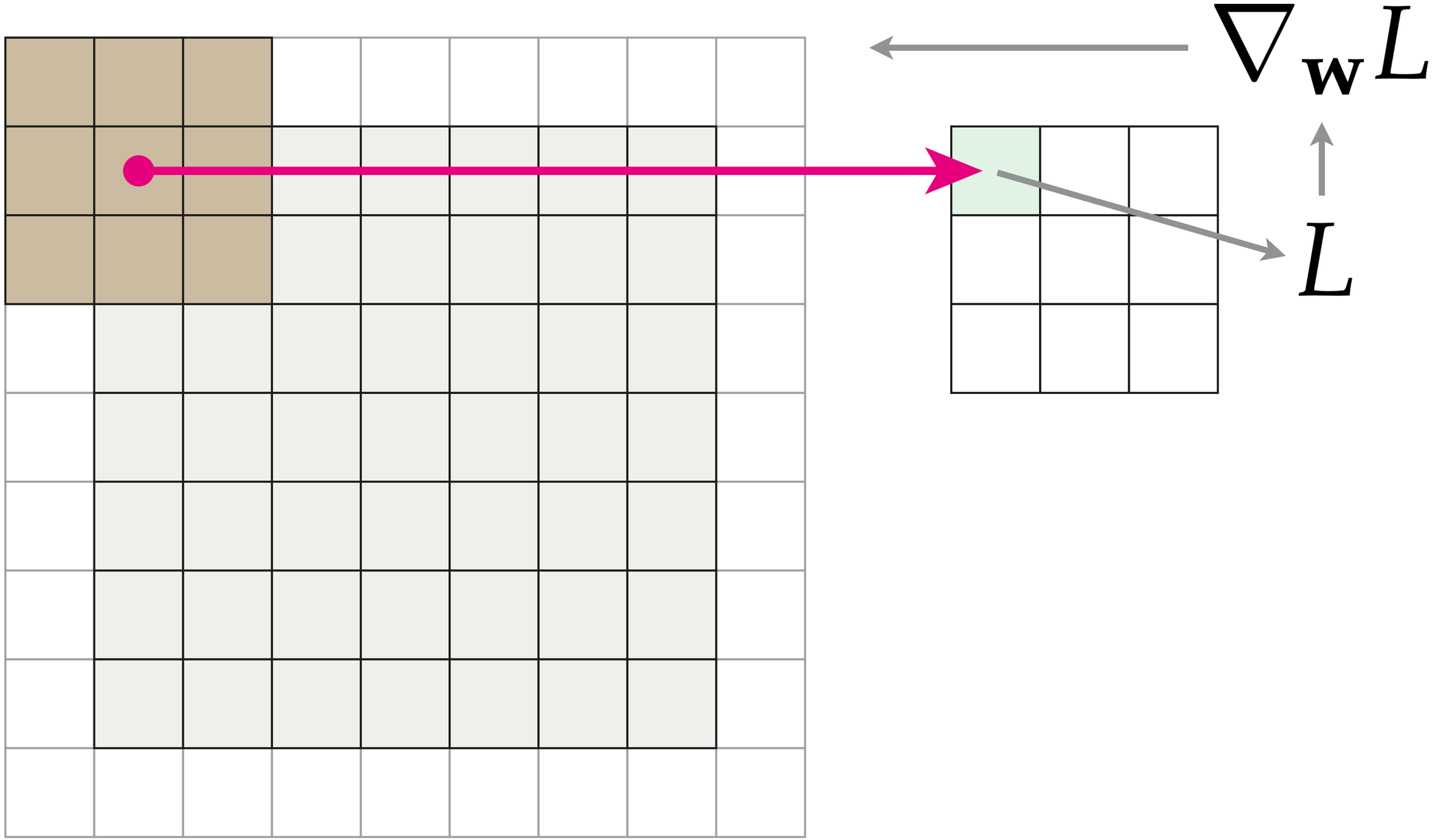

P
$D_{in}$
$D_{out}$
S
K

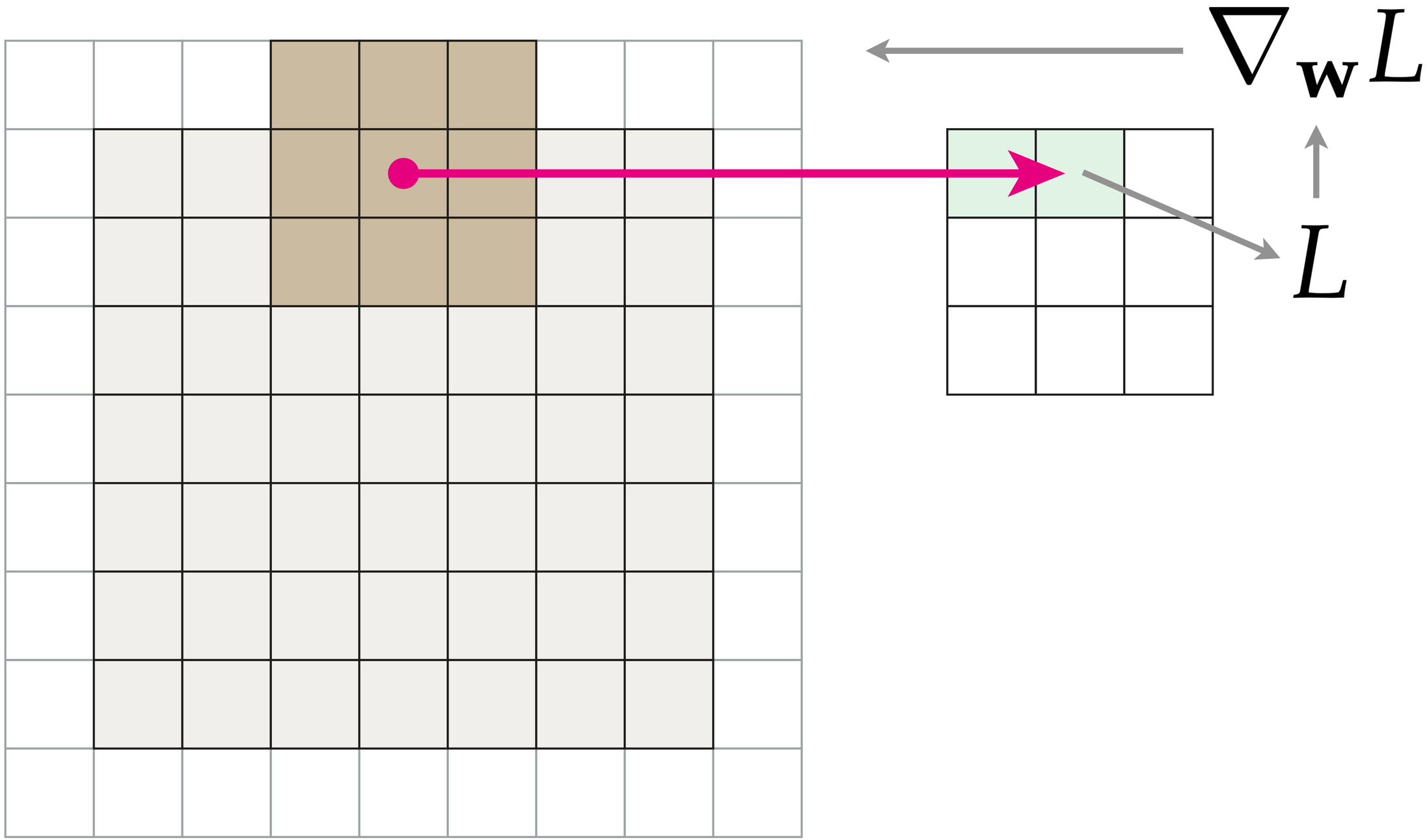
$$D_{out} = \frac{D_{in} - K + 2P}{S} + 1$$



$$\mathbf{f}_{[\ldots]} \cdot \mathbf{g}$$




$\nabla_{\mathbf{w}} L$
$L$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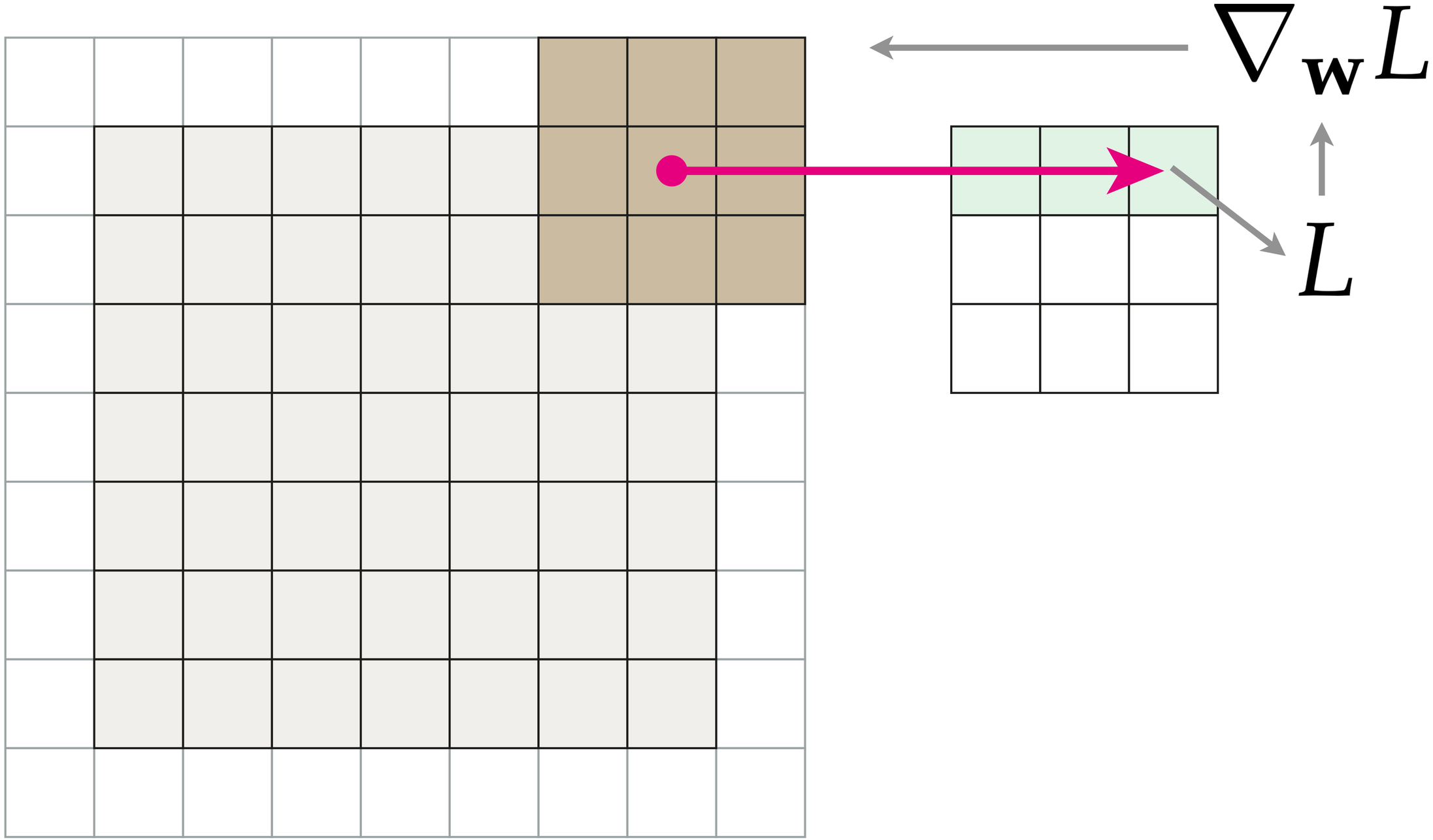
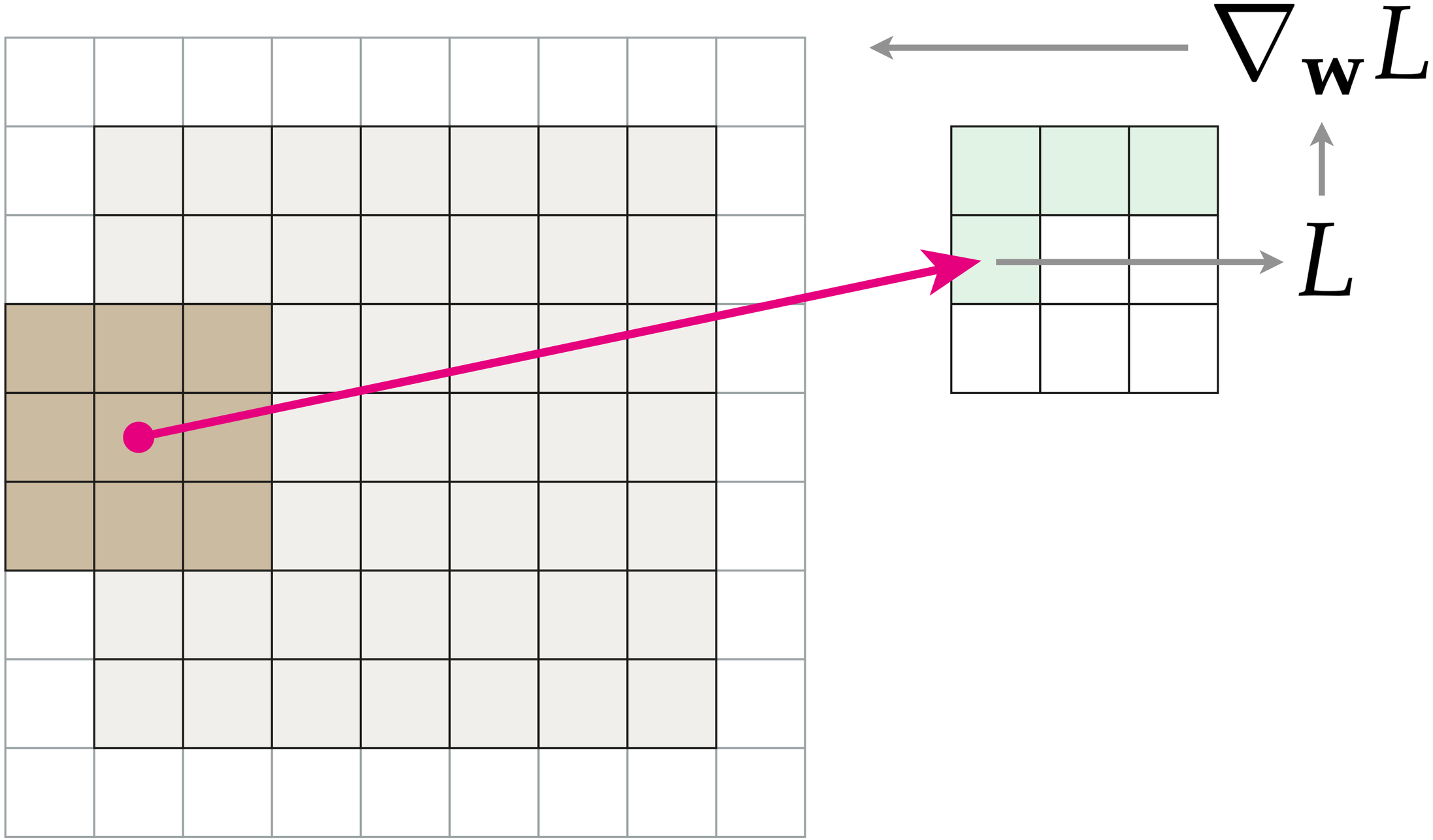
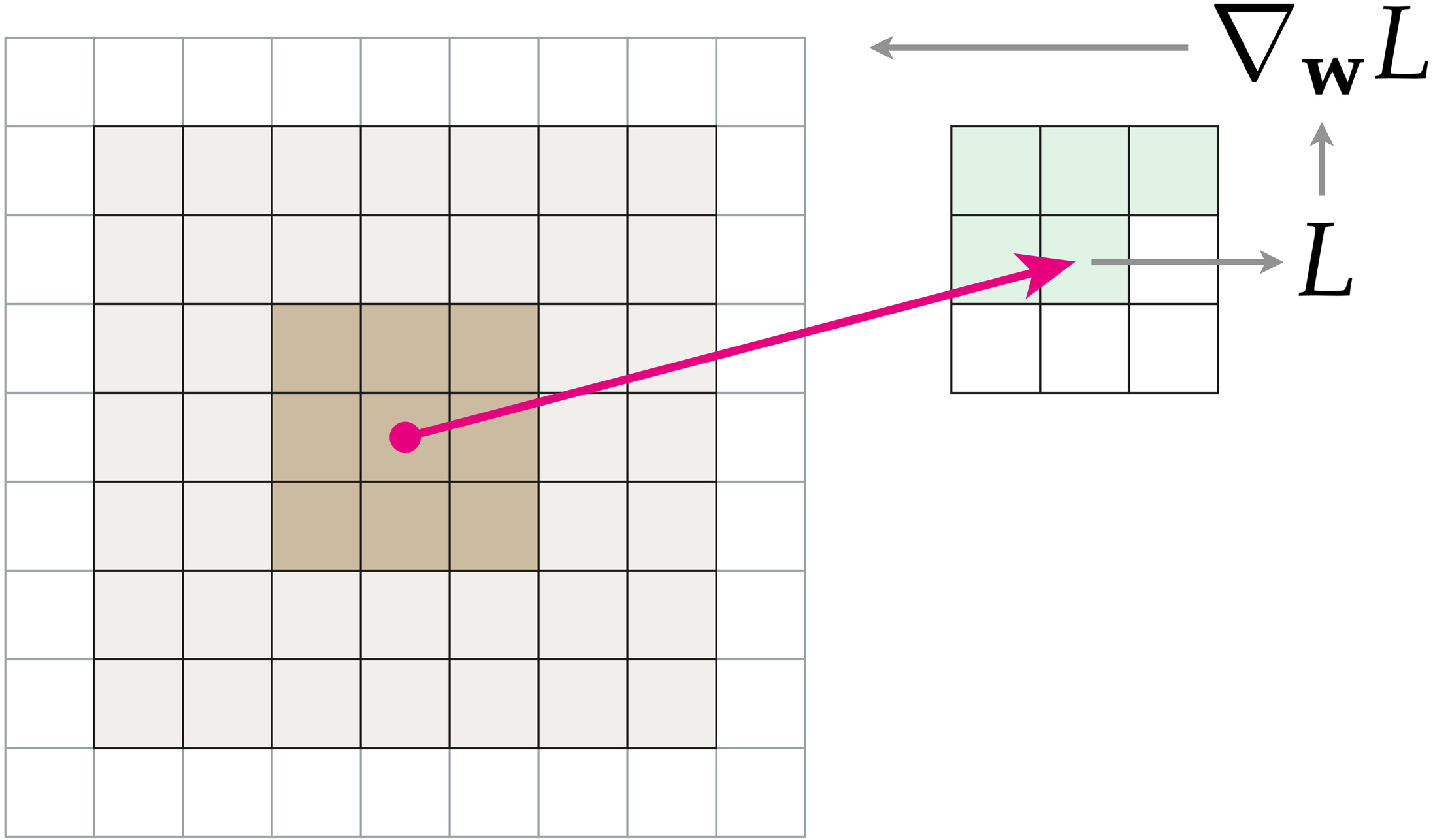
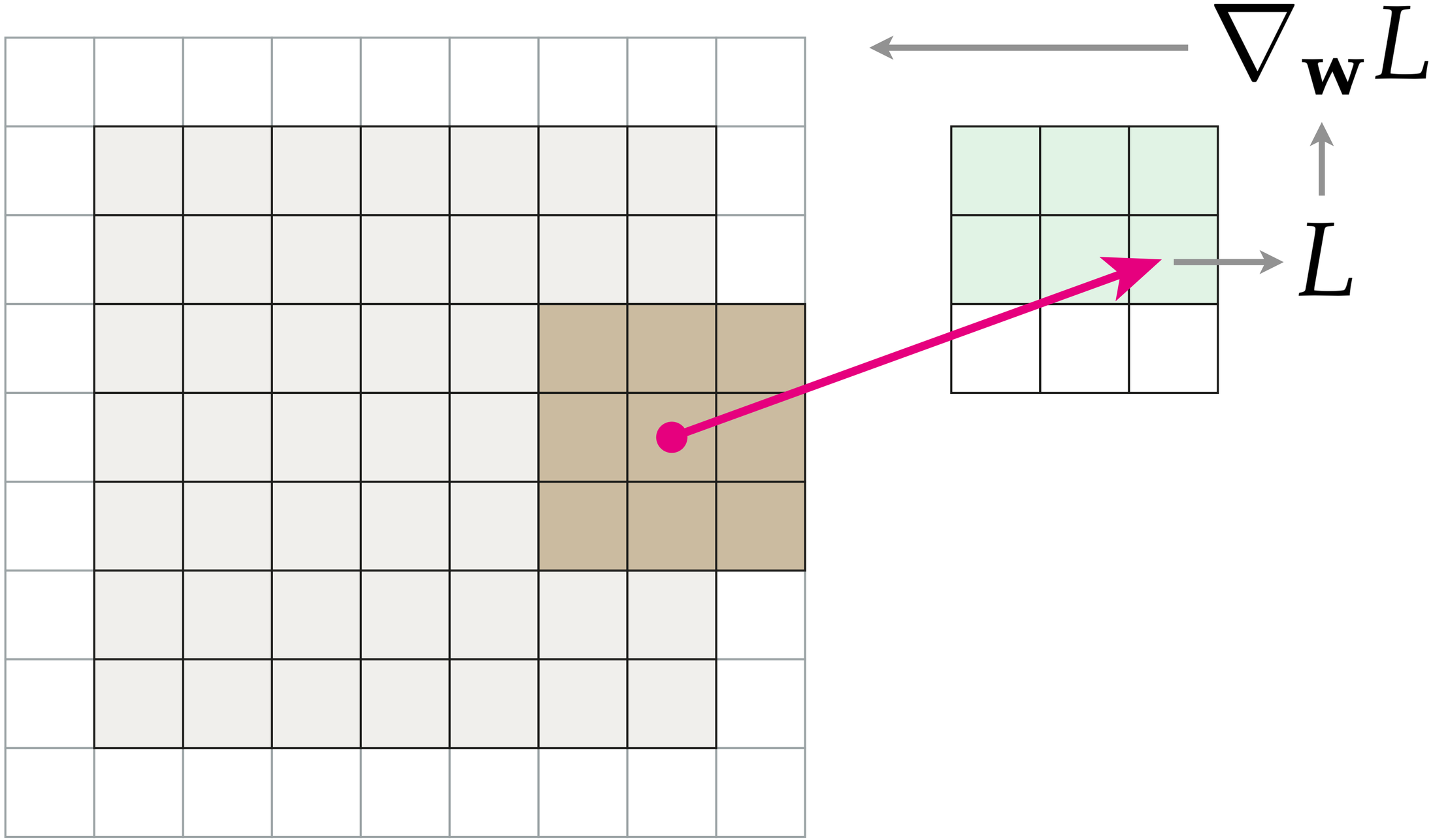
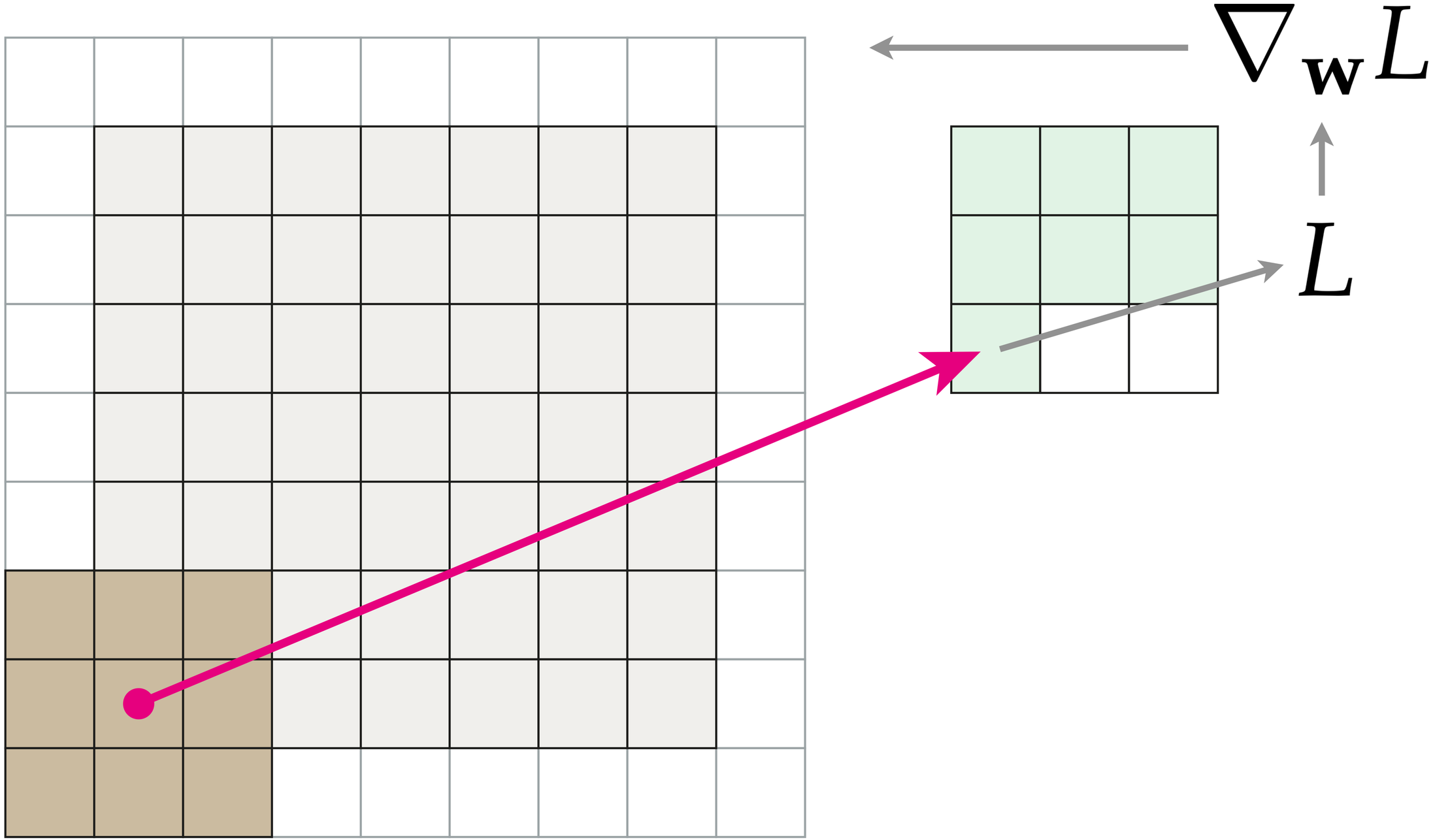
$L$

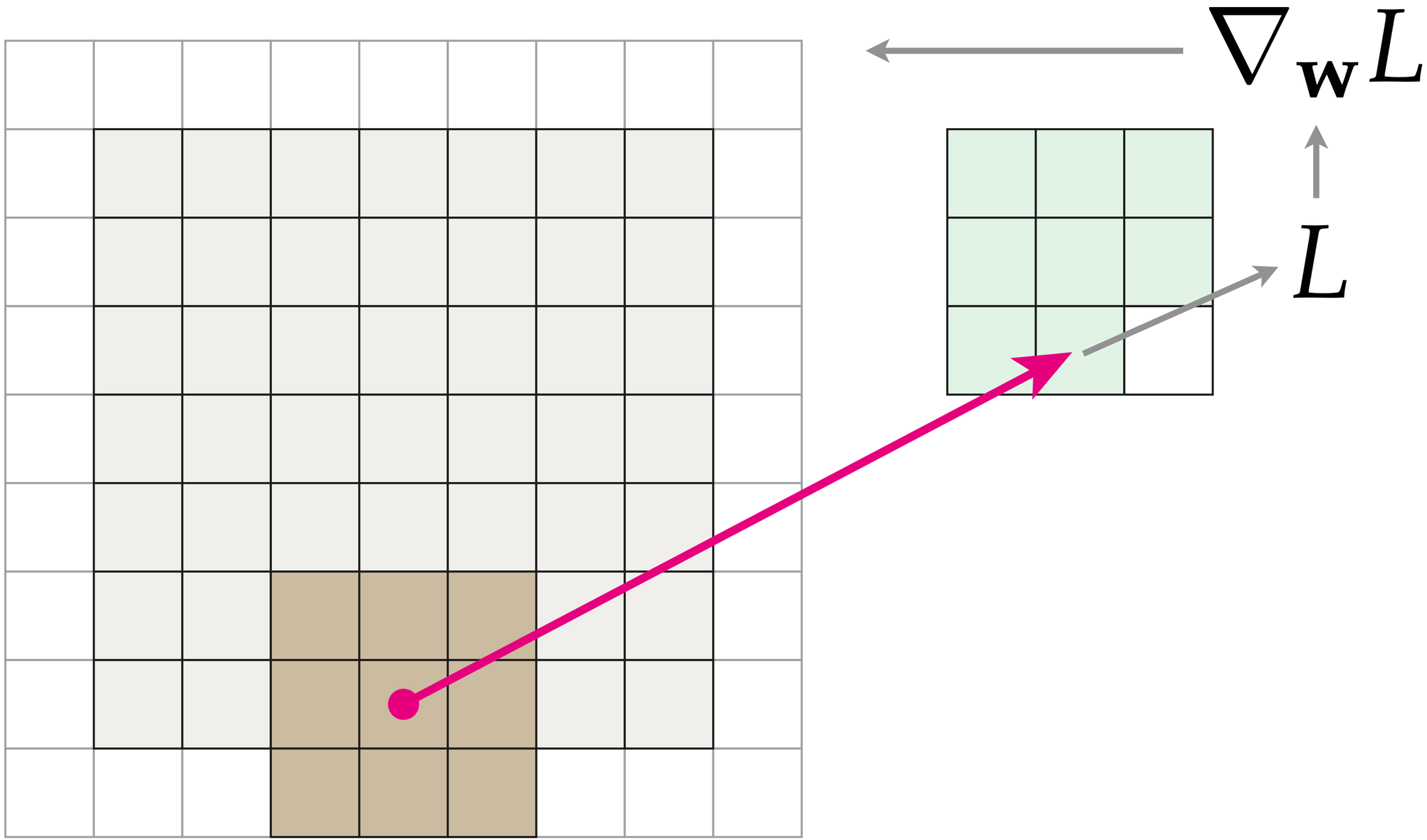

$\nabla_{\mathbf{w}} L$
$L$

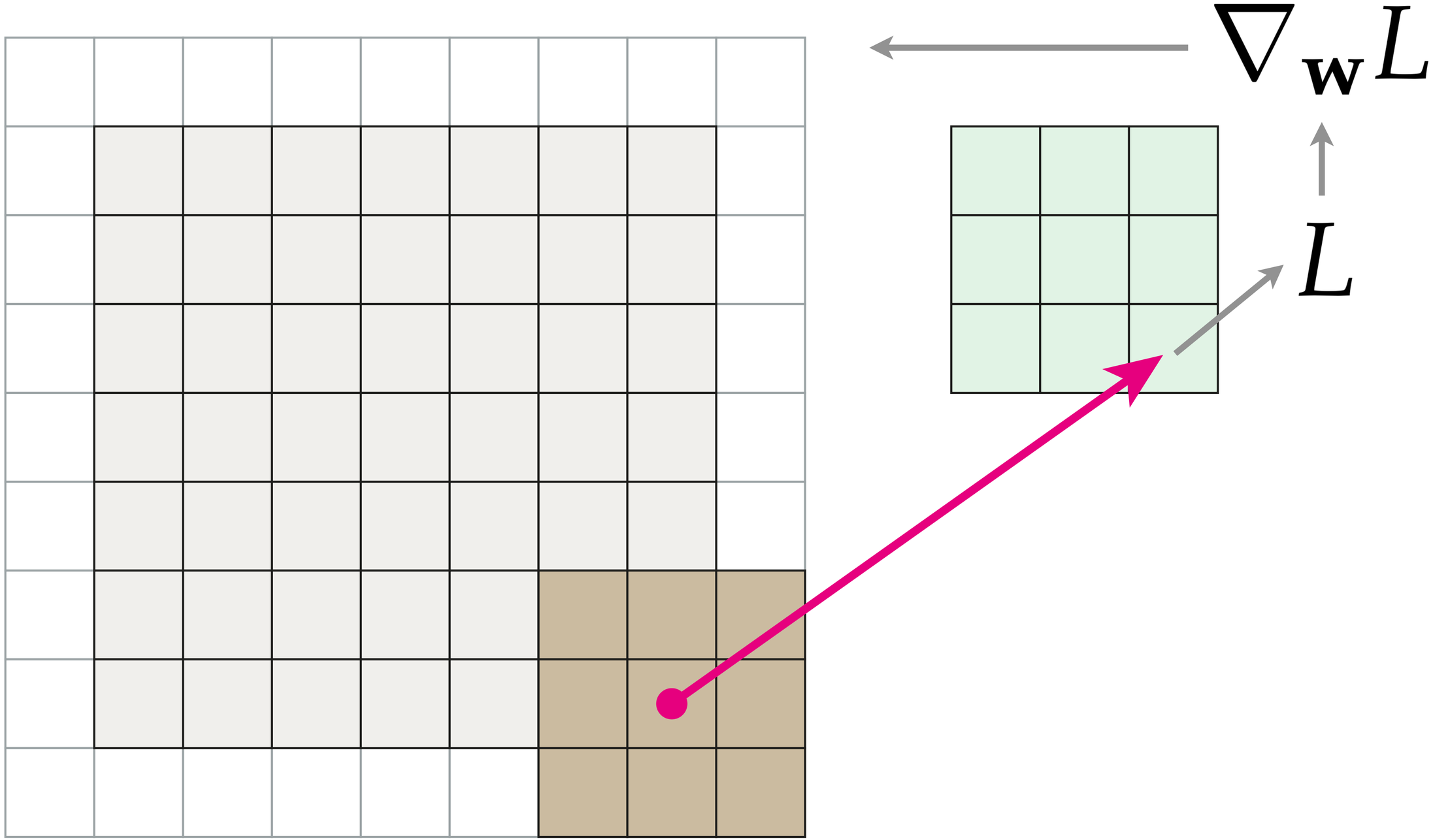

$\nabla_{\mathbf{w}} L$
$L$


$\nabla_{\mathbf{w}} L$
$L$

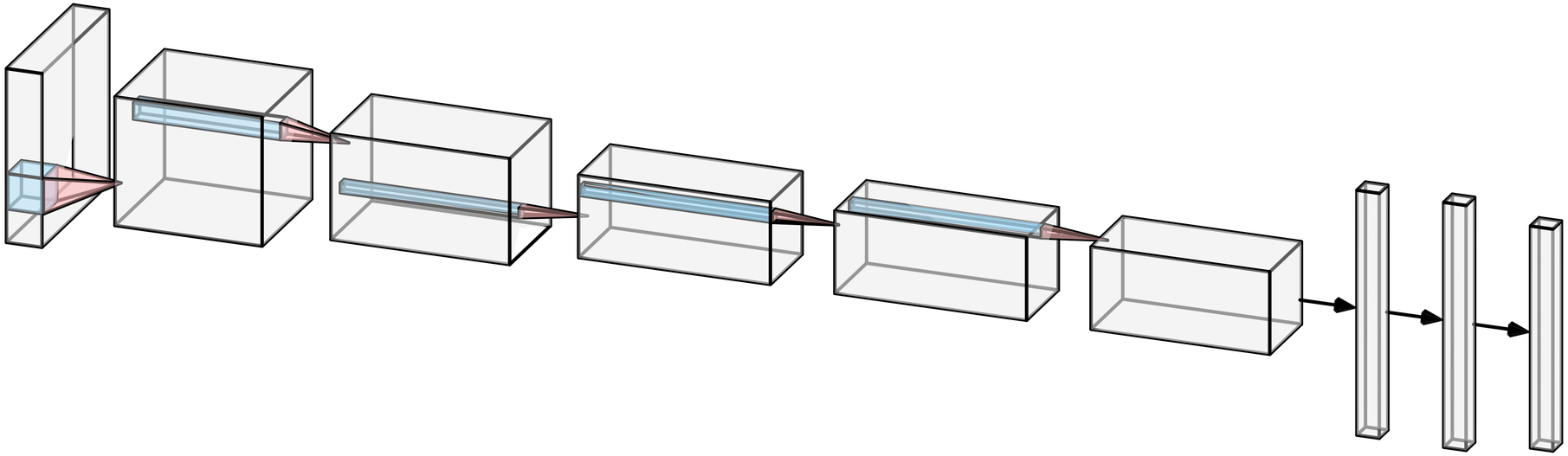

$\nabla_{\mathbf{w}} L$
$L$

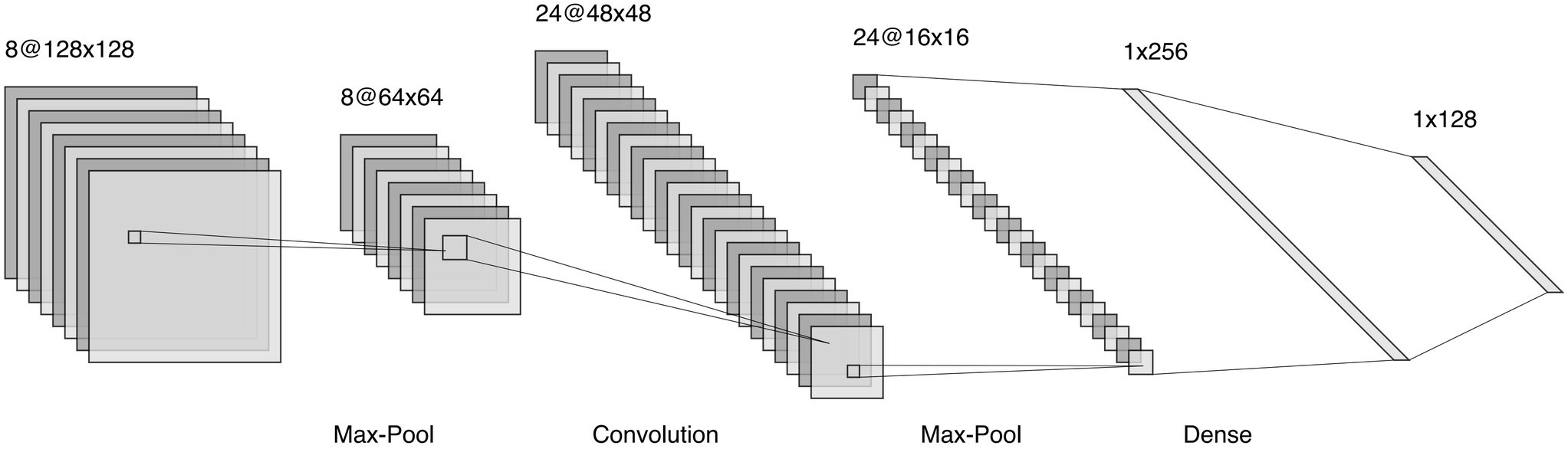

$\nabla_{\mathbf{w}} L$
$L$

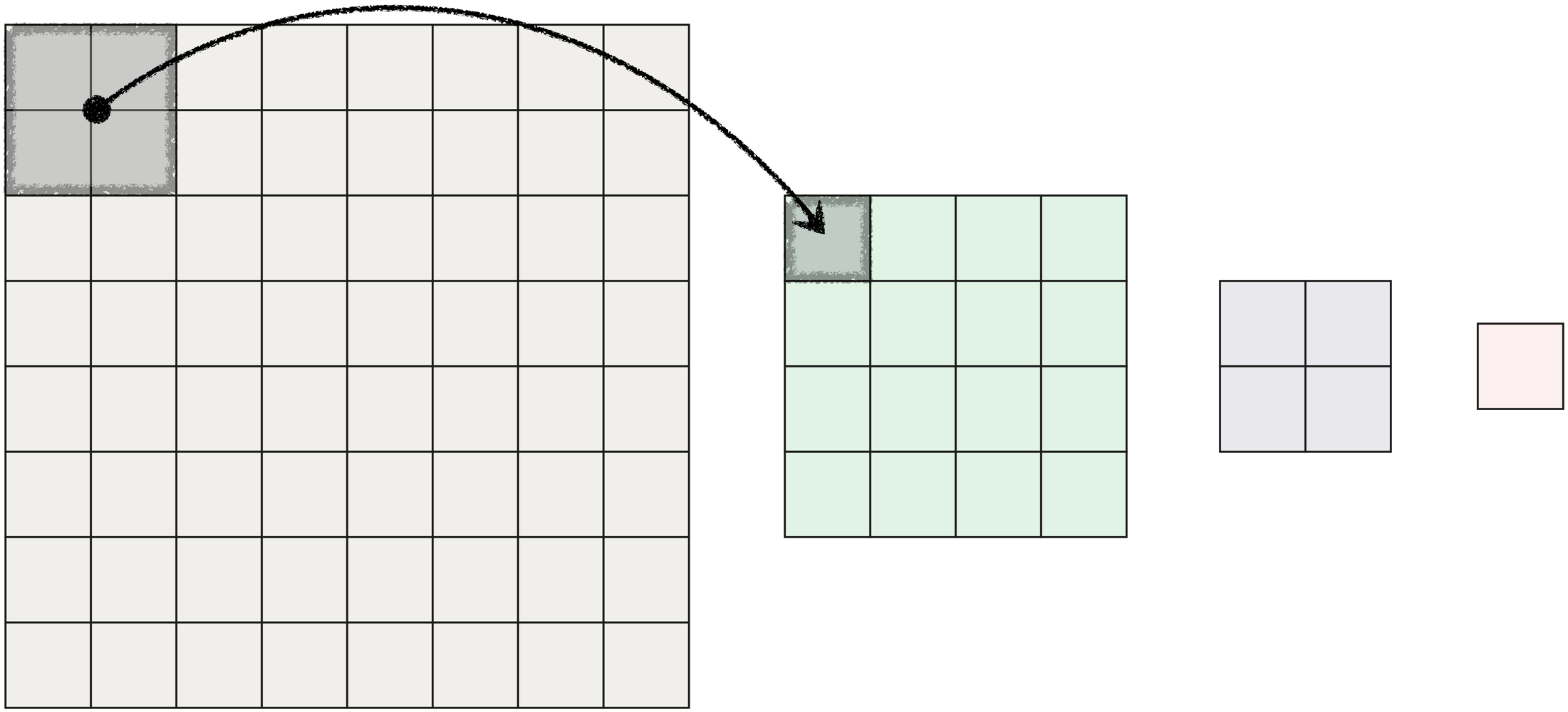

$\nabla_{\mathbf{w}} L$
$L$

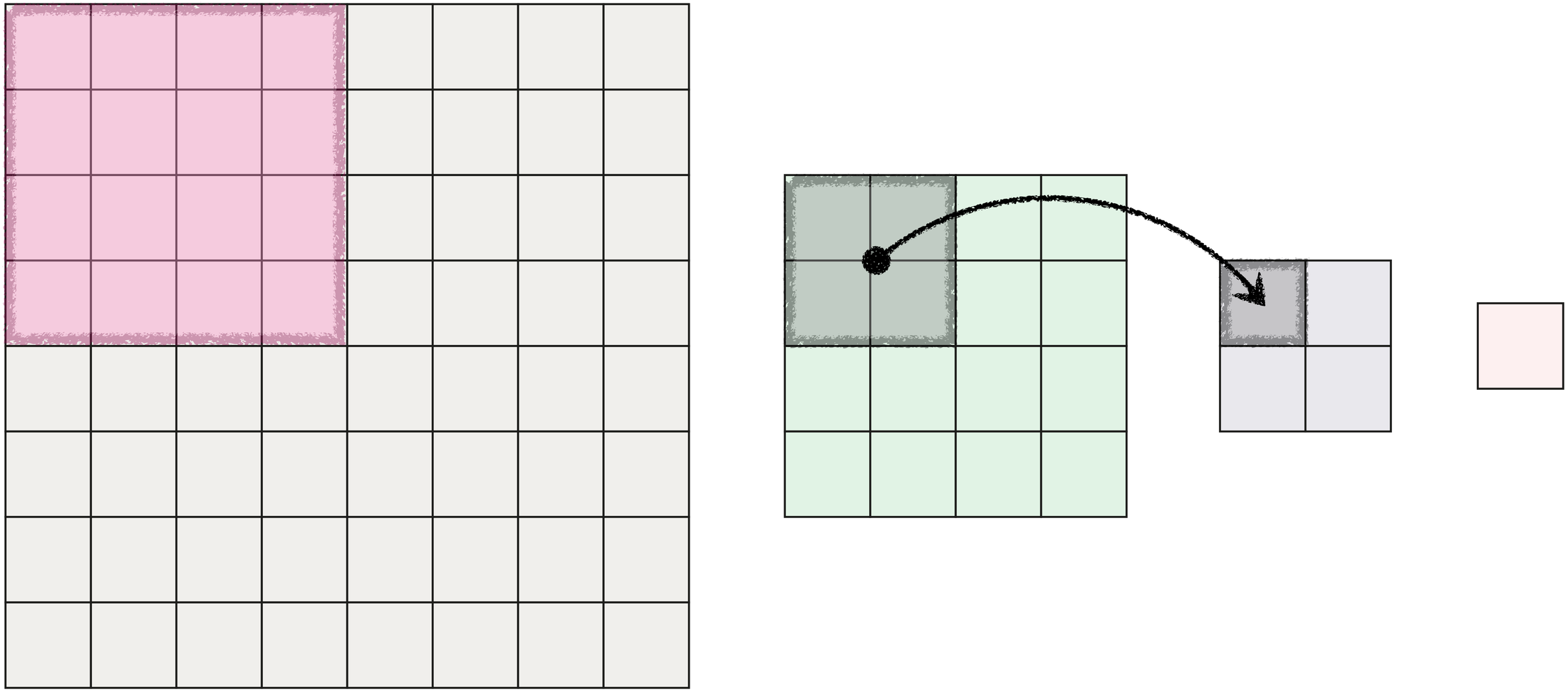

$\nabla_{\mathbf{w}} L$
$L$

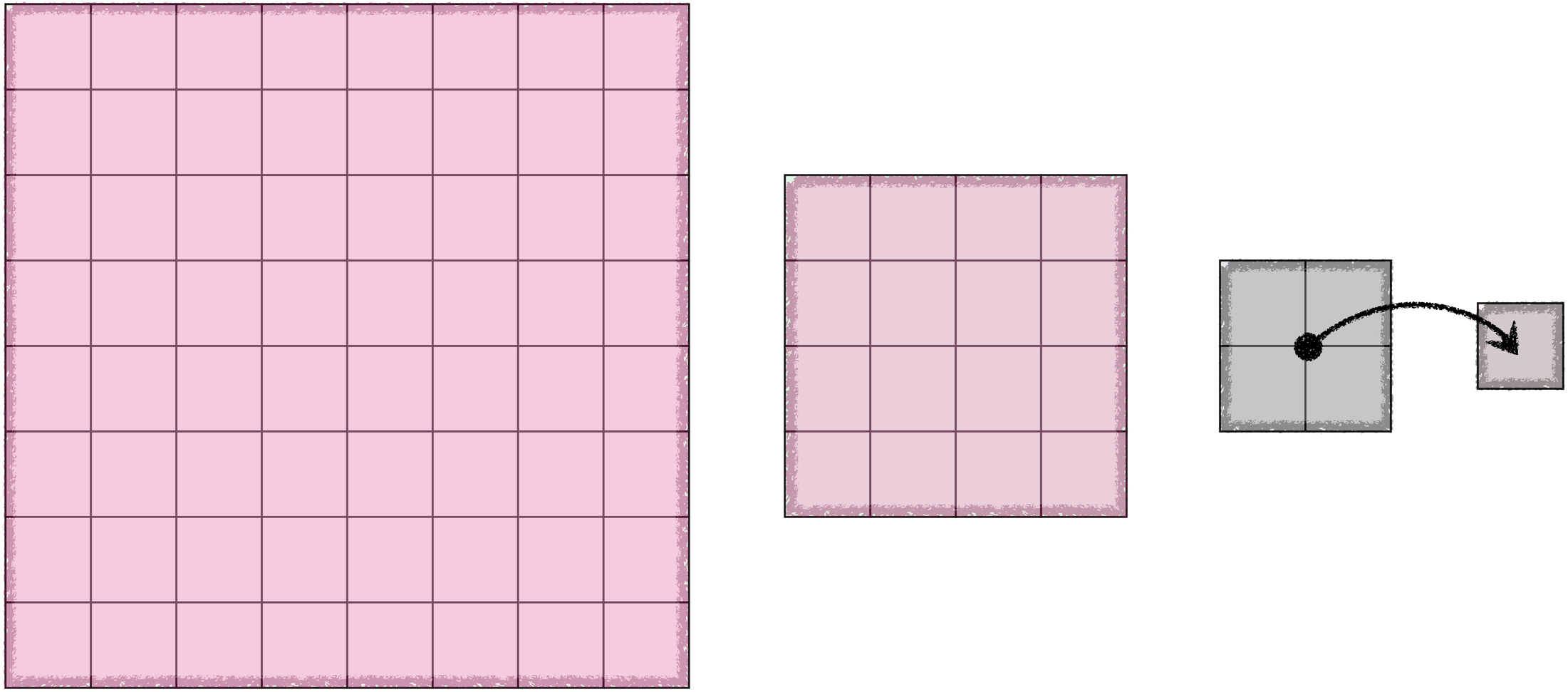
$$\mathbf{w} \leftarrow \mathbf{w} - \alpha \sum \nabla_{\mathbf{w}} L$$



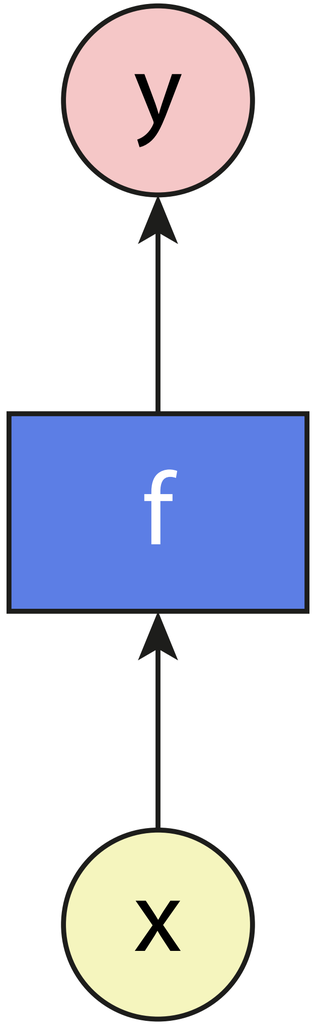

8@128x128
8@64x64
24@48x48
24@16x16
1x256
1x128
Max-Pool
Convolution
Max-Pool
Dense

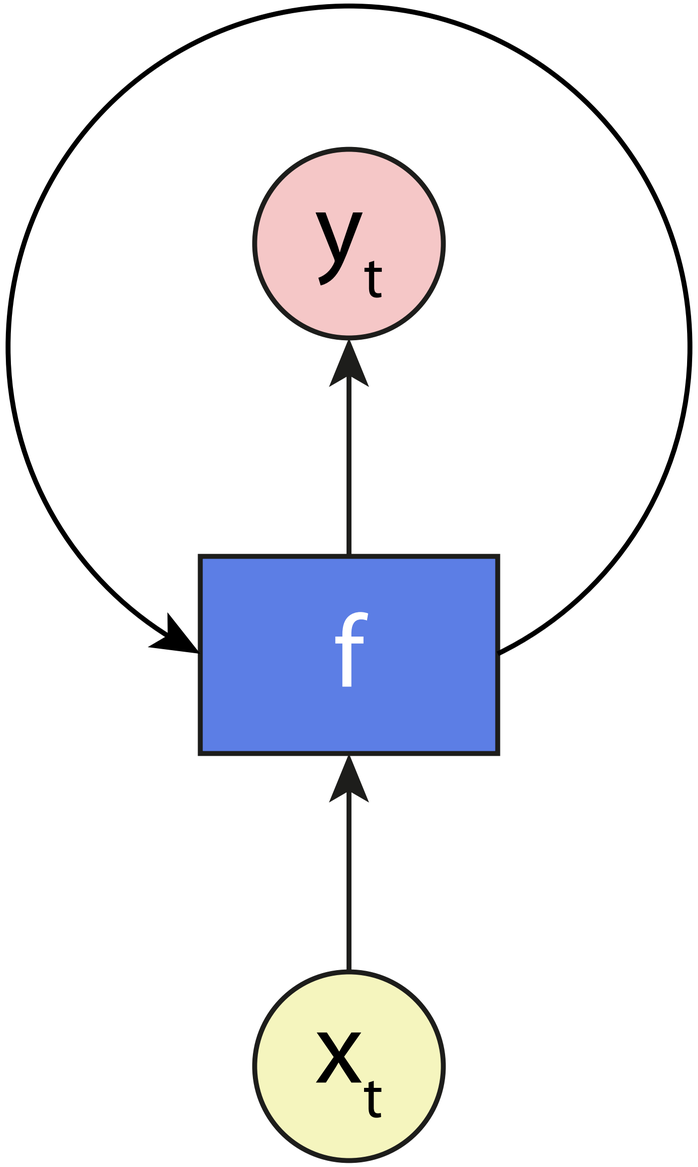




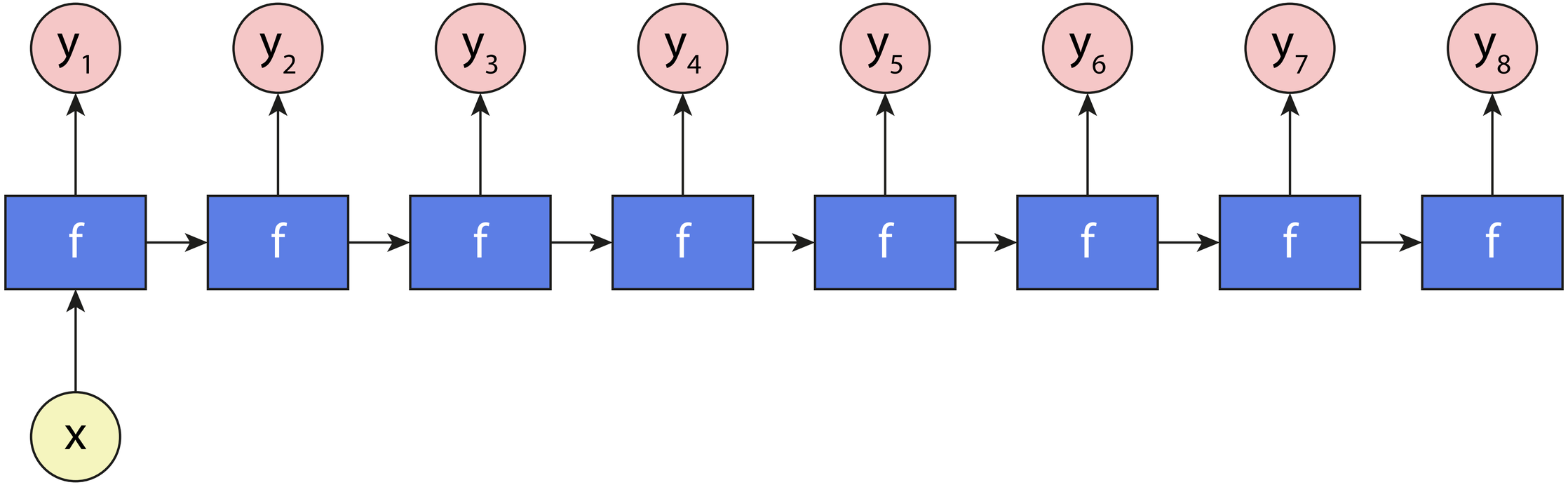


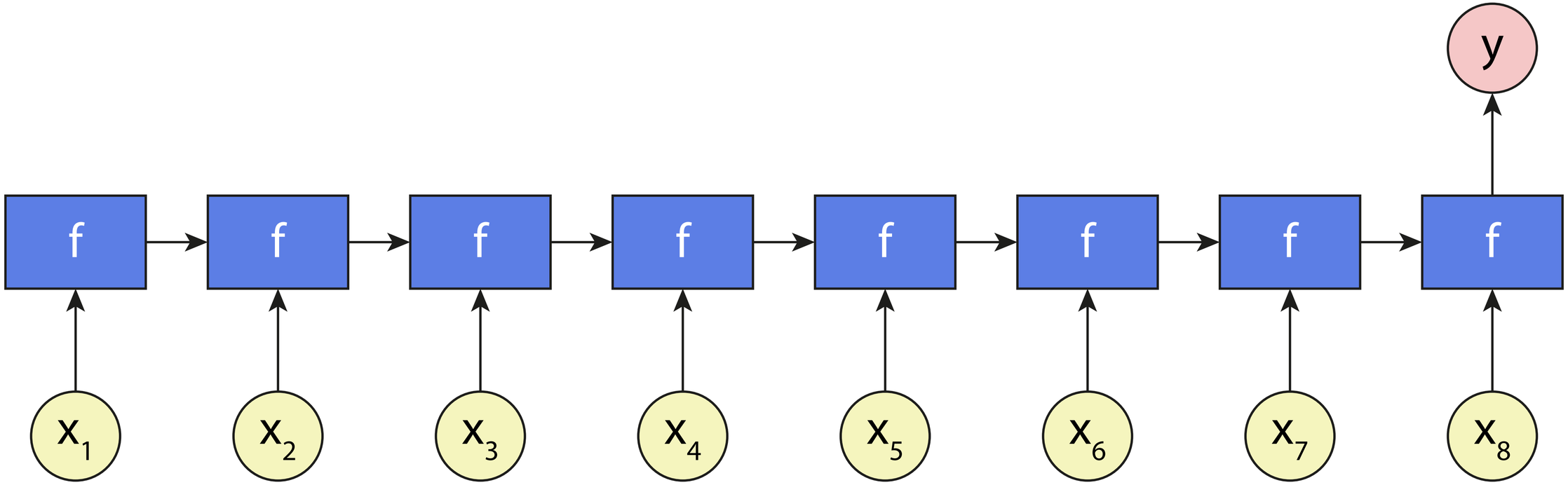
"Feature Visualization" Ohla et al 2017, Distill

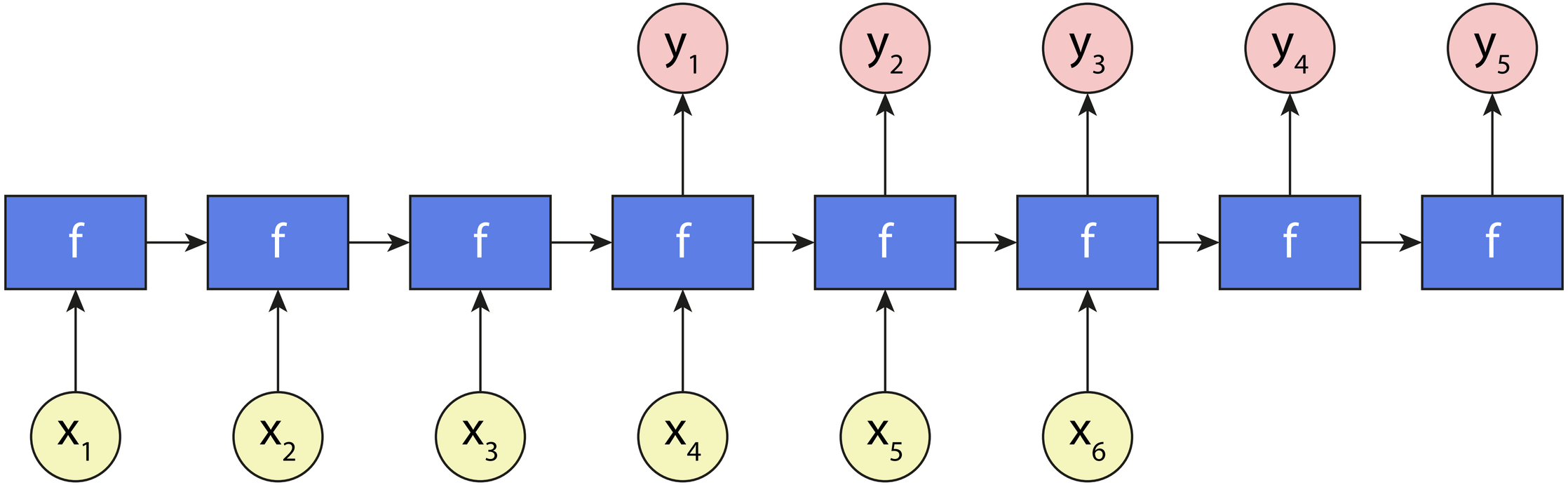

y
f
x

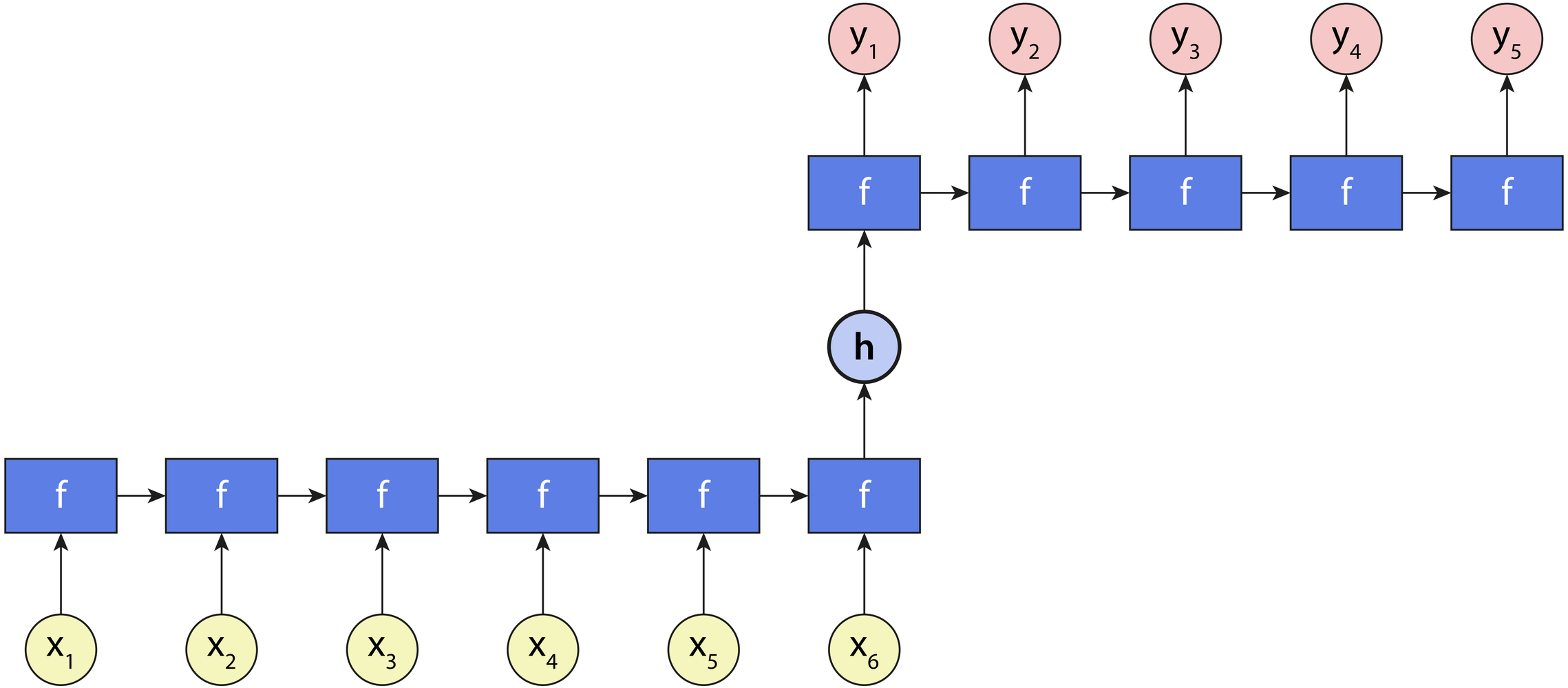

$y_t$
f
$x_t$

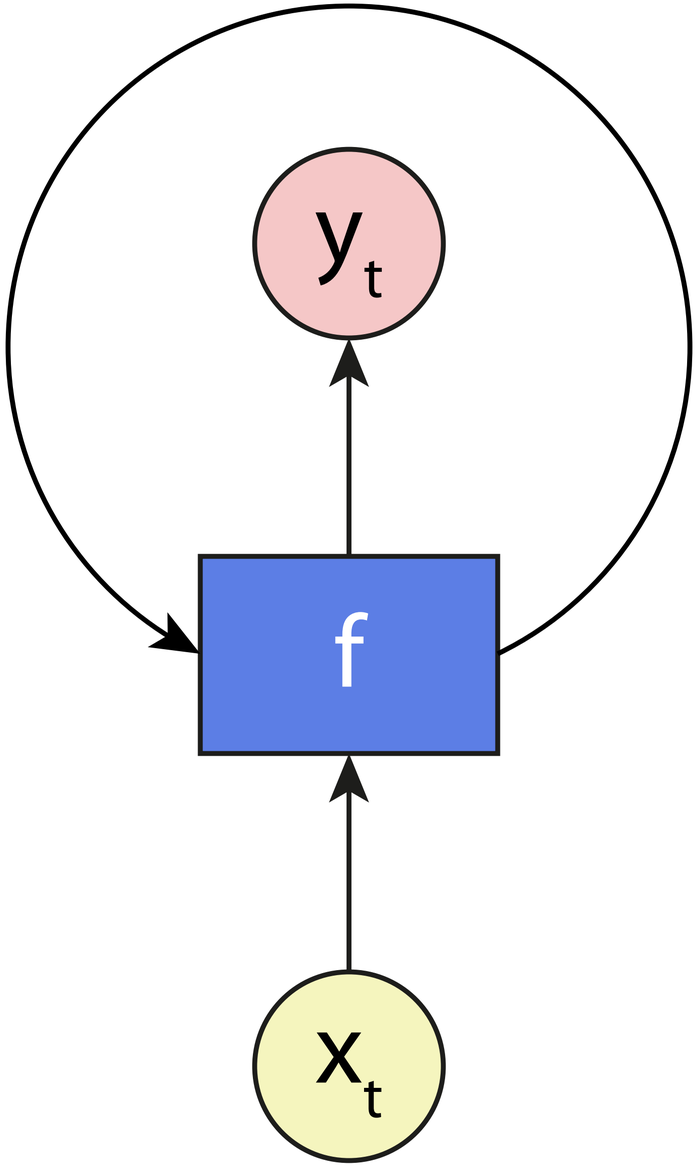
*

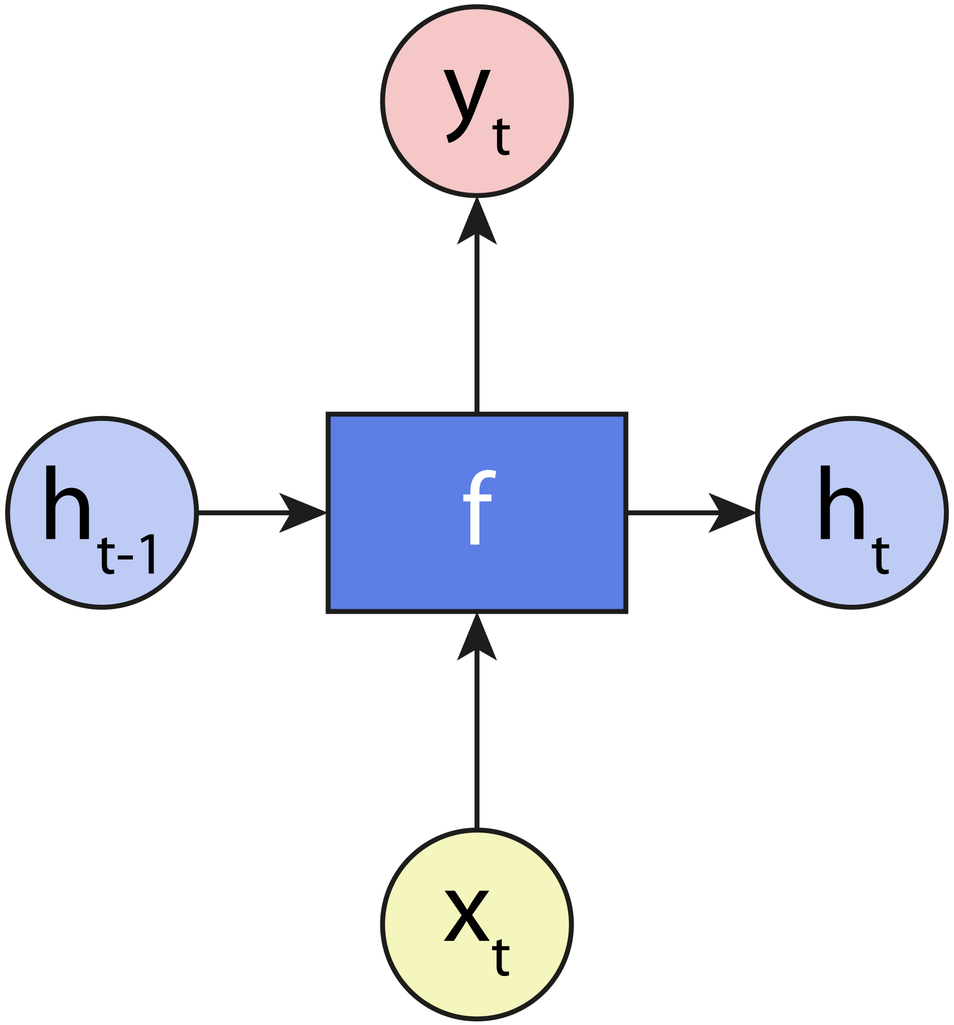

y1
y2
y3
y4
y5
y6
y7
y8
f
f
f
f
f
f
f
f
x


y
f
f
f
f
f
f
f
f
x1
x2
x3
x4
x5
x6
x7
x8


y1
y2
y3
y4
y5
f
f
f
f
f
f
f
f
x1
x2
x3
x4
x5
x6


y1
y2
y3
y4
y5
f
f
f
f
f
h
f
f
f
f
f
f
x1
x2
x3
x4
x5
x6

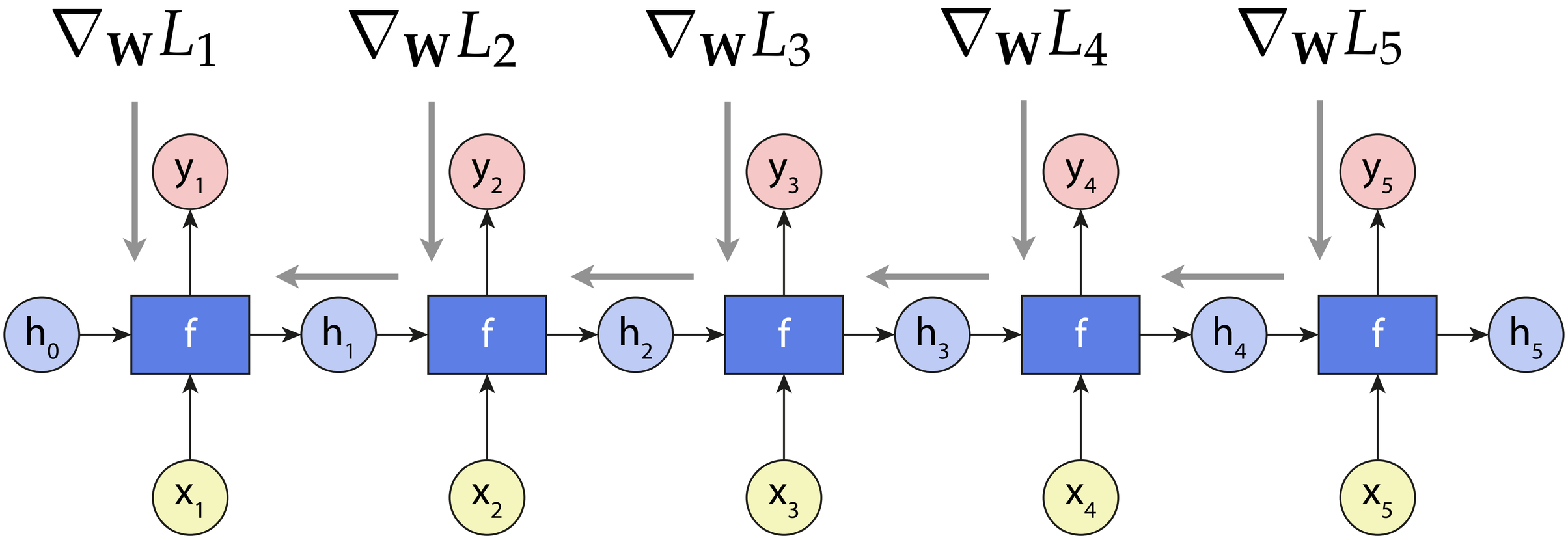

$y_t$
f
$x_t$

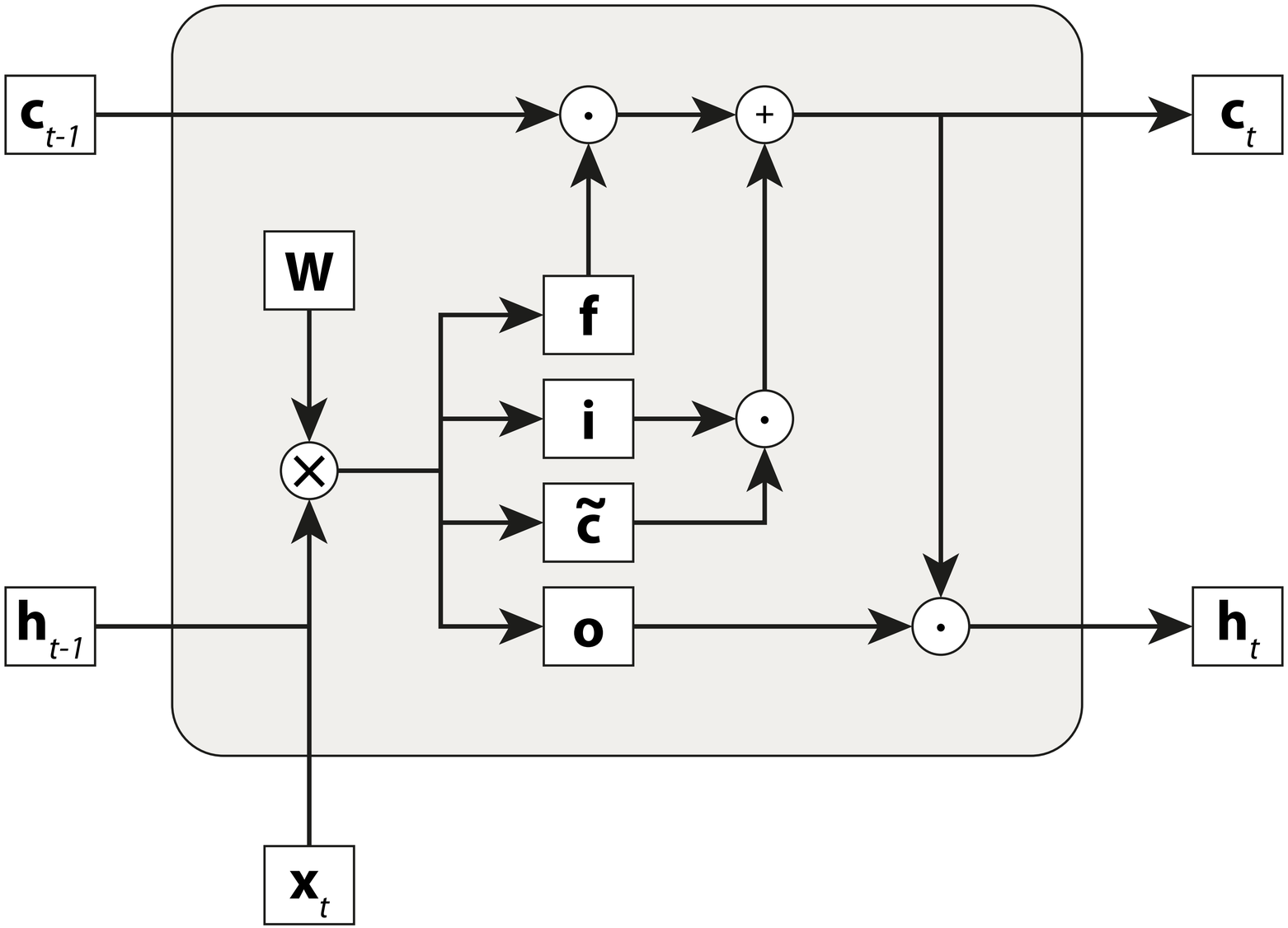

$y_t$
$h_{t-1}$
f
$h_t$
$x_t$

$$\mathbf{y} = a(\mathbf{x}\mathbf{W})$$

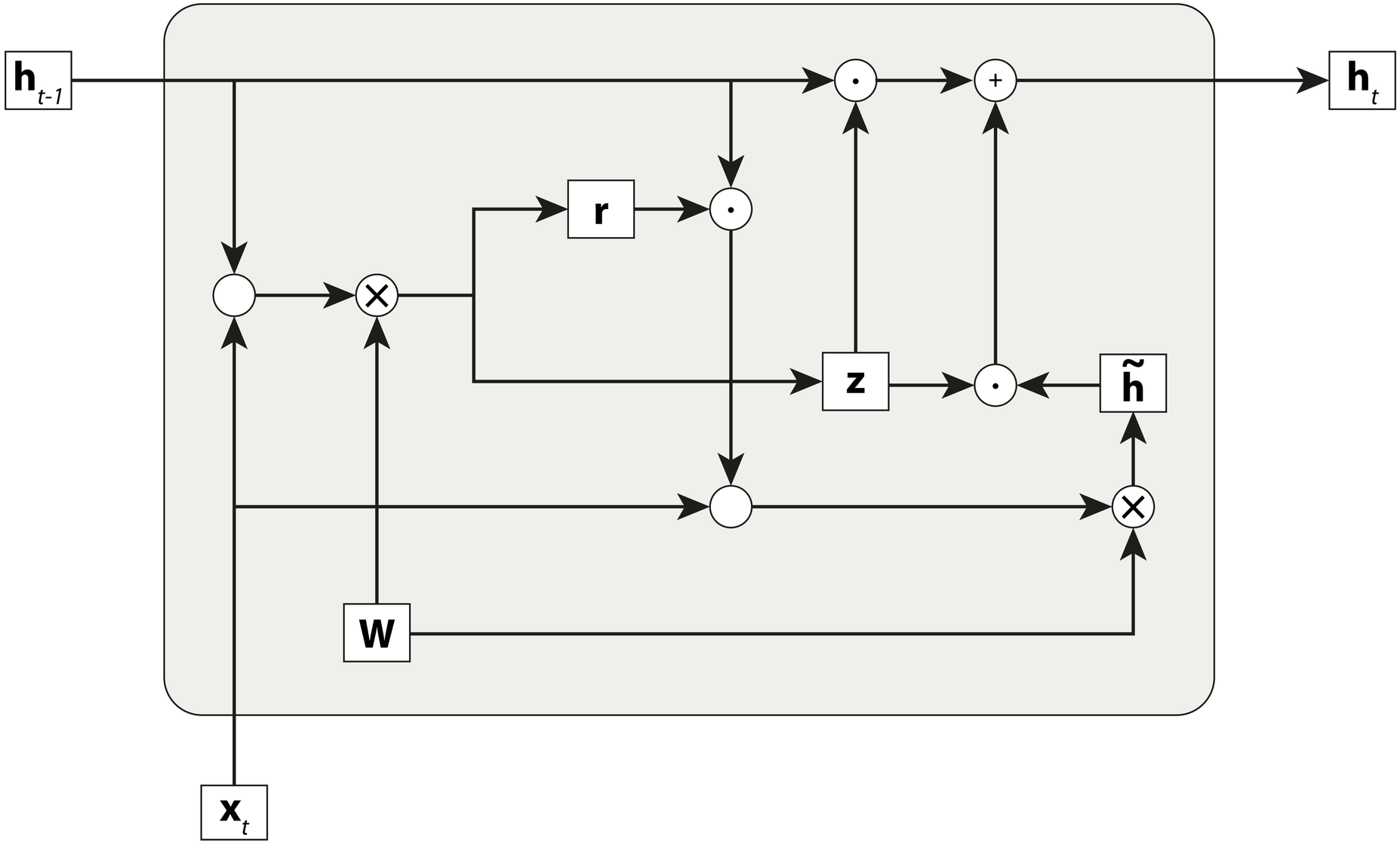
$$\mathbf{h}_t = \tanh([\mathbf{h}_{t-1}, \mathbf{x}_t]\boxed{\mathbf{W}_h})$$

$$\mathbf{y}_t = \mathbf{h}_t\boxed{\mathbf{W}_y}$$

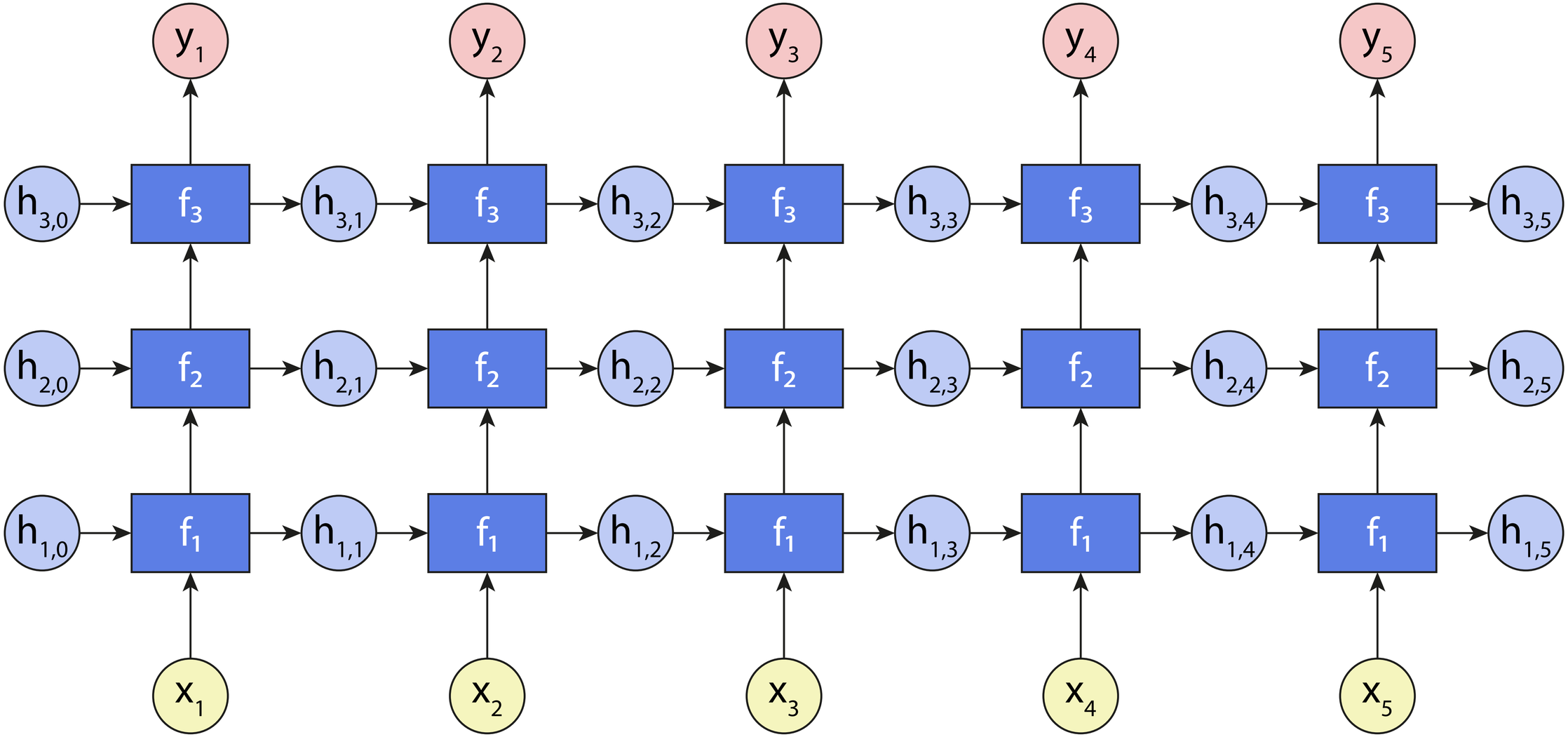

$\nabla_{\mathbf{W}} L_1$
$\nabla_{\mathbf{W}} L_2$
$\nabla_{\mathbf{W}} L_3$
$\nabla_{\mathbf{W}} L_4$
$\nabla_{\mathbf{W}} L_5$
$y_1$
$y_2$
$y_3$
$y_4$
$y_5$
$h_0$
f
$h_1$
f
$h_2$
f
$h_3$
f
$h_4$
f
$h_5$
$x_1$
$x_2$
$x_3$
$x_4$
$x_5$

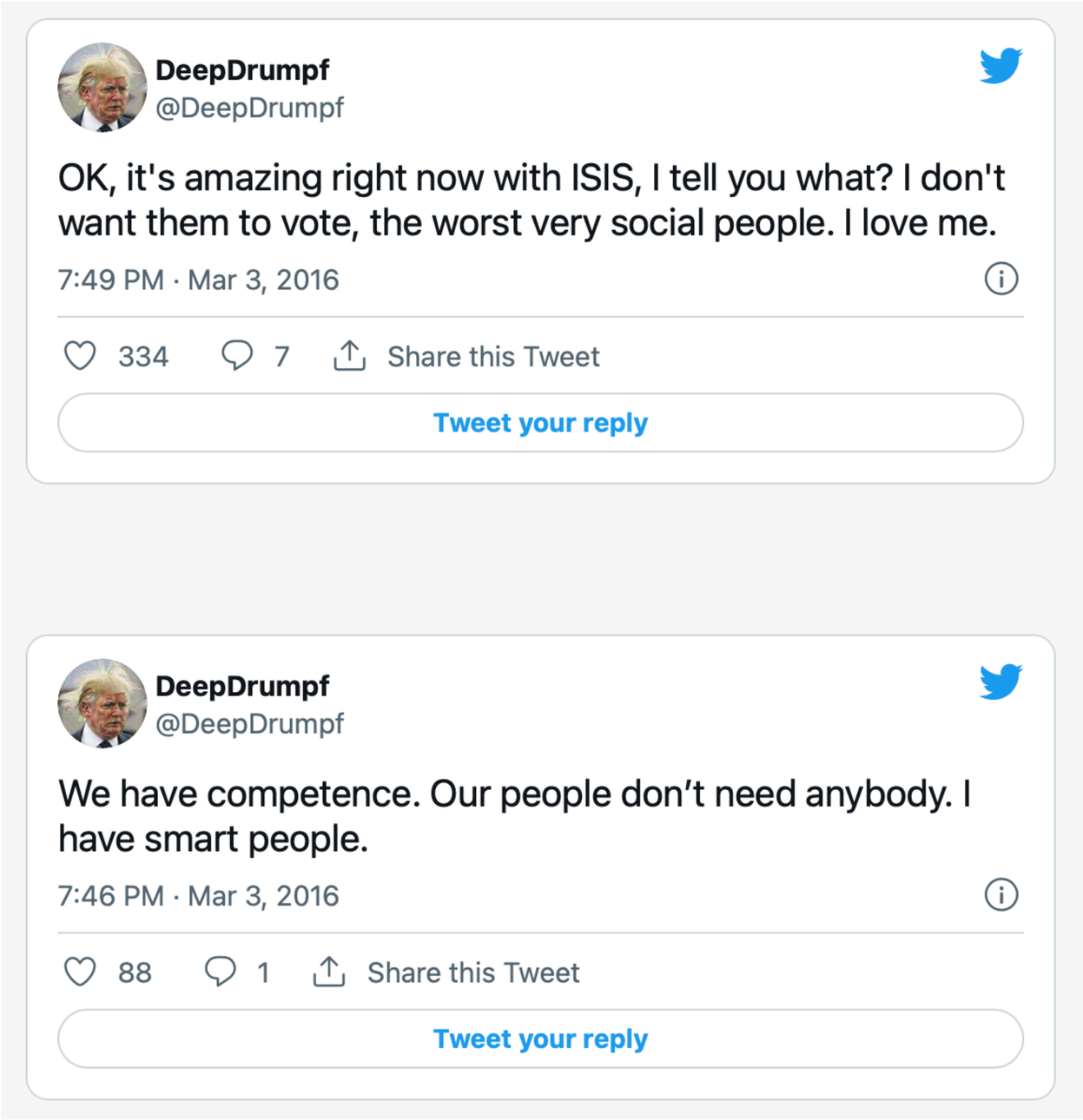

$c_{t-1}$
$c_t$
W
f
i
$\tilde{c}$
o
$h_{t-1}$
$h_t$
$x_t$

$$
\begin{aligned}
\mathbf{f}_t &= \sigma\big([\mathbf{h}_{t-1}, \mathbf{x}_t]\mathbf{W}_f\big) \\
\mathbf{i}_t &= \sigma\big([\mathbf{h}_{t-1}, \mathbf{x}_t]\mathbf{W}_i\big) \\
\mathbf{o}_t &= \sigma\big([\mathbf{h}_{t-1}, \mathbf{x}_t]\mathbf{W}_o\big) \\
\tilde{\mathbf{c}}_t &= \tanh\big([\mathbf{h}_{t-1}, \mathbf{x}_t]\mathbf{W}_c\big) \\
\mathbf{c}_t &= \mathbf{f}_t \odot \mathbf{c}_{t-1} + \mathbf{i}_t \odot \tilde{\mathbf{c}}_t \\
\mathbf{h}_t &= \mathbf{o}_t \cdot \tanh(\mathbf{c}_t)
\end{aligned}
$$


$\mathbf{h}_{t-1}$
$\mathbf{h}_t$
$\mathbf{r}$
$\mathbf{z}$
$\tilde{\mathbf{h}}$
$\mathbf{W}$
$\mathbf{x}_t$

$$
\begin{aligned}
\mathbf{r}_t &= \sigma\big([\mathbf{h}_{t-1}, \mathbf{x}_t]\mathbf{W}_r\big) \\
\mathbf{z}_t &= \sigma\big([\mathbf{h}_{t-1}, \mathbf{x}_t]\mathbf{W}_z\big) \\
\tilde{\mathbf{h}}_t &= \tanh\big([(\mathbf{r}_t \odot \mathbf{h}_{t-1}), \mathbf{x}_t]\mathbf{W}_c\big) \\
\mathbf{h}_t &= \mathbf{z}_t \odot \mathbf{h}_{t-1} + (1 - \mathbf{z}_t) \odot \tilde{\mathbf{h}}_t
\end{aligned}
$$


y1
y2
y3
y4
y5
h3,0
f3
h3,1
f3
h3,2
f3
h3,3
f3
h3,4
f3
h3,5
h2,0
f2
h2,1
f2
h2,2
f2
h2,3
f2
h2,4
f2
h2,5
h1,0
f1
h1,1
f1
h1,2
f1
h1,3
f1
h1,4
f1
h1,5
x1
x2
x3
x4
x5


DeepDrumpf
@DeepDrumpf
OK, it's amazing right now with ISIS, I tell you what? I don't want them to vote, the worst very social people. I love me.
7:49 PM · Mar 3, 2016
334
7
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Tweet your reply
DeepDrumpf
@DeepDrumpf
We have competence. Our people don't need anybody. I have smart people.
7:46 PM · Mar 3, 2016
88
1
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# Questions?

# Next: Unsupervised Learning