Information Technology for Digital Humanities

Lecture 6

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Università degli Studi di Bergamo

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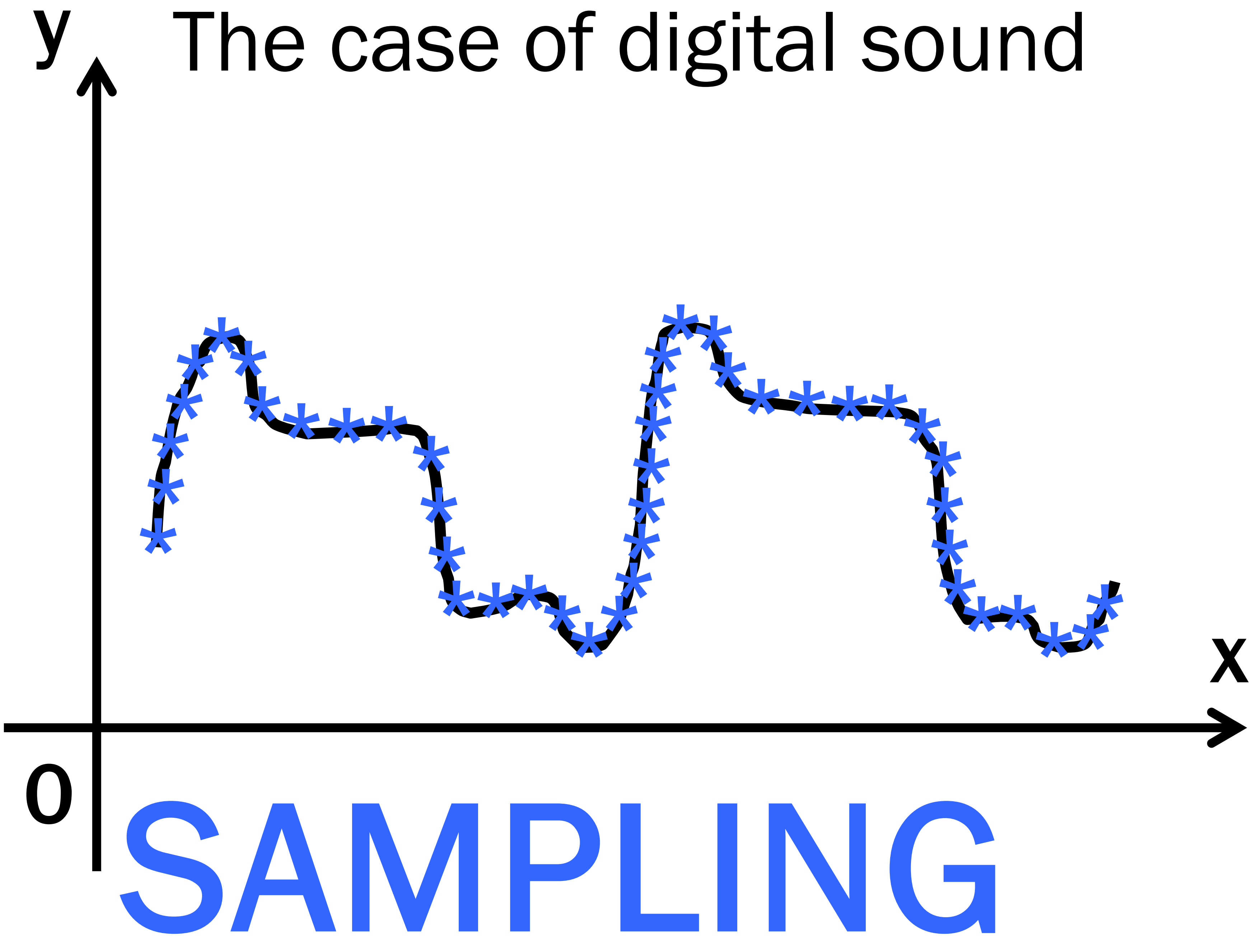
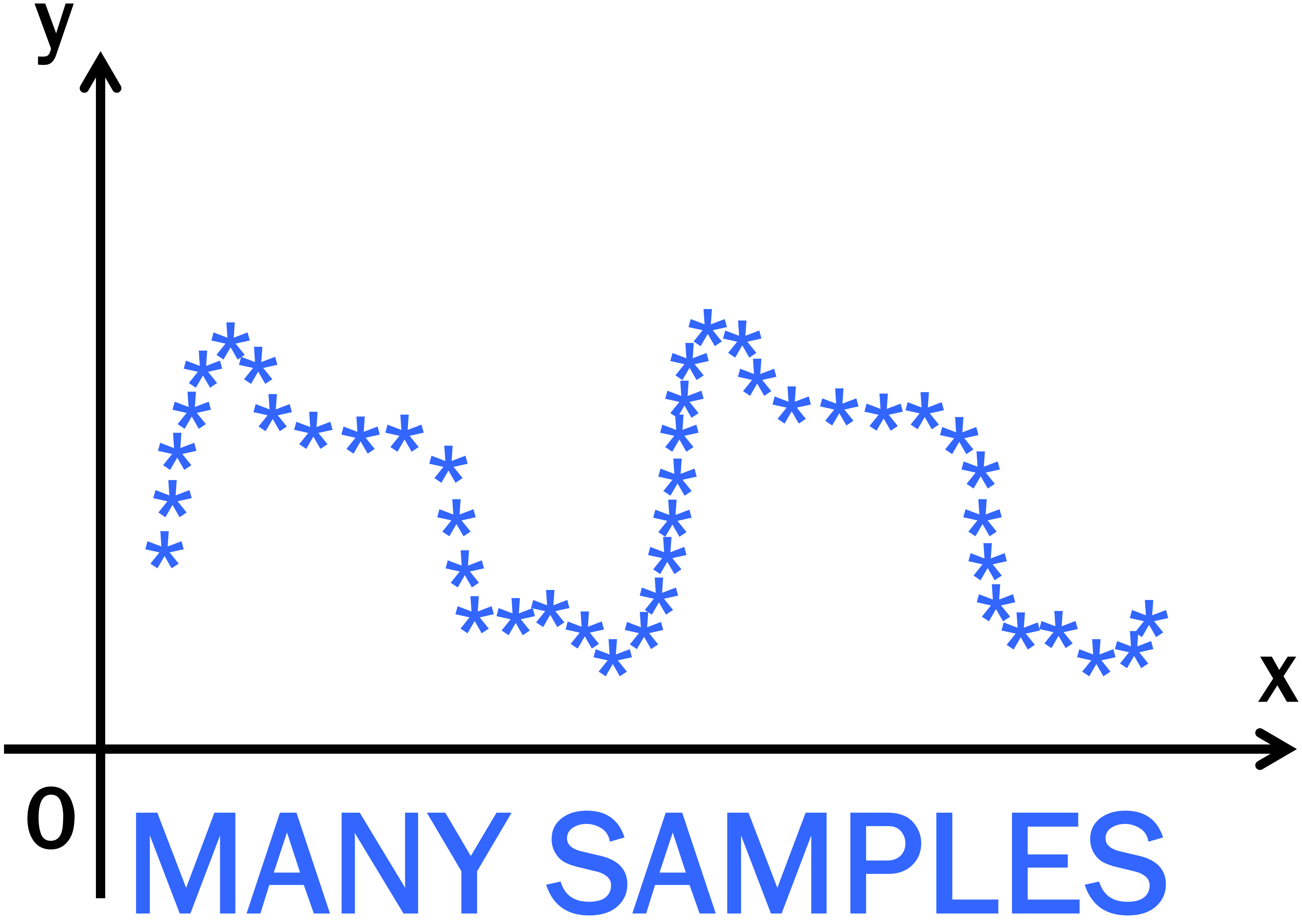
Lecture 6 (October 11 2023)

- Digital vs Physical vs Analog


The case of digital sound
y
x
0
SAMPLING

SAMPLING

- We pick a point on the wave to compute coordinates for only every interval of time
- Each picked point is called a SAMPLE
- The number of samples per unit of time is called SAMPLING RATE
- The higher the sampling rate, the more samples we have
- The more samples we have, the better the numerical description of the wave is


y
x
0
MANY SAMPLES

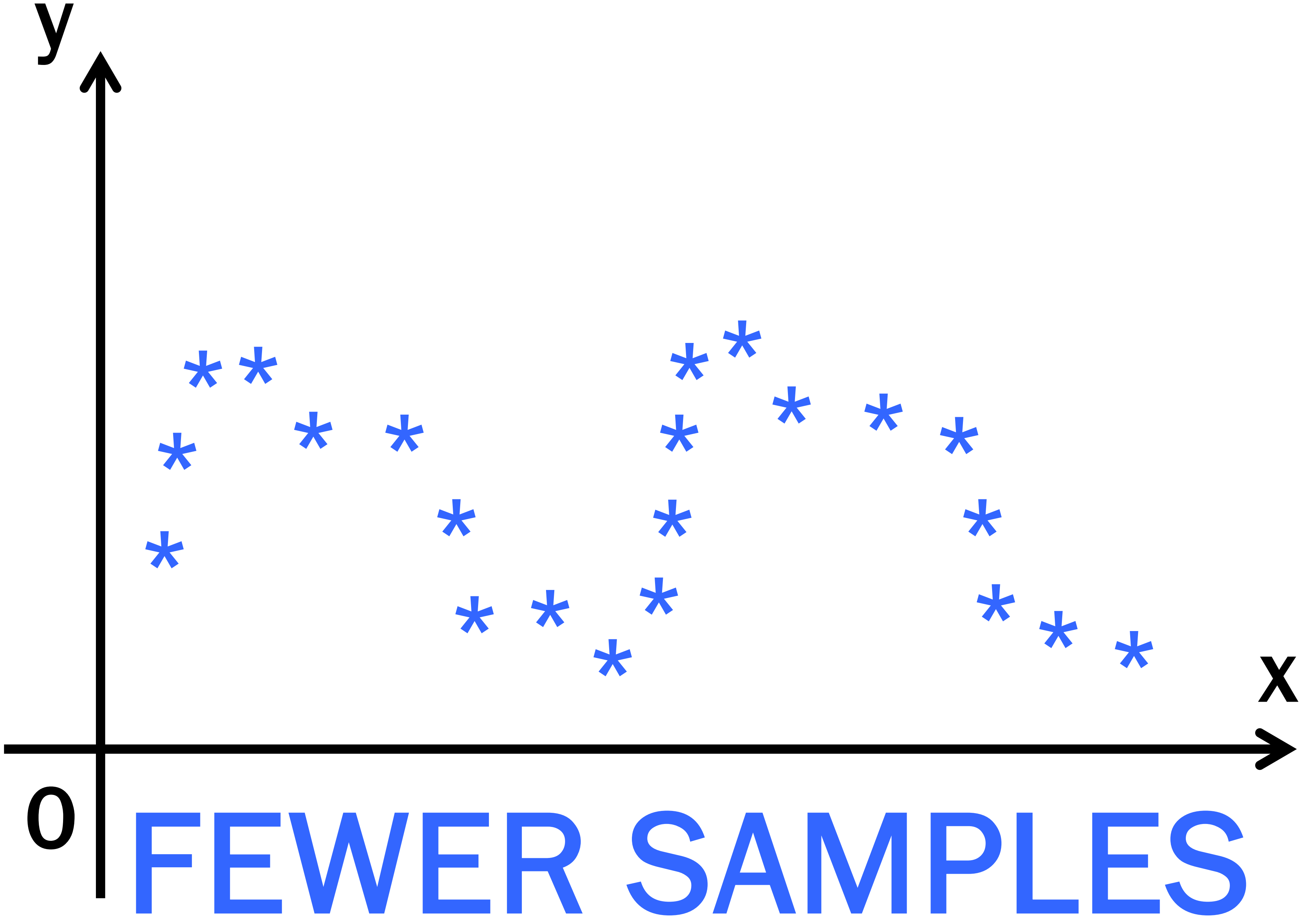
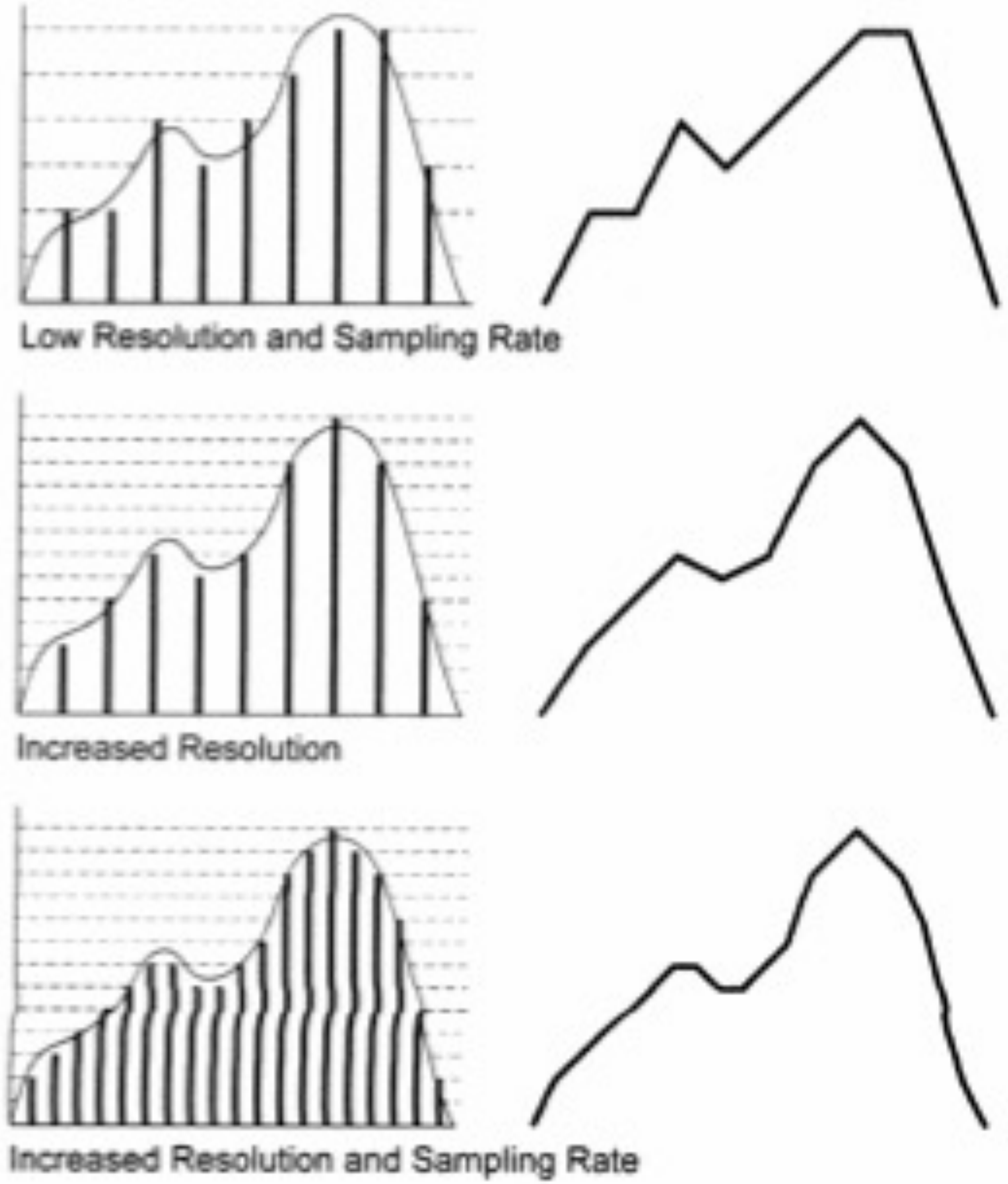

y
x
0
FEWER SAMPLES

Figure 20 - Effect of Increased Resolution and Sampling Rates



SAMPLING

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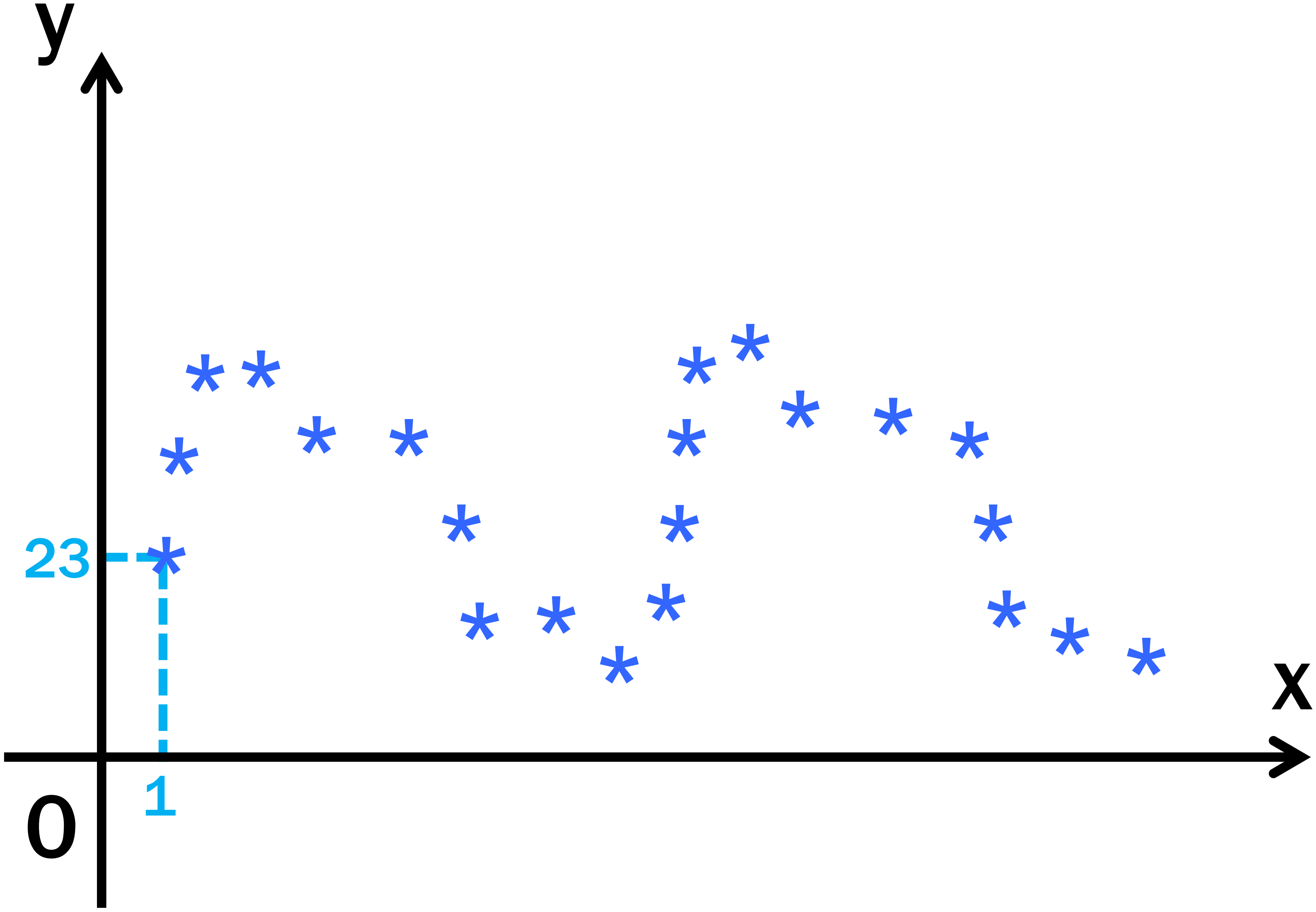
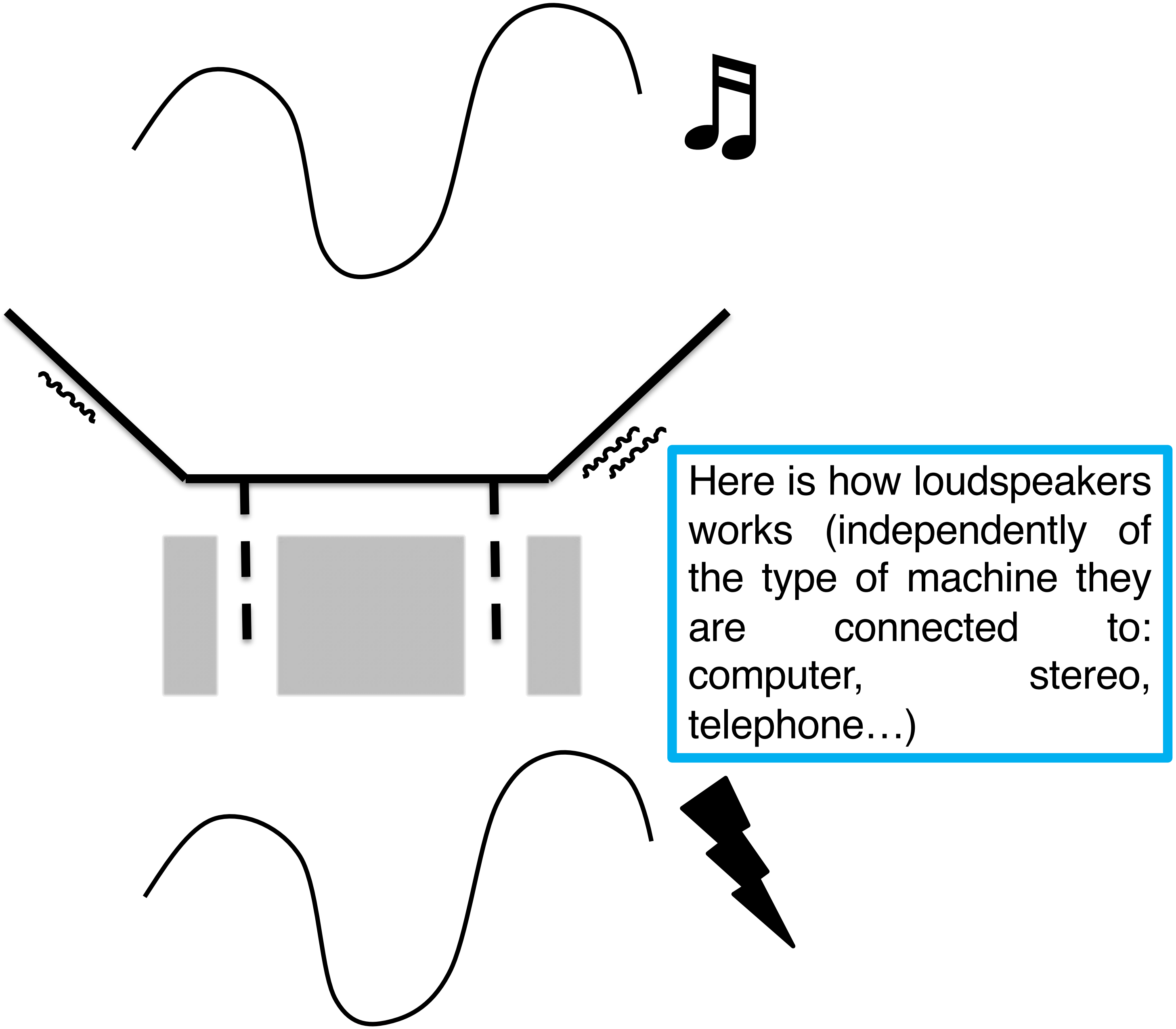
(1, 23) (2, 30) (3, 28) (4, 30) (5, 29) (6,35) (7, 37) (8, 22) (9,18) (10, 13) (11, 8) (12, 2) (13, 4) (14, 8) (15, 10) (16, 18) (17, 20)...

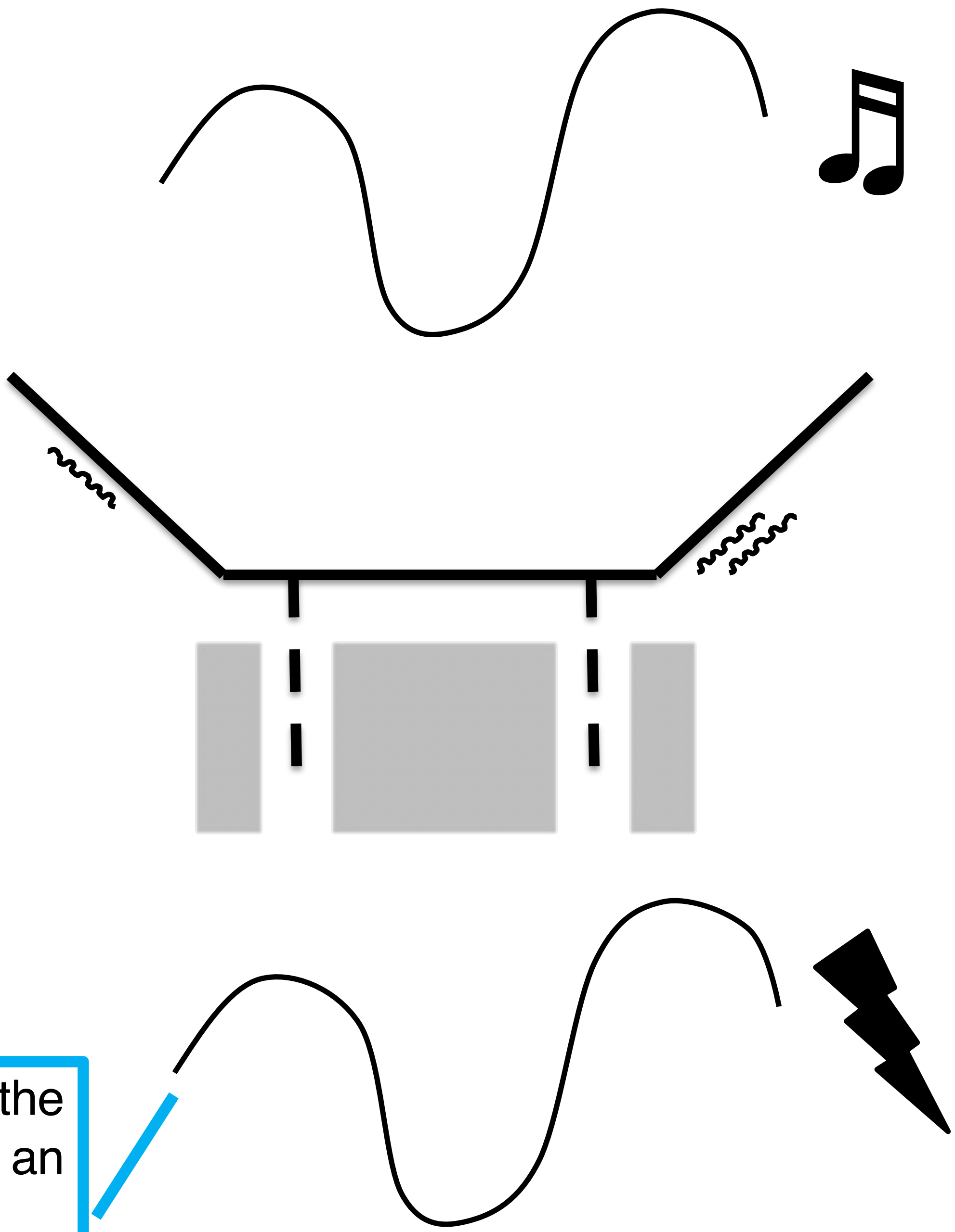

y
x
0
23
1

DIGITAL SOUNDS IN THE PHYSICAL WORLD: LOUDSPEAKERS

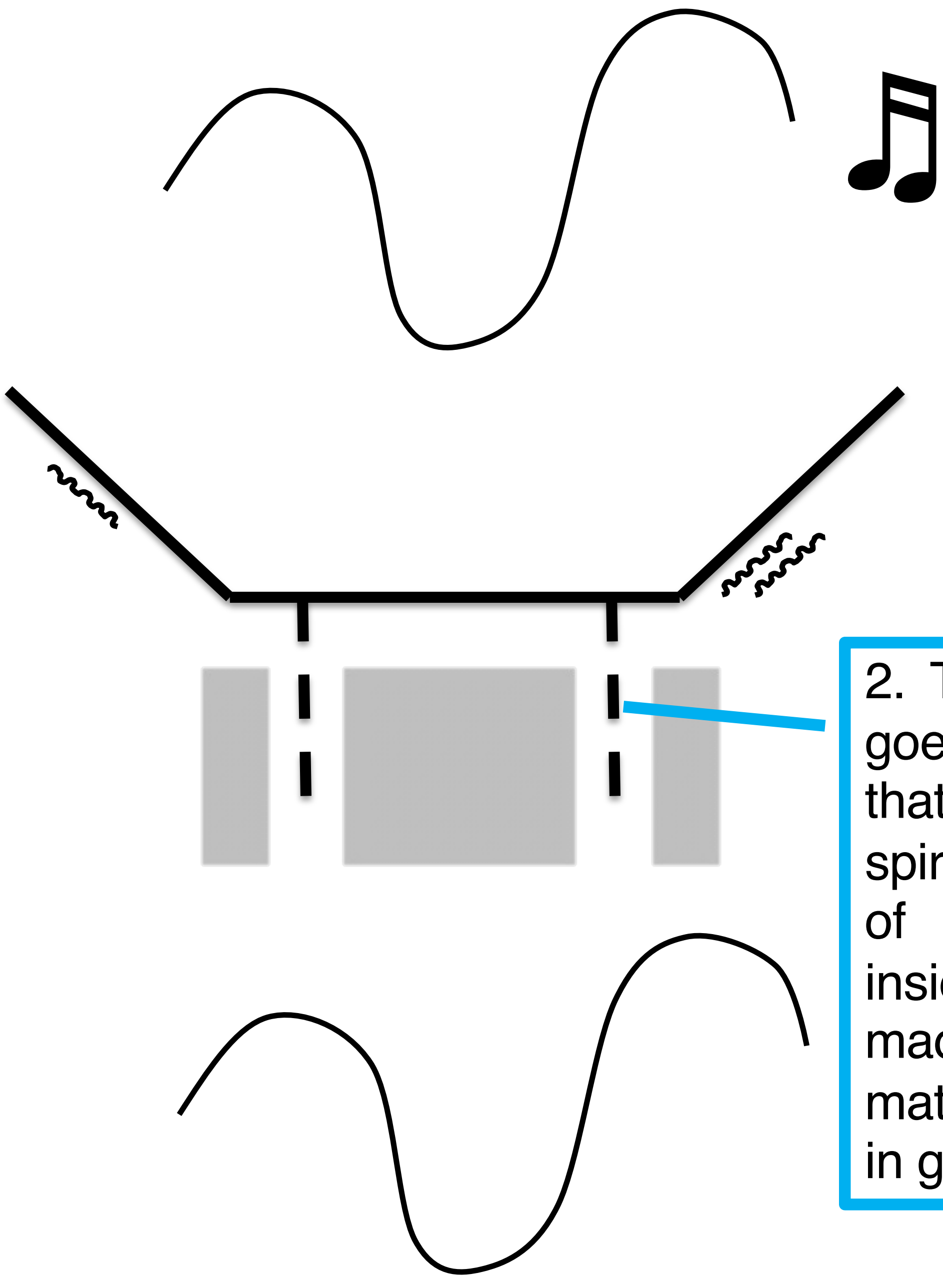
THE NEED FOR HARDWARE

- As it always happens, digital technology needs physical tools that convert numbers into physical phenomena

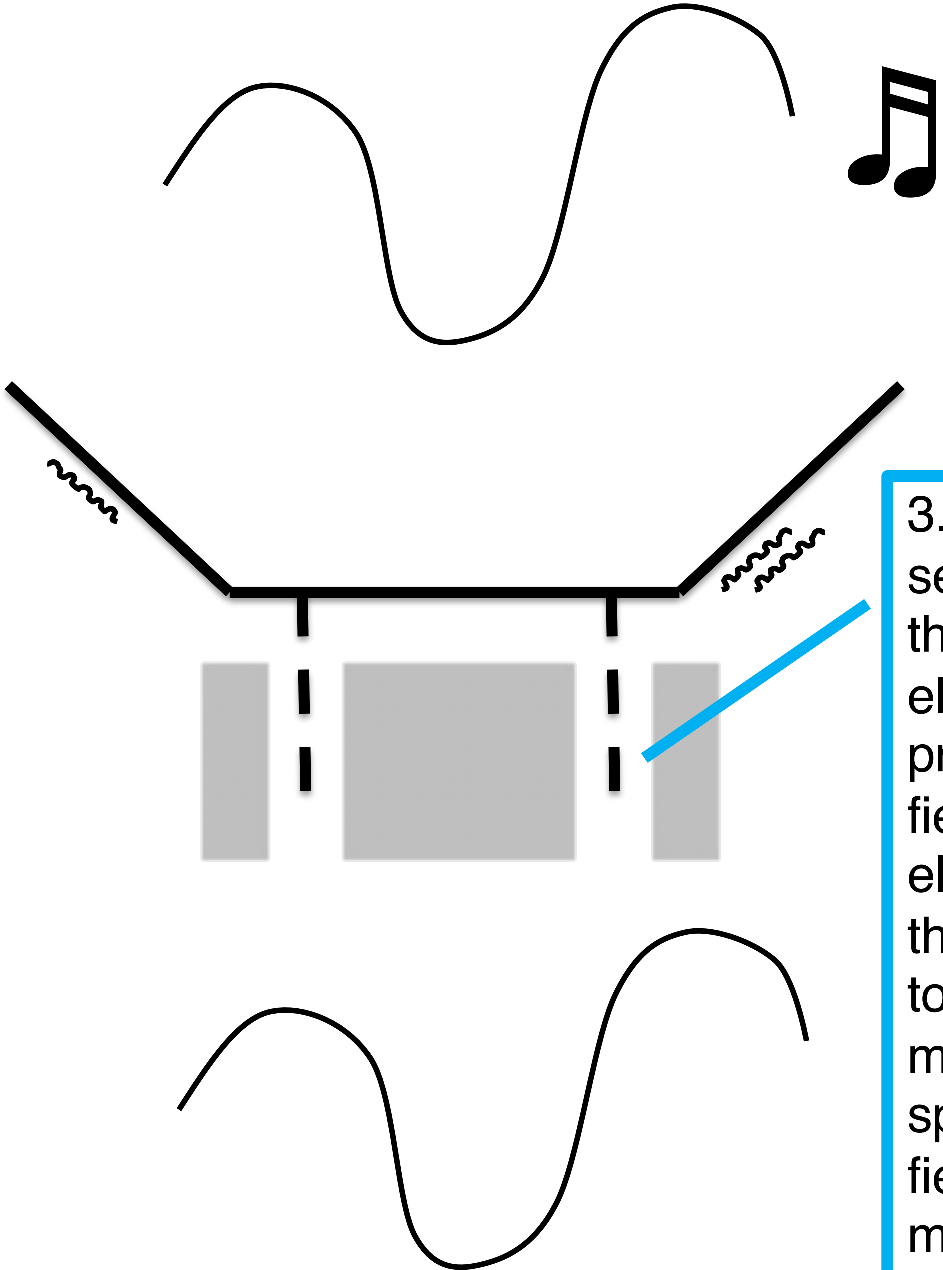

Here is how loudspeakers works (independently of the type of machine they are connected to: computer, stereo, telephone…)



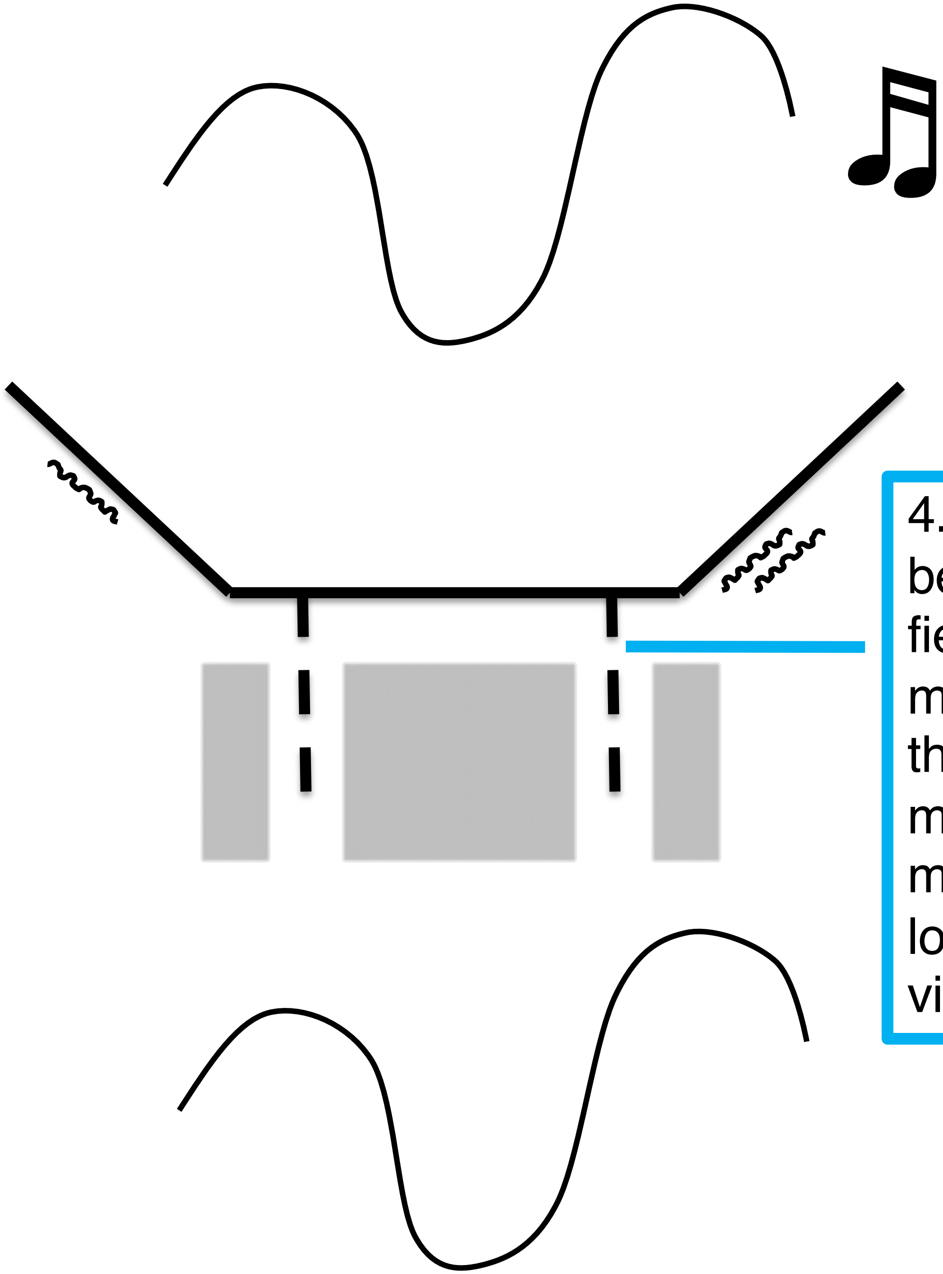
1. The input to the loudspeaker is an electric signal.



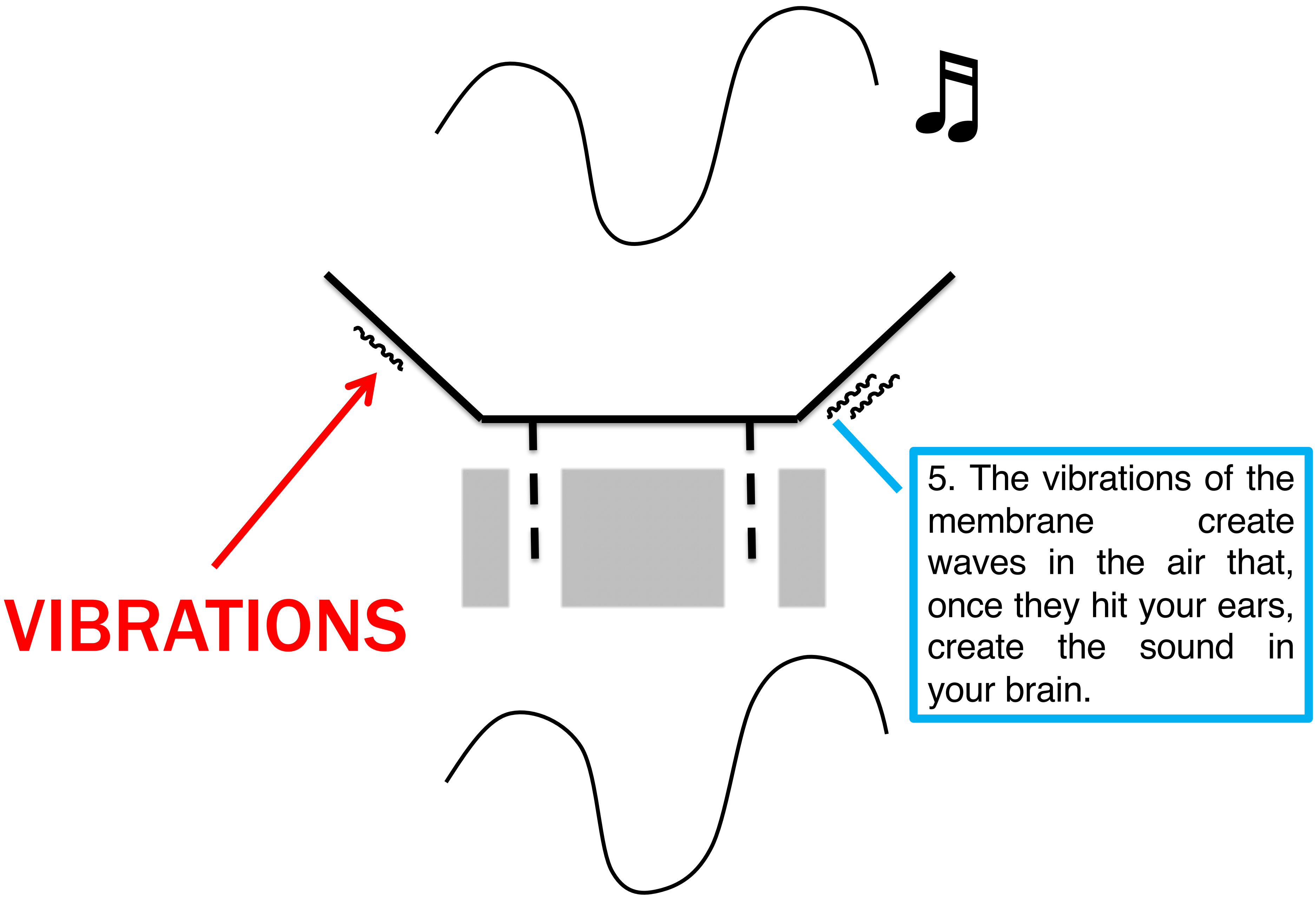
2. The electrical signal goes through a cable that is shaped like a spiral around a cylinder of magnetic material, inside a tube also made with magnetic material (depicted here in gray).



3. The laws of physics see to it that when there is a change in an electrical field, this produces a magnetic field. Here, the electricity flowing through the cable leads to the creation of a magnetic field in the spiral. Such magnetic field interacts with the magnetic field of the magnet.

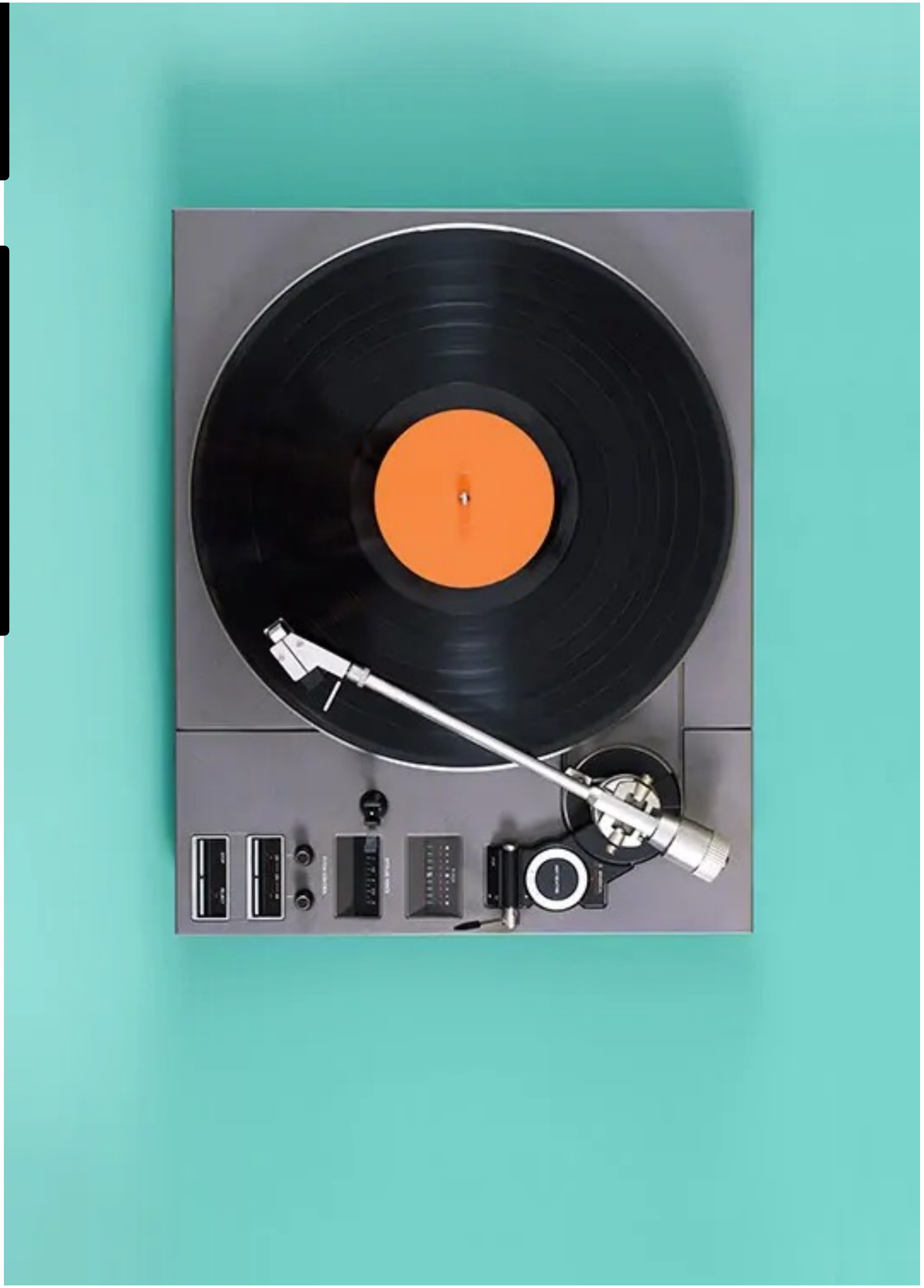


4. The interaction between the magnetic fields makes the spiral move and, in turn, those movements make it hit the membrane of the loudspeaker, making it vibrate.

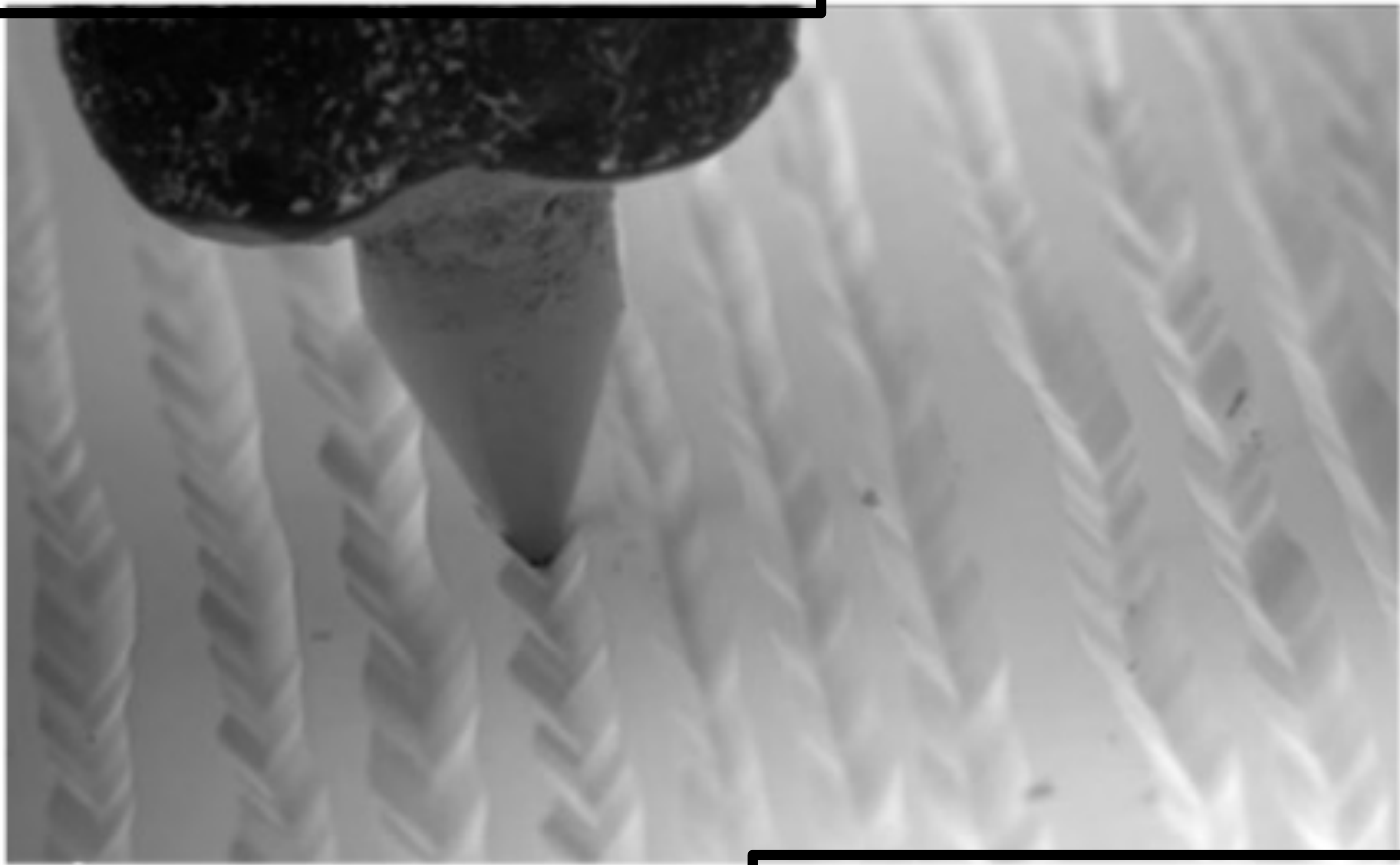

VIBRATIONS
5. The vibrations of the membrane create waves in the air that, once they hit your ears, create the sound in your brain.

Where does the electric signal come from?

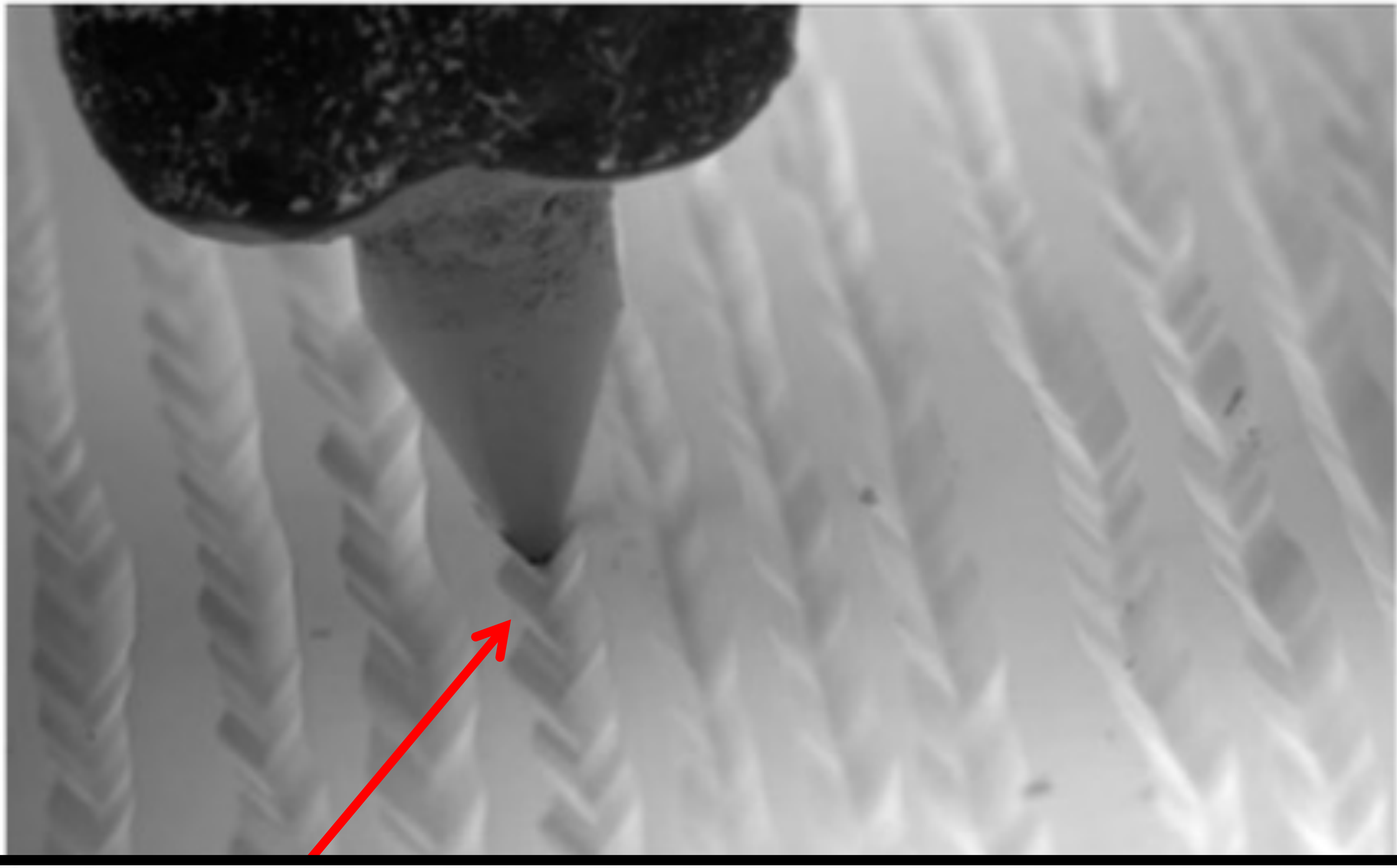
In the case of a record player, the needle is put inside the groove of the record, and it follows its physical profile.



The needle oscillates following the groove’s profile, which has been shaped in the recording process in accordance with the soundwaves of the recorded music.



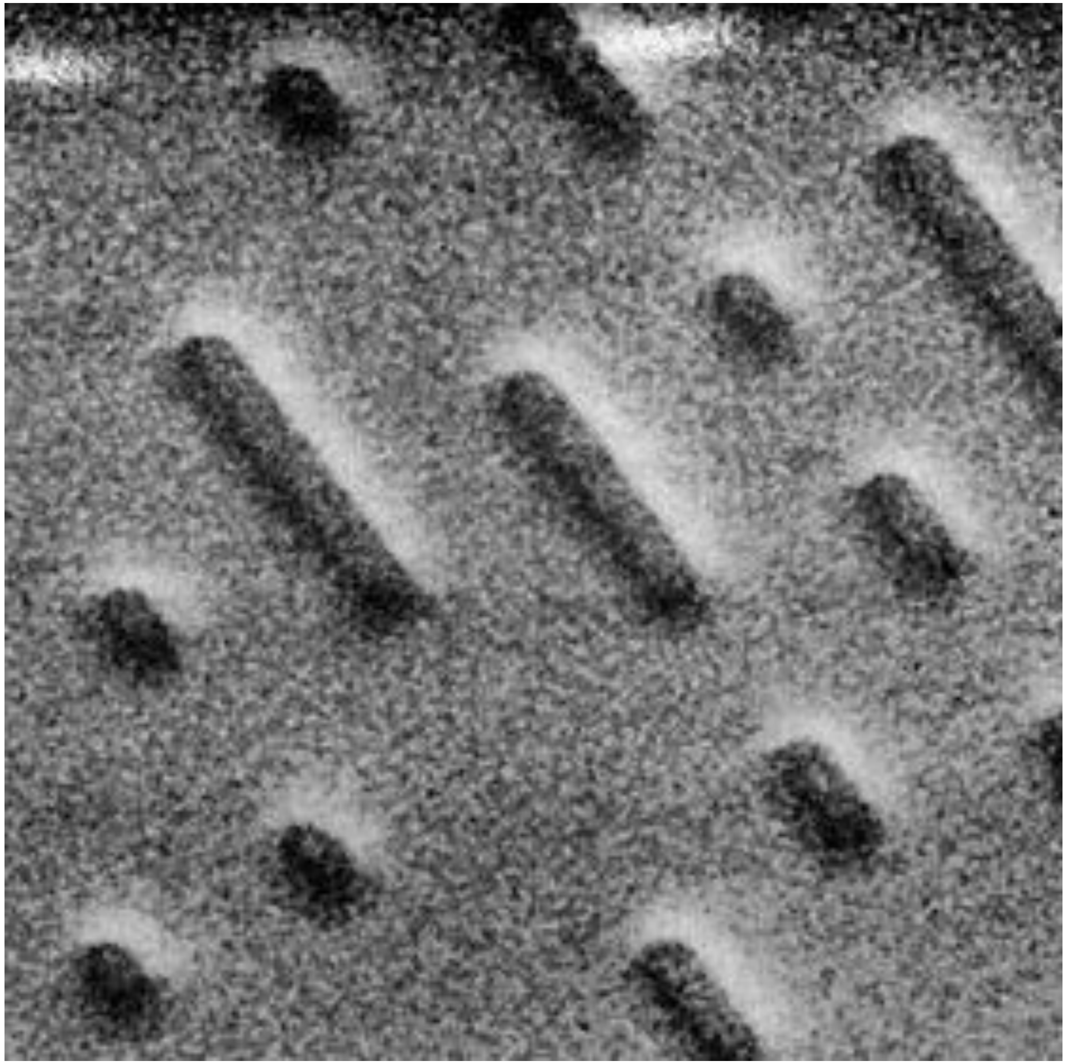
The record player contains electro-magnetic devices that create an electric signal whose shape is analogous to the profile of the groove.



This is why we call a record player an “analog” system: it is based on an analogy, or similarity. The similarity is between the shape of the soundwaves of the music being recorded, the profile of the groove on the record, the shape of the electric wave, and the soundwaves produced by the membrane of the loudspeaker.

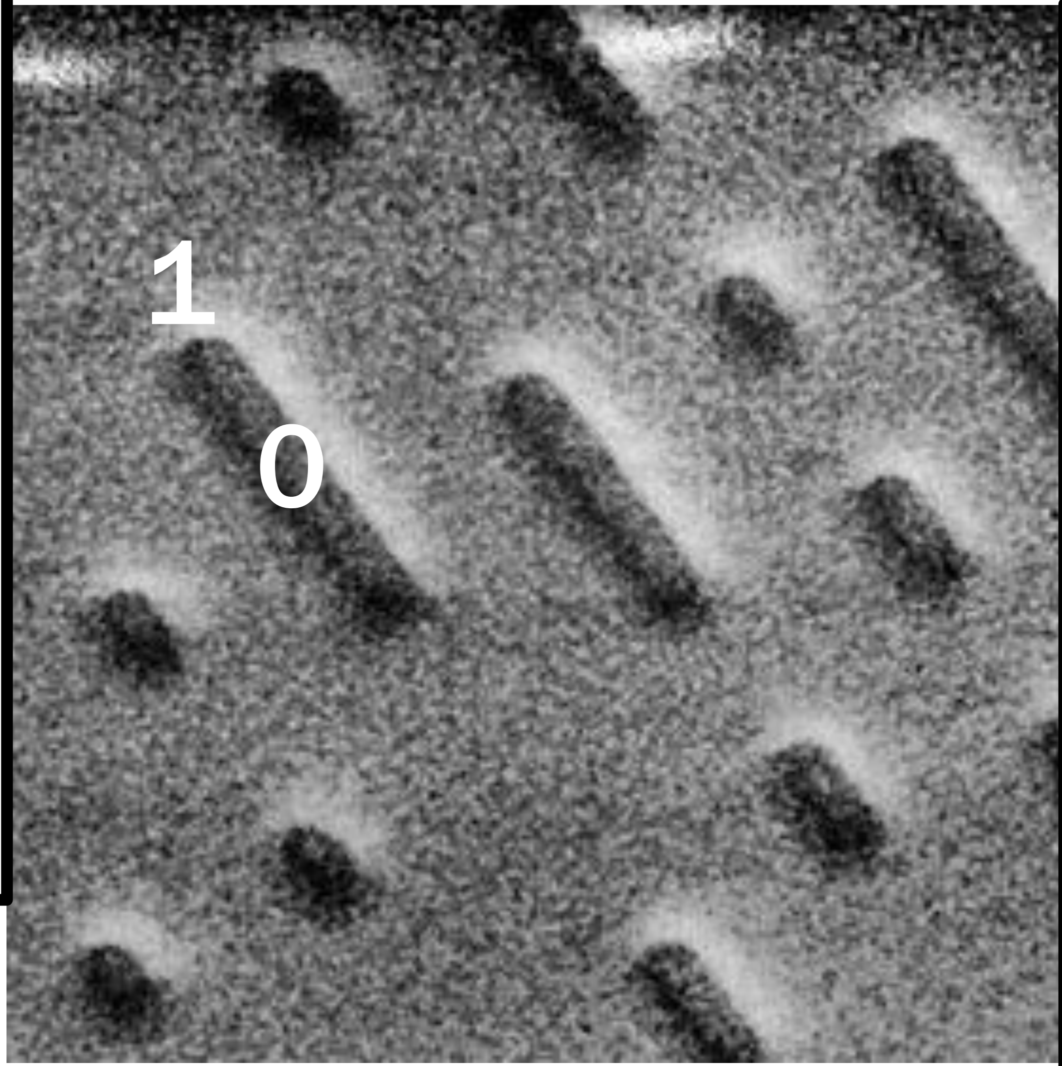
Despite looking like a record, a CD (Compact Disc) records music in a different way: not analog, but digital – in the sense that music is recorded on a CD in the form of (binary) numbers.

Indeed, if we zoom in on a CD surface, we see something extremely different from a groove with edges in the shape of waves. Instead, we see long and short linear grooves.

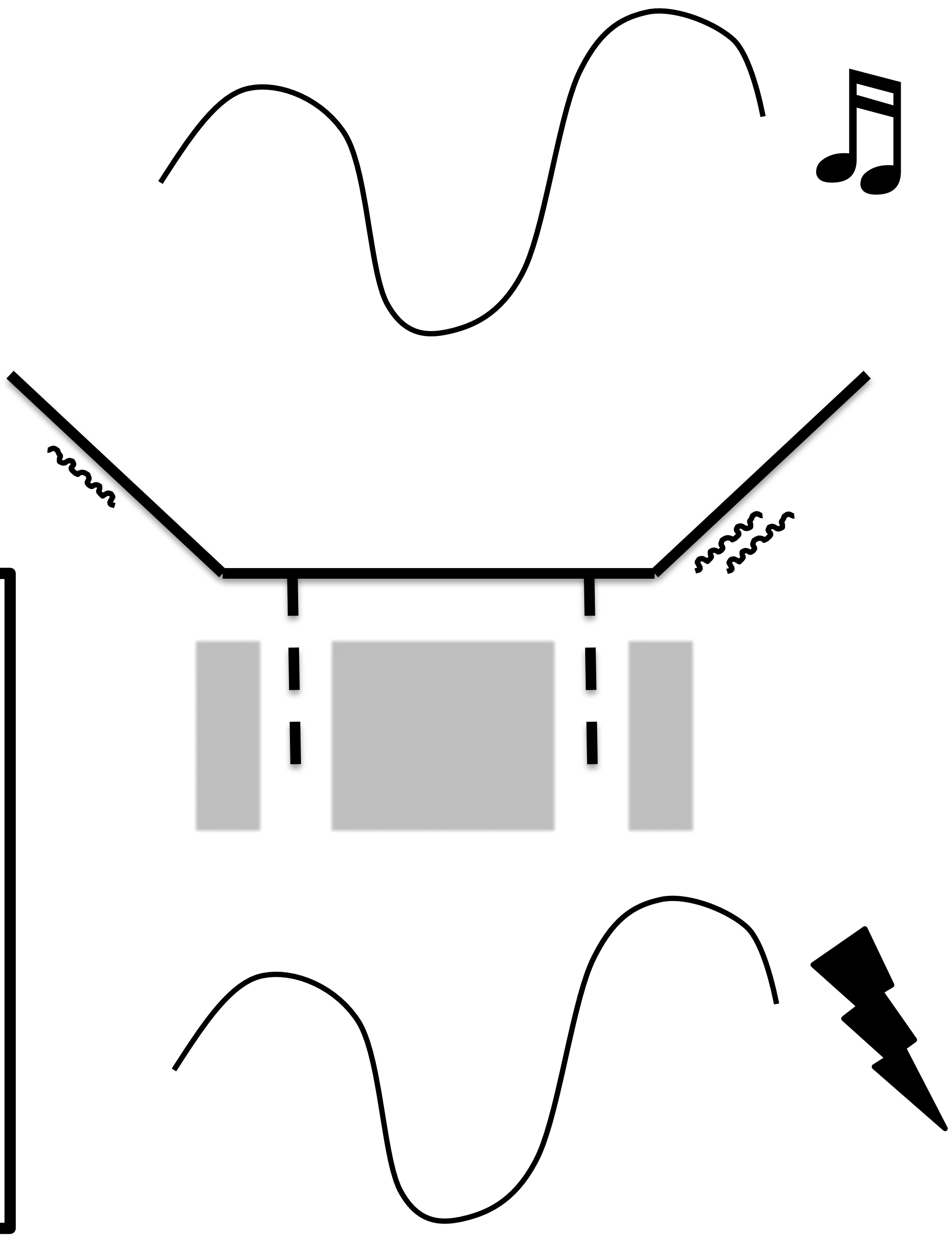


They might remind you of how Morse code looks like on paper (long line for a long beep and short line for a short beep), and you might think that the long and short lines form a binary system where long stands for 1 and short for 0, but it is not like that.

0s and 1s are indeed recorded on a CD, but in a different way: when a groove starts or finishes, that is, there is a step down or step up on the surface, we have a 1; when nothing changes, so the surface stays on the same level (whether inside a groove or outside doesn't matter, we have a 0.

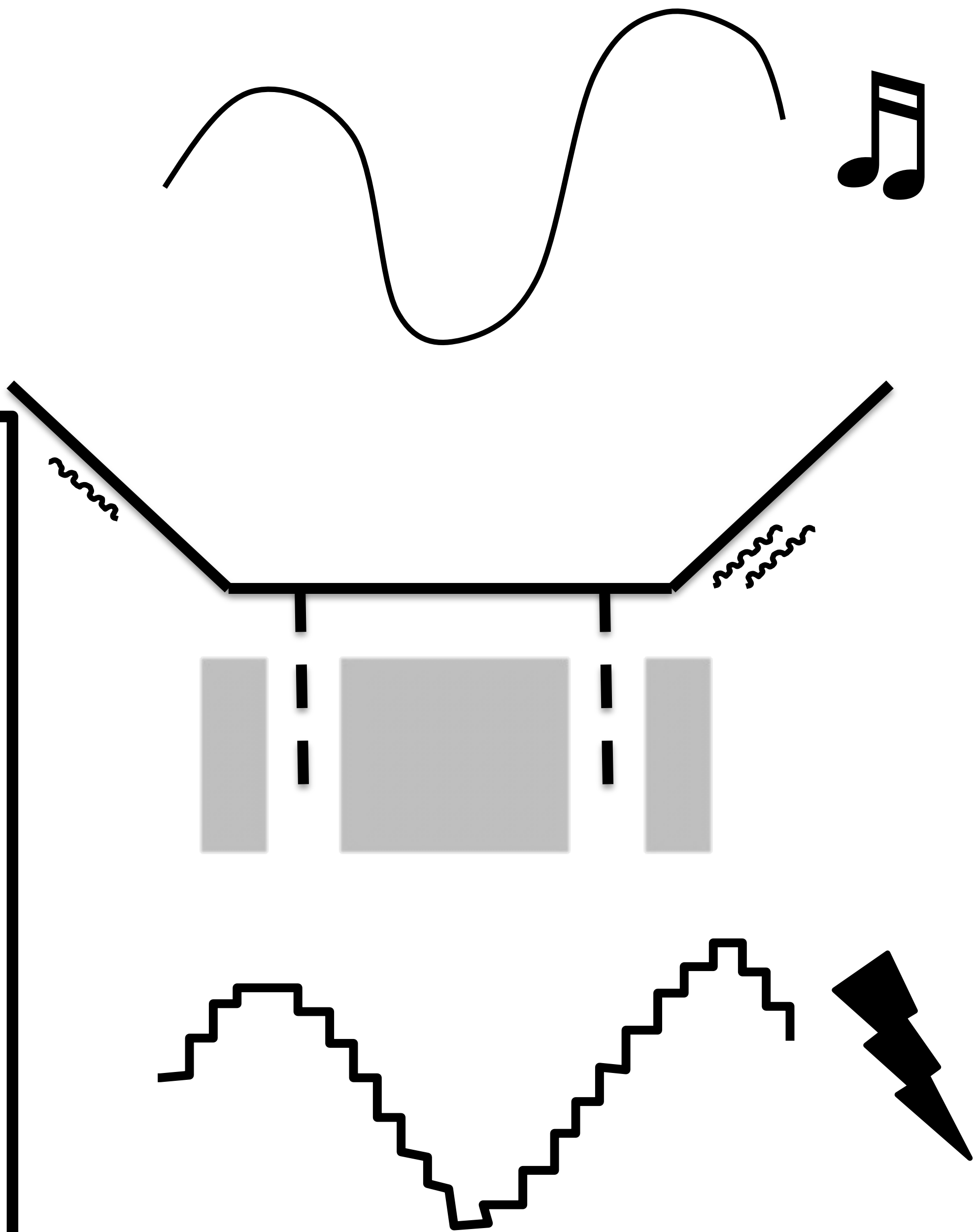


This means that a correct reading of the 0s and 1s on the surface of the CD must be done with a correctly timed CD reader: sampling surface points too fast or too slow will give too many or too few bits compared to the ones correctly describing the soundwave in a digital way.
The same goes for analog records: you have to play that at the correct speed to have the sound as it was recorded.



A loudspeaker connected to an analog music system will receive an electric signal that is a smooth curve, derived from the smooth curves of the edges of the groove on the record.

A loudspeaker connected to an digital music system will receive an electric signal that is a curve that has steps, because it derives from a finite and discrete sequence of numbers, created by means of sampling the original sound.

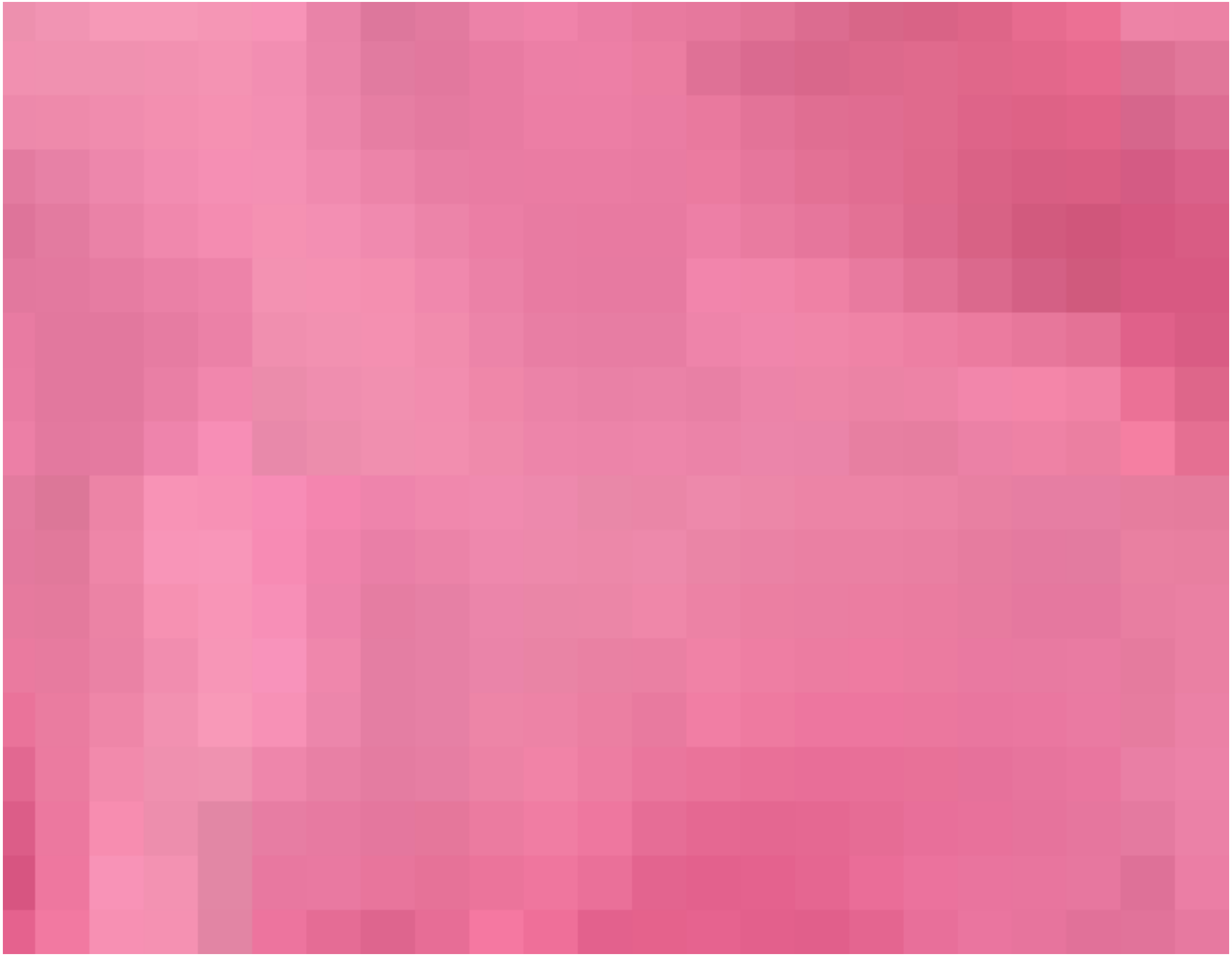



MUSIC IS A PROOF THAT
THERE IS NO REAL DIVIDE
BETWEEN ANALOG
AND DIGITAL TECHNOLOGY

DIGITAL IMAGES: MONITORS

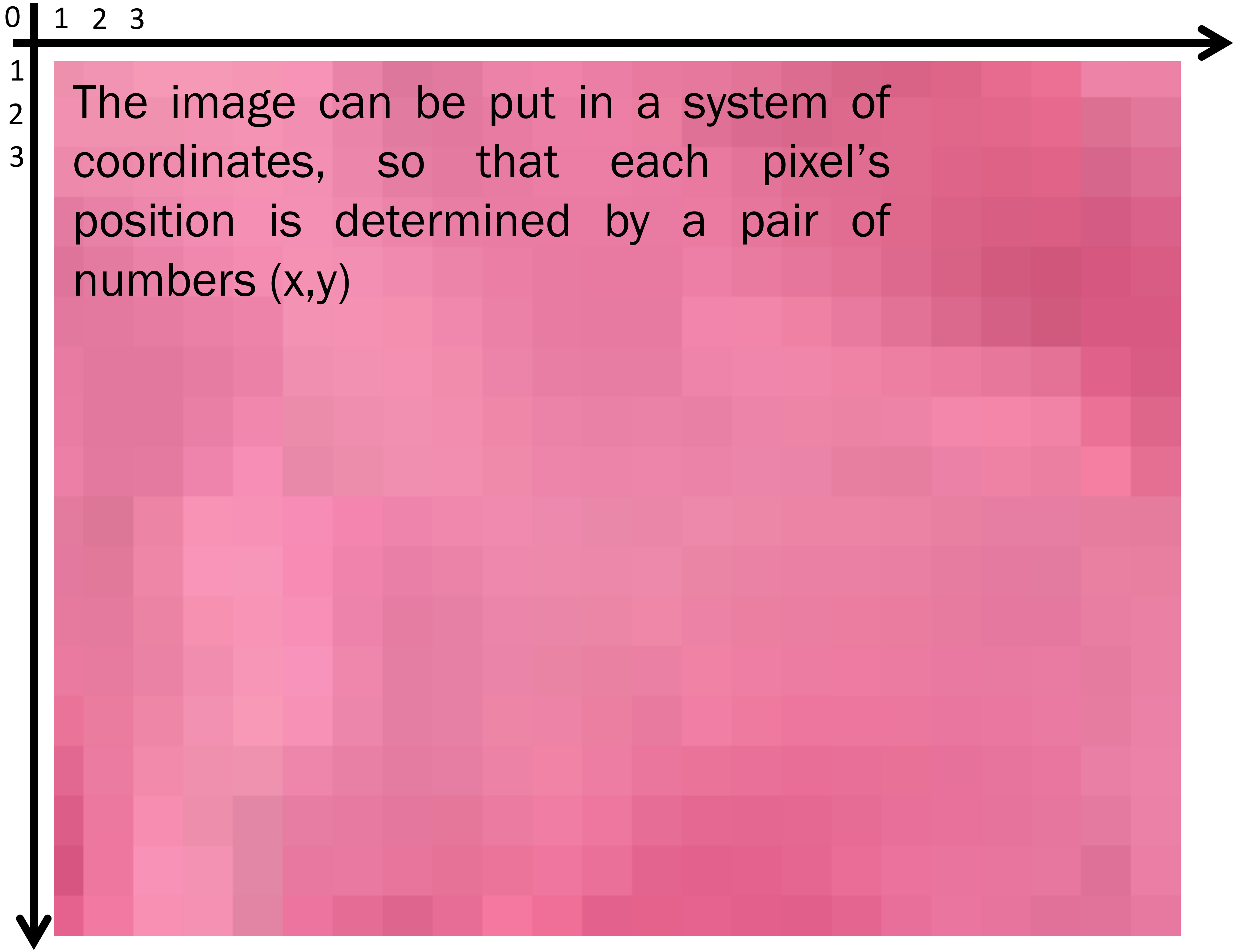
Digital <insert noun here>

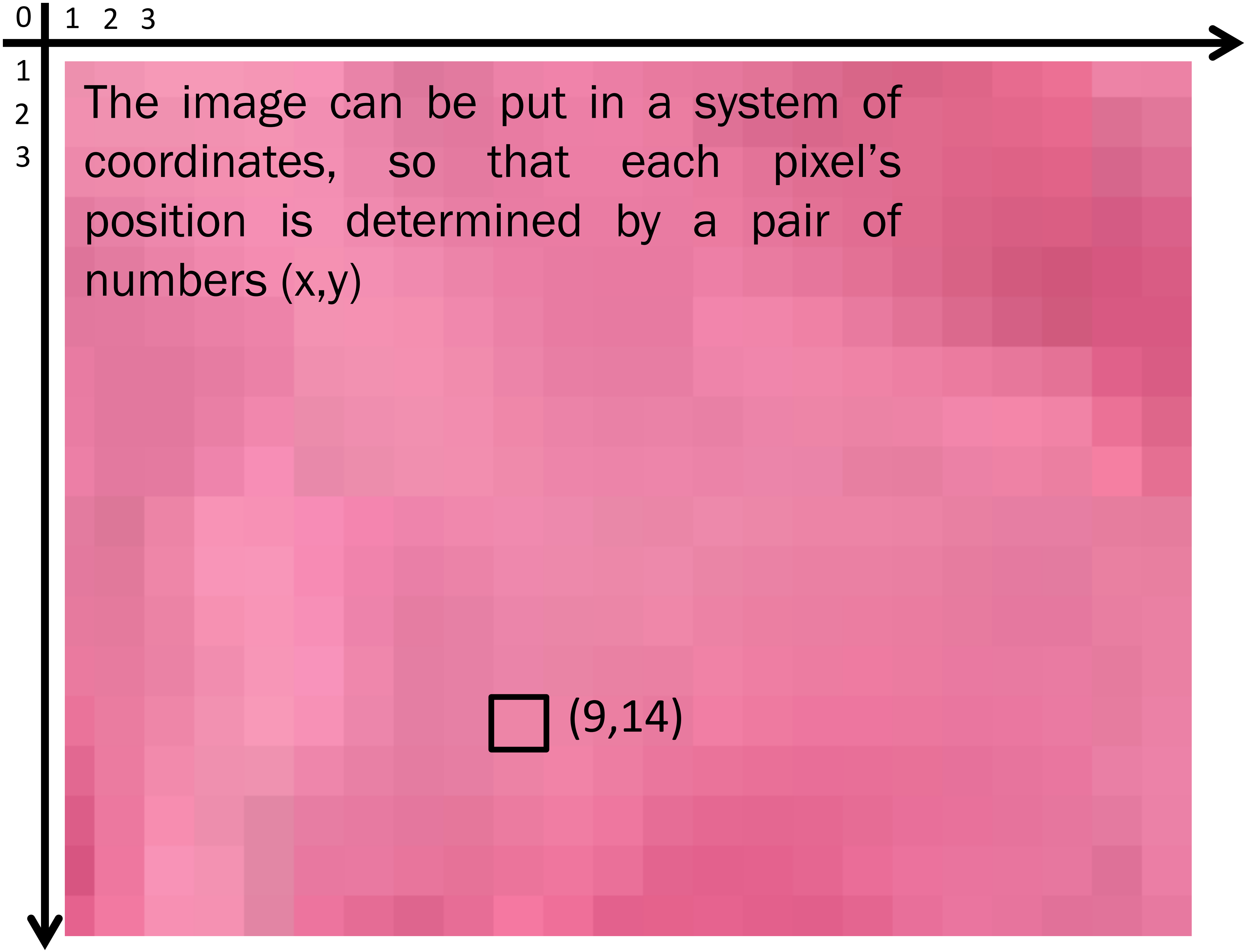
- For an entity to be digital, that entity has to be <u>described</u> in terms of numbers
- A digital image, for instance, is an image described in terms of numbers

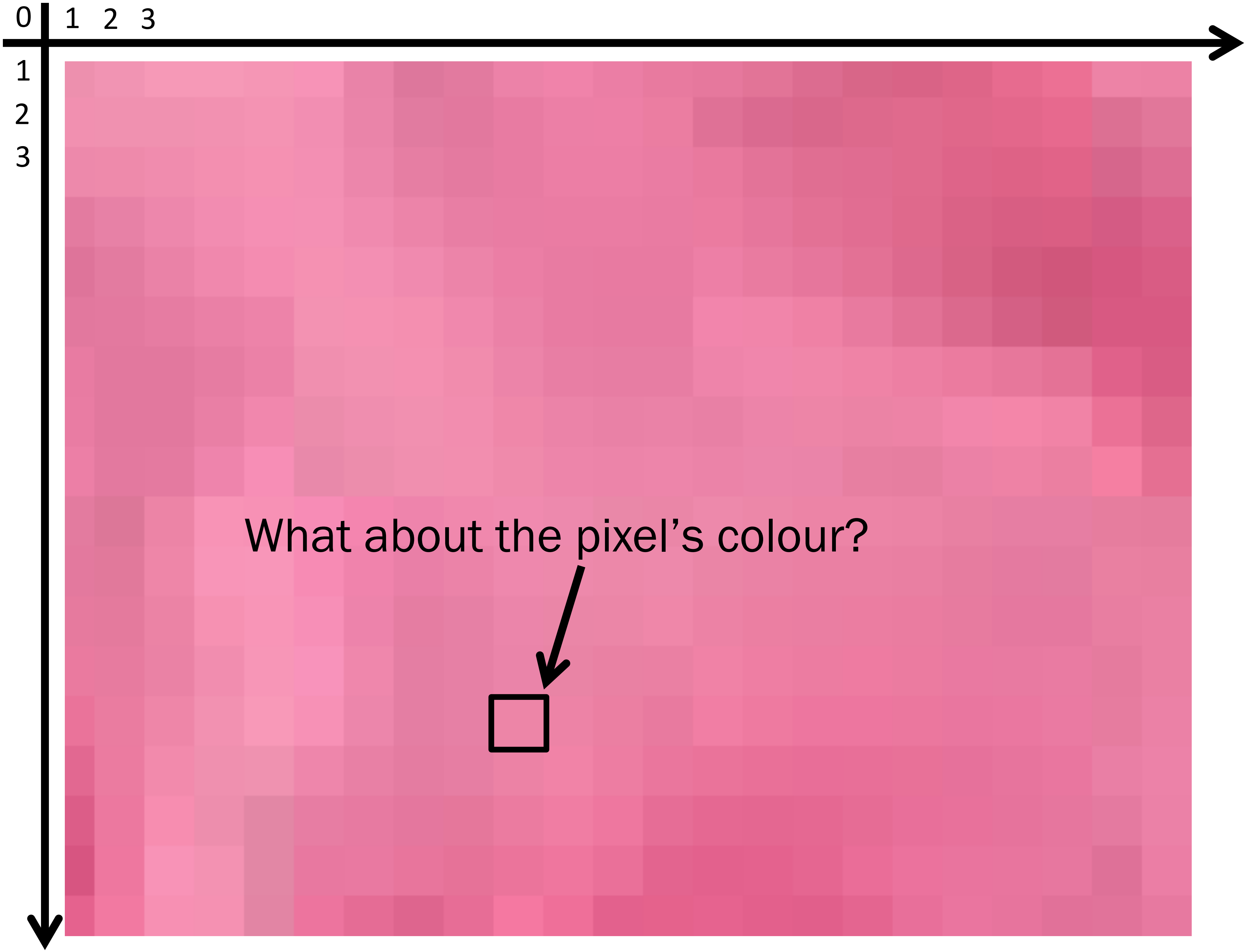


Where are the numbers?

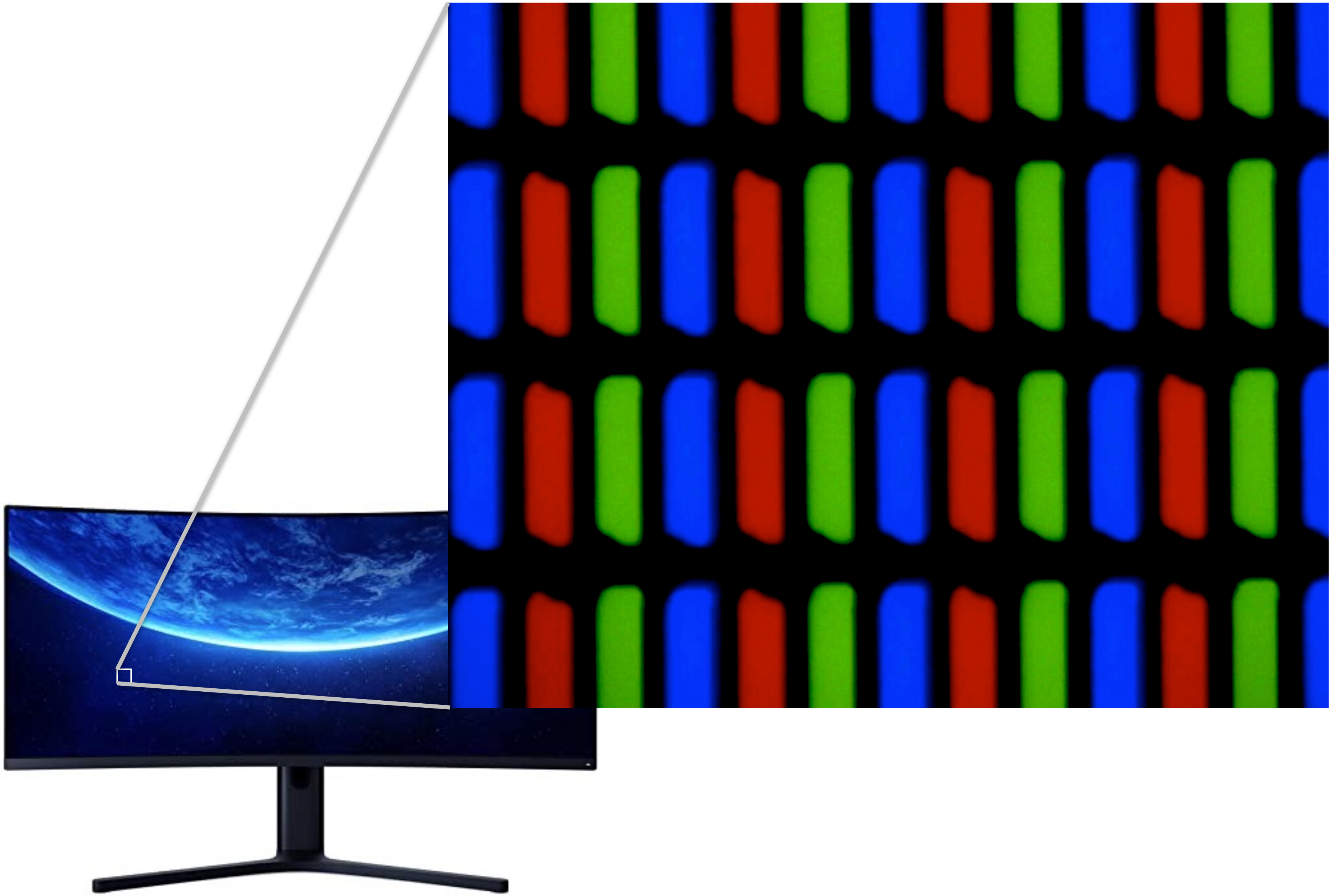
The image can be put in a system of coordinates, so that each pixel's position is determined by a pair of numbers (x,y)




0
1
2
3
1
2
3
The image can be put in a system of coordinates, so that each pixel's position is determined by a pair of numbers (x,y)
(9,14)


0
1
2
3
1
2
3
What about the pixel's colour?

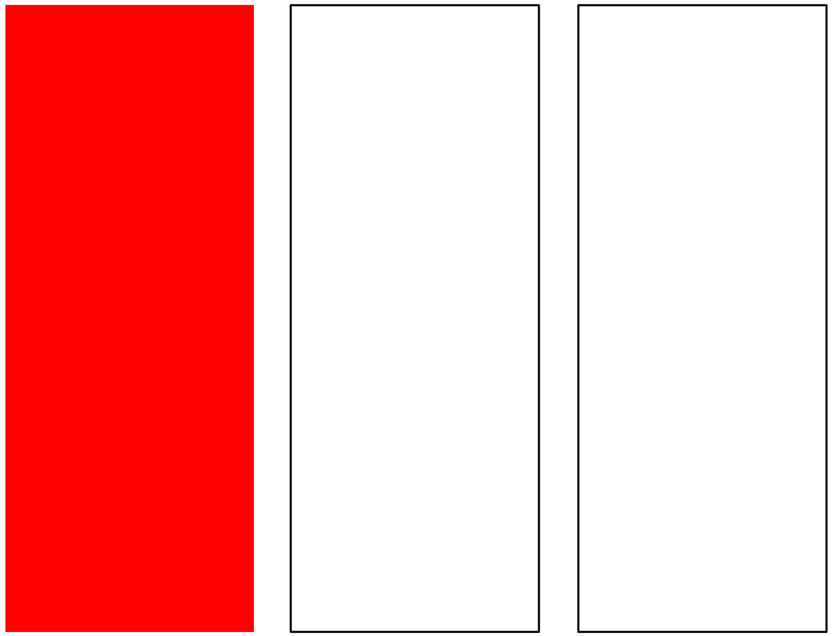
Monitor, magnified 300x



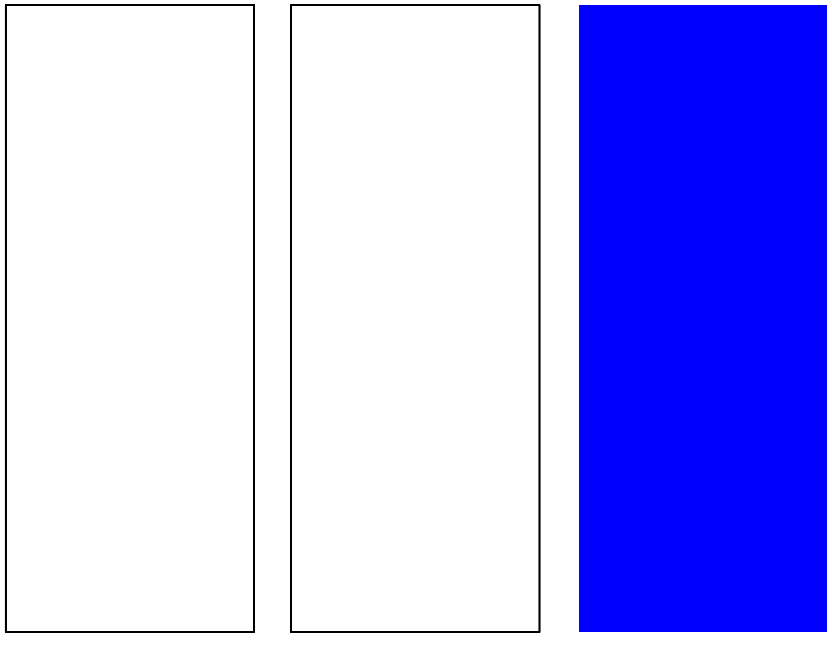
The origin of colours

- Physicists discovered that all coloured light can be split into three fundamental components: red light, green light, and blue light
- Monitors exploit this principle
- Monitors are rectangular matrices of triplets of LEDs (light emitting diodes): one red, one green, one blue
- By calibrating the luminosity of each LED in a triplet, we can make it emit any colour of the spectrum

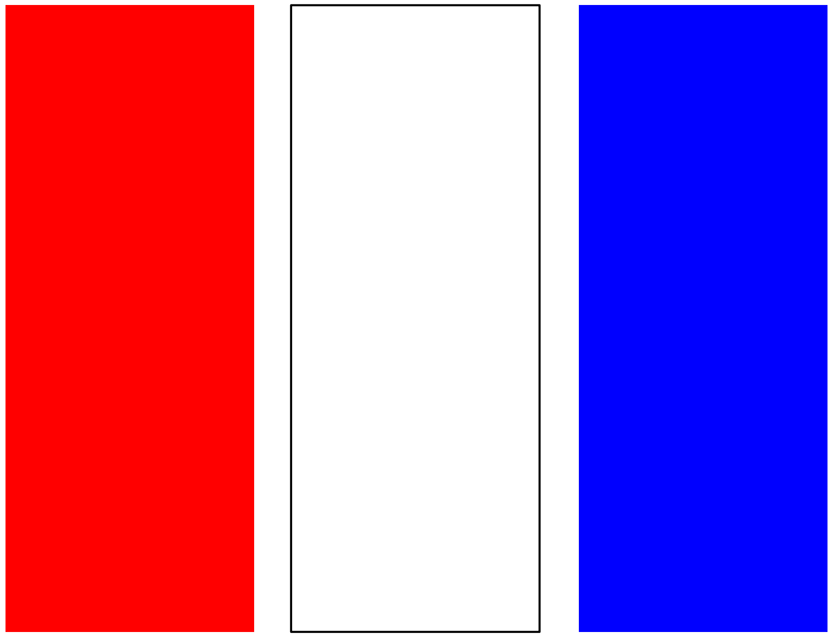
Pure red



Pure blue



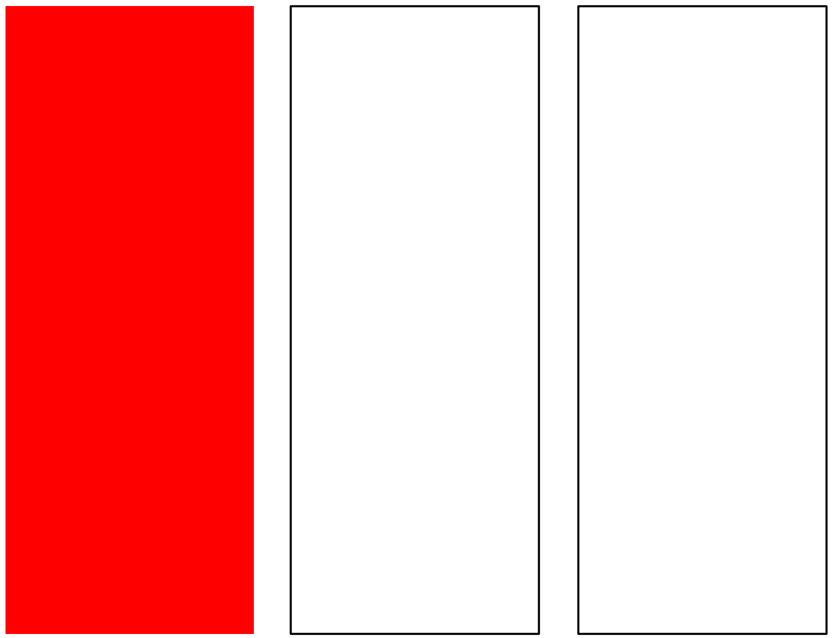
Violet



Colours and numbers

- Numbers can be used to indicate the strength of each component in the triplet
- The higher the number, the more component participates in the blend that produces the final result
- The most widespread standard specifies that these numbers go from 0 (no component) to 255 (full component)

Pure red

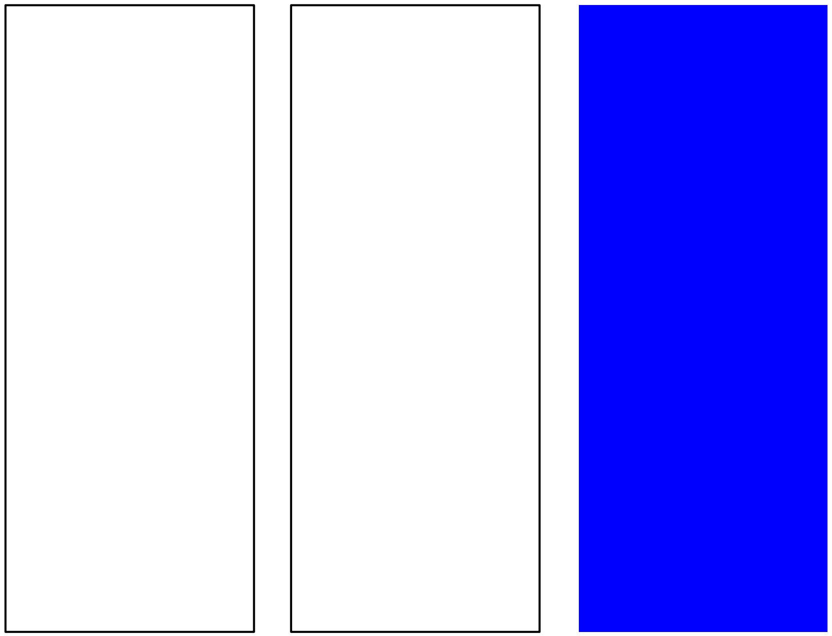


The number 255 will be interpreted by the graphic card as a command to give that particular LED full power.

(255,0,0)

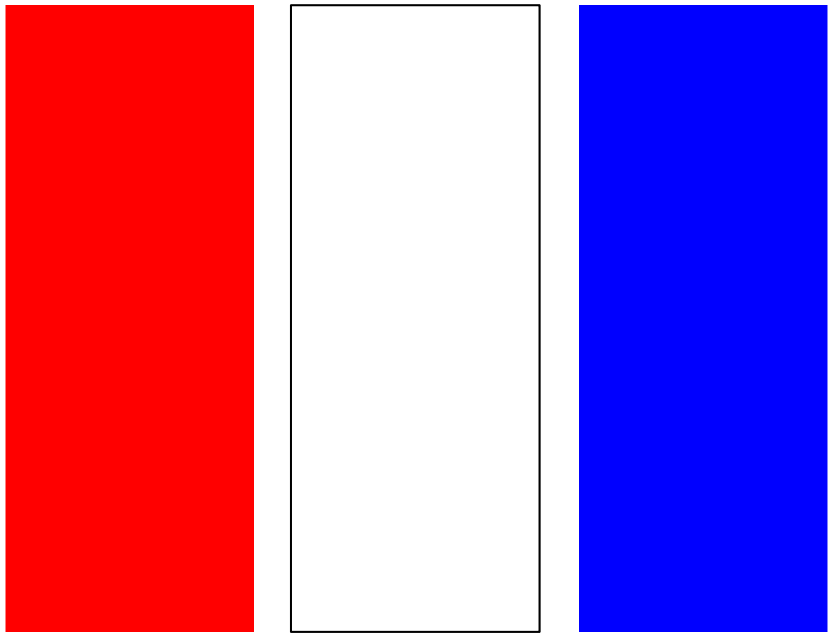
The numbers 0, instead, tell the graphic card that the other two LEDs must stay off: no power at all.

Pure blue



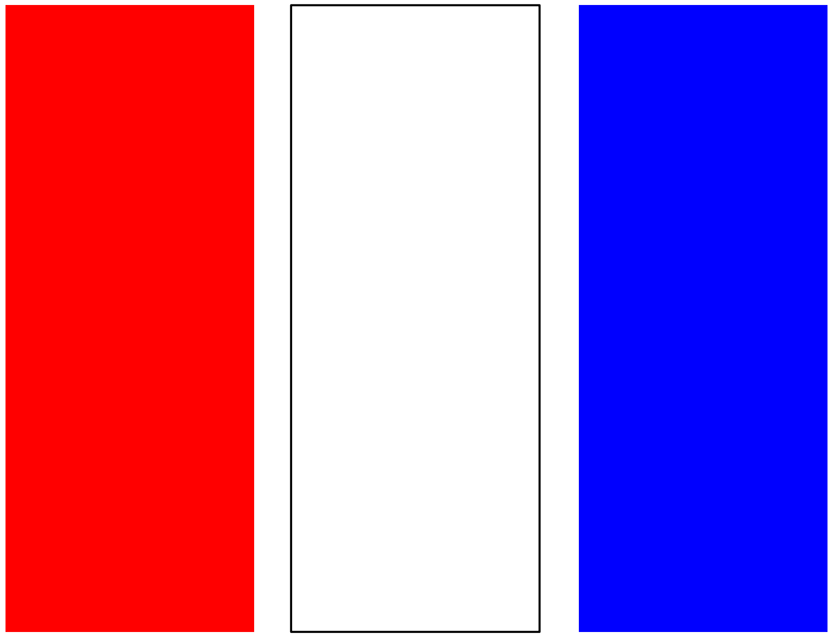
(0,0,255)

Violet



(255,0,255)

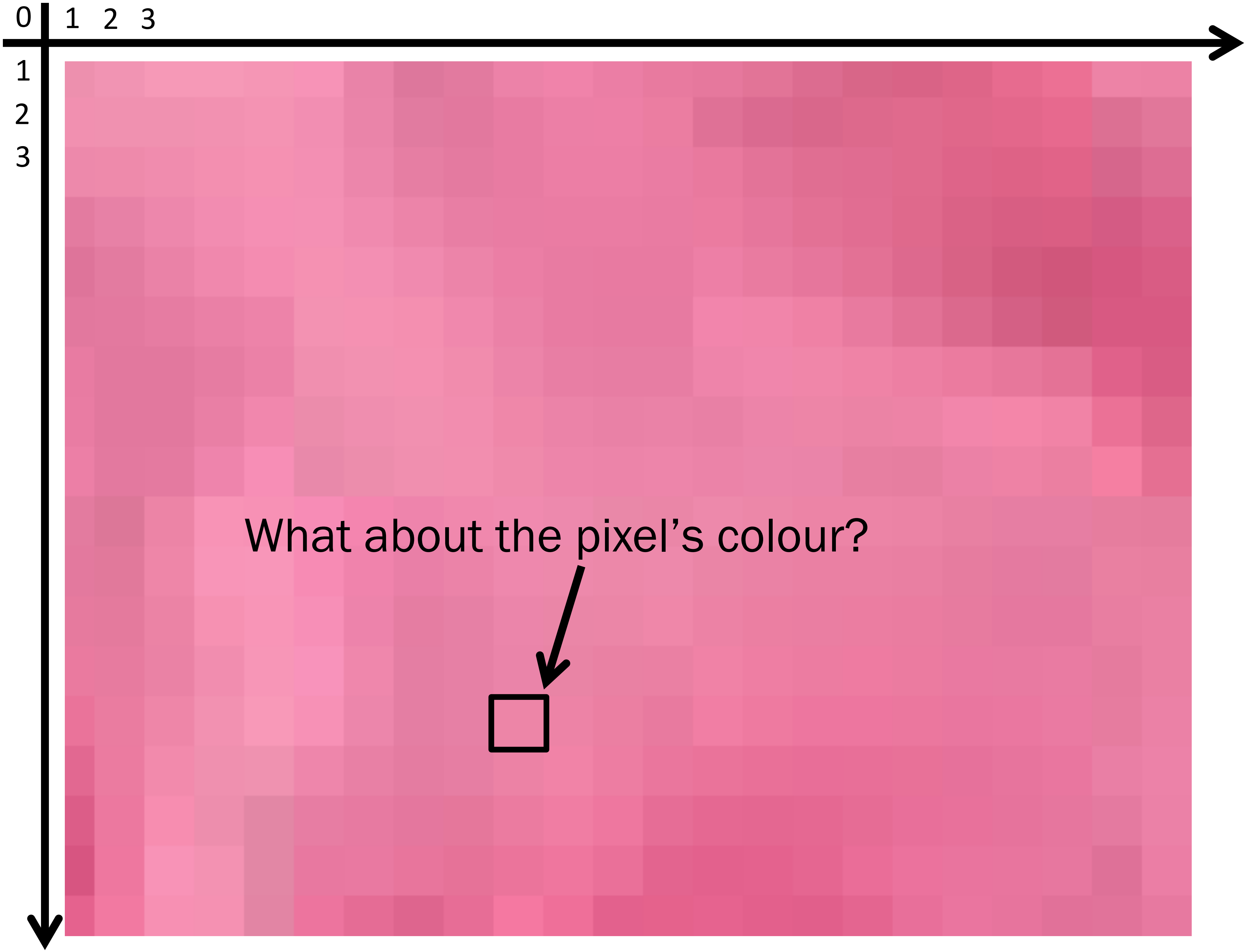
Violet

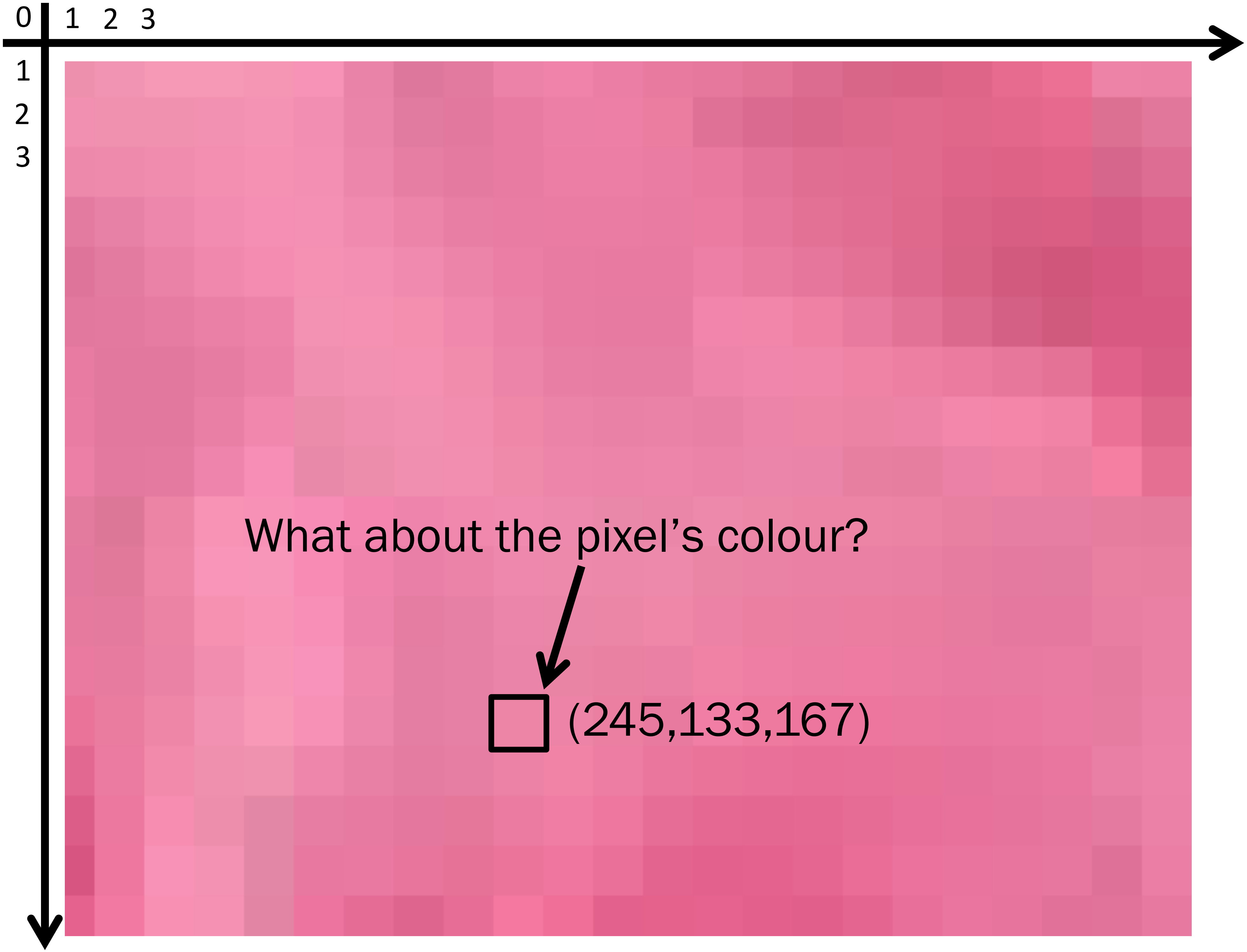


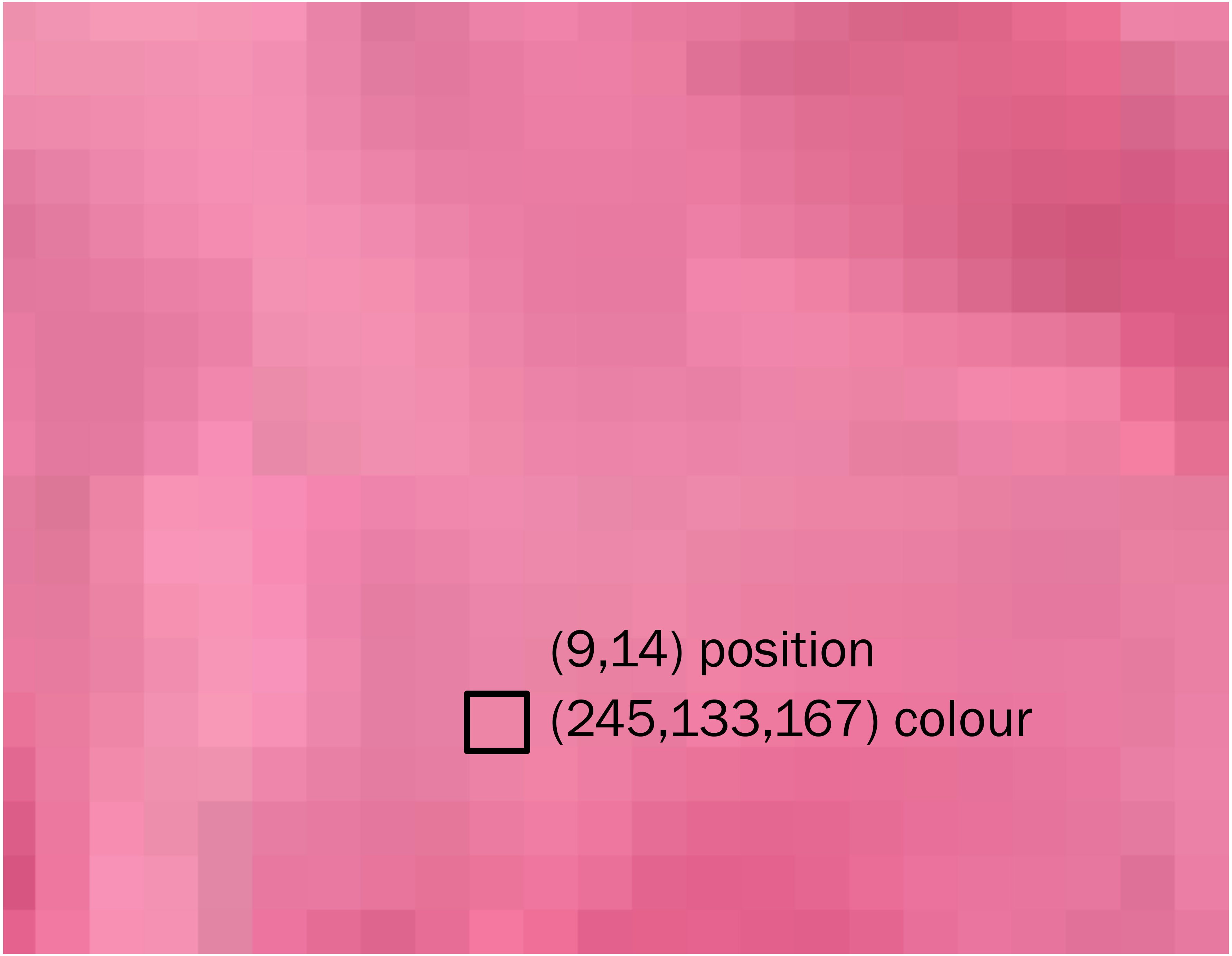
(255,0,255)

often written as 0xFF00FF

The “0x” indicates that a hexadecimal system is used, and the convention is that each pair of hex digit represent a number of the triplet (min: 0 - max: 255)


0
1
2
3
1
2
3
What about the pixel's colour?


0
1
2
3
1
2
3
What about the pixel's colour?
(245,133,167)


(9,14) position
(245,133,167) colour


x y r g b
(9,14,245,133,167)

(9,14,245,133,167)

Numbers describing a pixel

- Even if the pixel isn’t there, the 5 numbers that describe its position within the image and its colour are enough to recreate the pixel whenever needed
- Applying the same technique to all the pixels of a digital image, we can describe a whole image with quintuplets of numbers, and we can use those quintuplets to rebuild the image whenever needed

(9,14,245,133,167)

3,217)	(8,87,245,133,167)	(9,03,245,133,167)	(9,18,245,13
3,152)	(8,88,245,200,211)	(9,04,245,133,167)	(9,19,245,13
3,007)	(8,89,245,150,167)	(9,05,245,133,180)	(9,20,245,13
3,098)	(8,90,245,133,167)	(9,06,245,133,167)	(9,21,245,17
3,111)	(8,91,245,133,167)	(9,07,245,110,100)	(9,22,215,13
3,167)	(8,92,245,133,167)	(9,08,245,133,200)	(9,23,250,13
3,168)	(8,93,245,099,001)	(9,09,245,133,201)	(9,24,245,13
3,122)	(8,94,245,133,167)	(9,10,251,133,167)	(9,25,245,13
3,250)	(8,95,245,133,167)	(9,11,240,133,167)	(9,26,245,13
3,077)	(8,96,245,133,167)	(9,12,245,133,088)	(9,27,245,13
3,199)	(8,97,245,133,167)	(9,13,245,099,071)	(9,28,245,13
3,023)	(8,98,245,133,167)	(9,14,245,133,167)	(9,29,245,13
3,071)	(8,99,245,133,167)	(9,15,245,133,167)	(9,30,245,13
3,185)	(9,01,245,133,167)	(9,16,245,099,121)	(9,31,245,13
3,130)	(9,02,245,133,167)	(9,17,245,133,167)	(9,32,245,13

Digital images

- A digital image is an image <u>described</u> in terms of numbers
- Whoever has the numbers is able to rebuild that image
- This is what makes digital images different from physical objects: instead of moving around objects, we are moving around numbers

Working with numbers

- The special characteristics of digital images derive from the fact that we can work with numbers in many different ways

The need for hardware

- First of all, numbers alone cannot create anything
- We need apt machinery that is commanded by these numbers and creates physical objects accordingly
- In the case of digital images, we need monitors and screens (matrices of triplets of LEDs) that convert the RBG numbers into actual coloured light

The need for standards

- Moreover, for society to be able to work with numbers and use them to build images on different devices around the world, everybody must agree on the correspondence between numbers and pixels' position and colour
- A standard is a universal agreement between hardware builders and content producers on how the numbers will be used to describe images
- Famous standards are: RGB, JPG, BMP, TIF

USASCII code chart

				$b_7 b_6 b_5$ →	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
Bits b_4	b_3	b_2	b_1	Column → / Row ↓	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	|
1	1	0	1	13	CR	GS	–	=	M	]	m	}
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1	1	1	1	15	SI	US	/	?	O	—	o	DEL

The physical universe and more

- Isn’t everything that exists in the universe made of atoms anyway?
- No: an agreement between people is not made of atoms
- The hardware that allows for the creation of digital images is indeed comprised of physical objects
- However, the standards that make the exchange of digital images among people and devices are not physical

Being digital

- It is possible to describe an entity in terms of numbers
- These numbers can be exchanged among people, possibly with the support of computers and telecommunication networks
- The format of these numbers must be established by universally shared standards
- Special devices are needed to create physical objects from their numerical description