

Steam, factories and industrial society

ENG 151 · Lecture 6
Science and Technology
Mehmet Göktürk

Factory life



More goods—but whose better life?

A factory brings machinery, workers, fuel and transport together.

Greater output can make goods more available. It can also bring long hours, dependence on wages and dangerous work.

Who controls the working day, and who receives the gains?

Technology before industrialization

Practical technologies grew across ancient, Islamic, medieval and Renaissance societies.

Water and wind power, materials, mechanisms and skilled workshops long preceded the steam factory.

The industrial transition combined and enlarged existing capabilities while introducing new ones.

Mechanisms before the factory



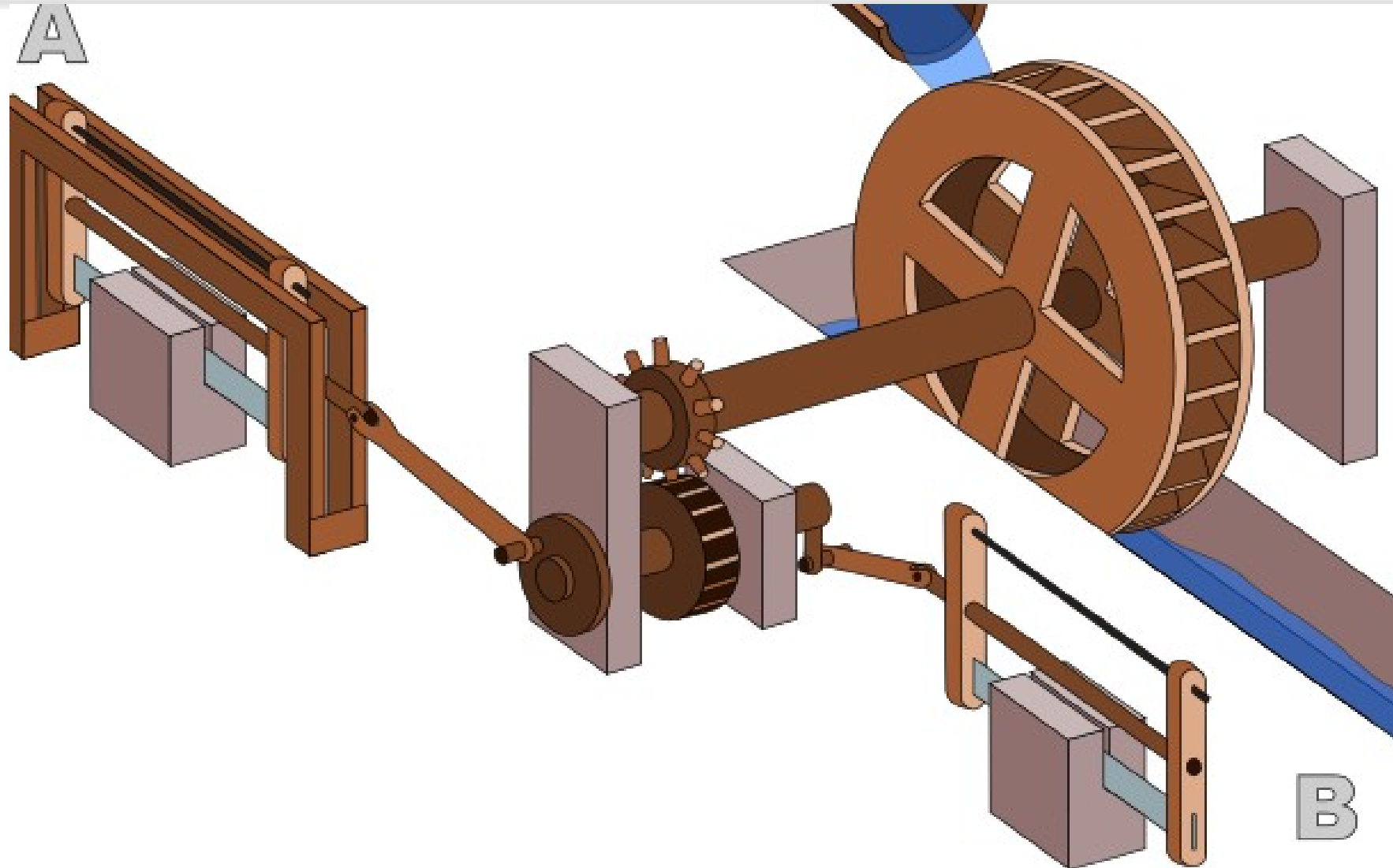
Spinning before mechanized mills



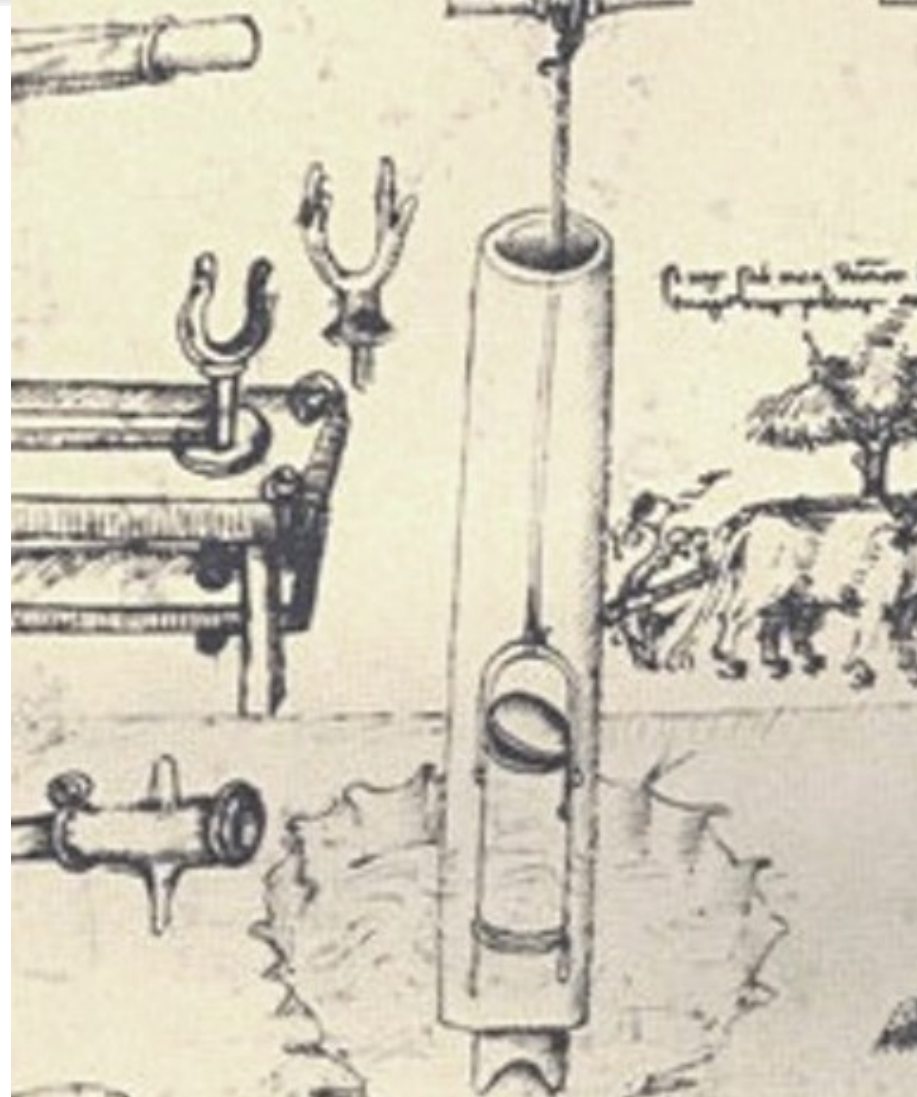
Structural craft before industry



Water power and mechanical motion



Representing a mechanism



A modern winch comparison



Georg Andreas Böckler

German architect, engineer and author of machine books.

His *Theatrum Machinarum Novum* (1661) illustrated mills, pumps and other mechanisms.

Drawings and explanations helped technical knowledge travel beyond one workshop.

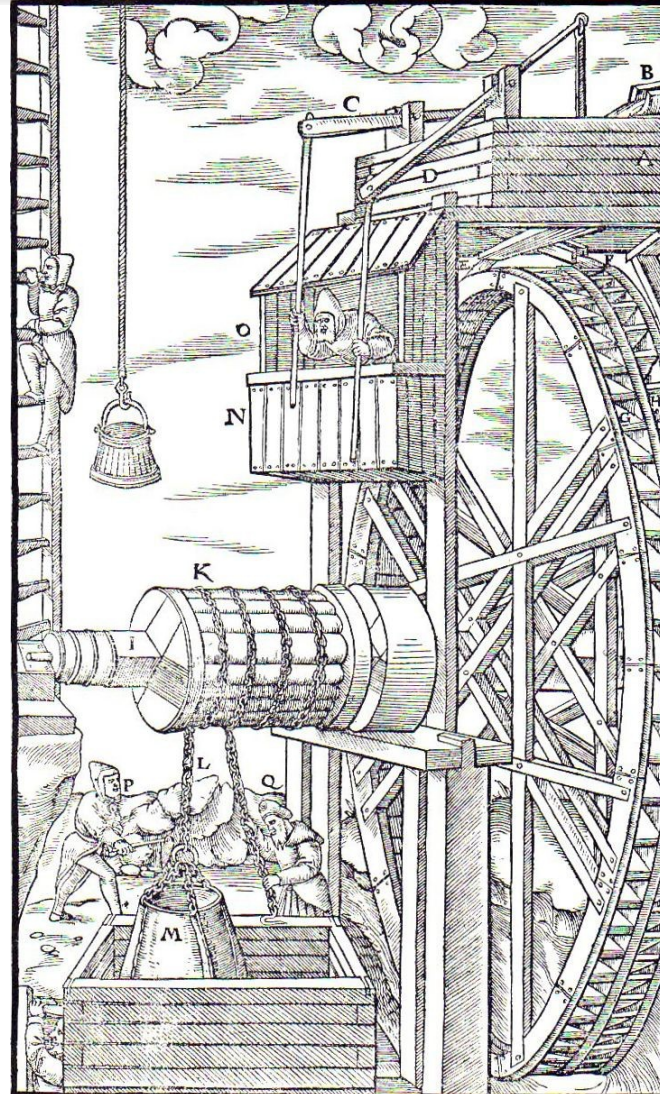


Georg Andreas Böckler

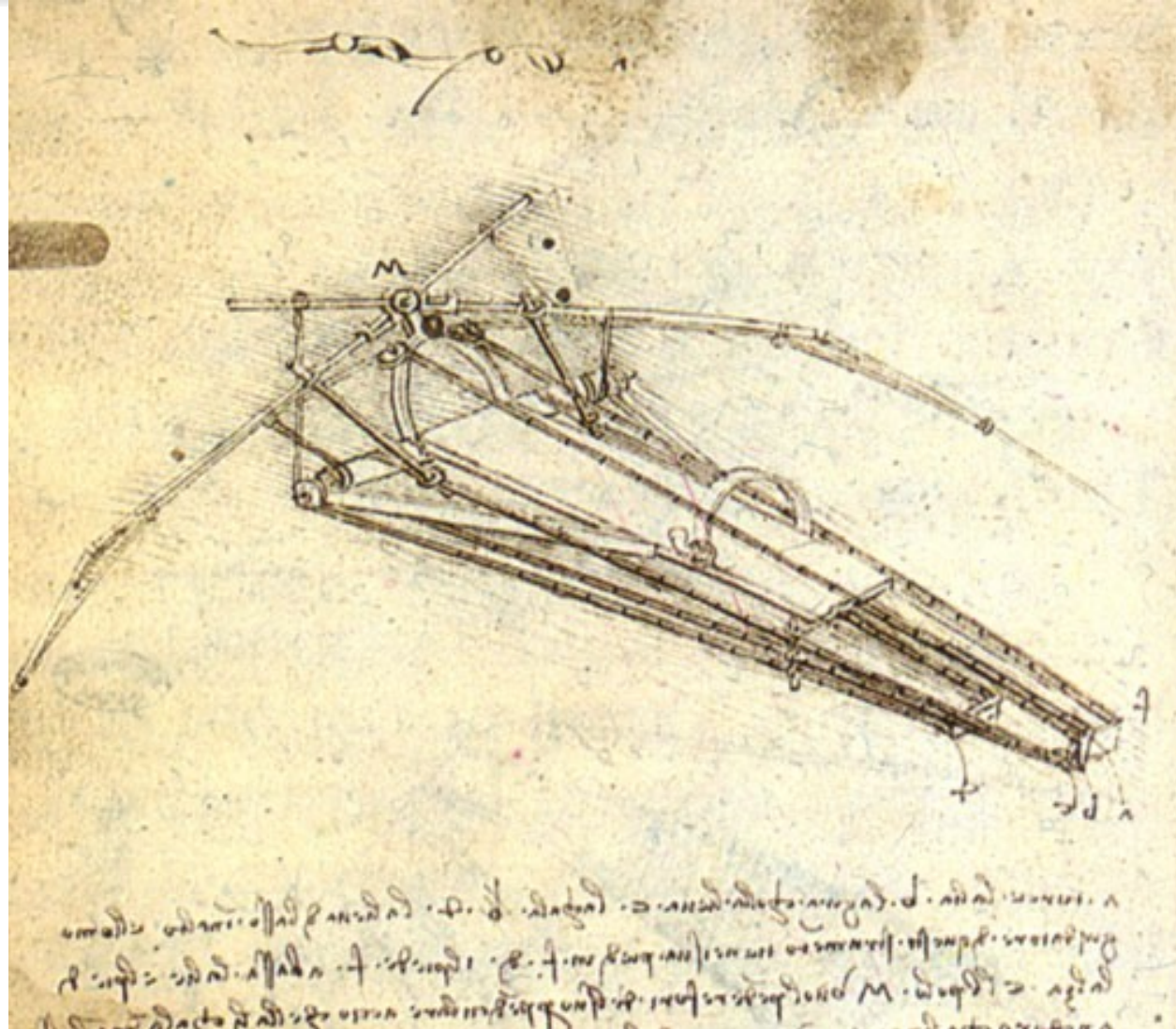
1661: a water-raising mechanism



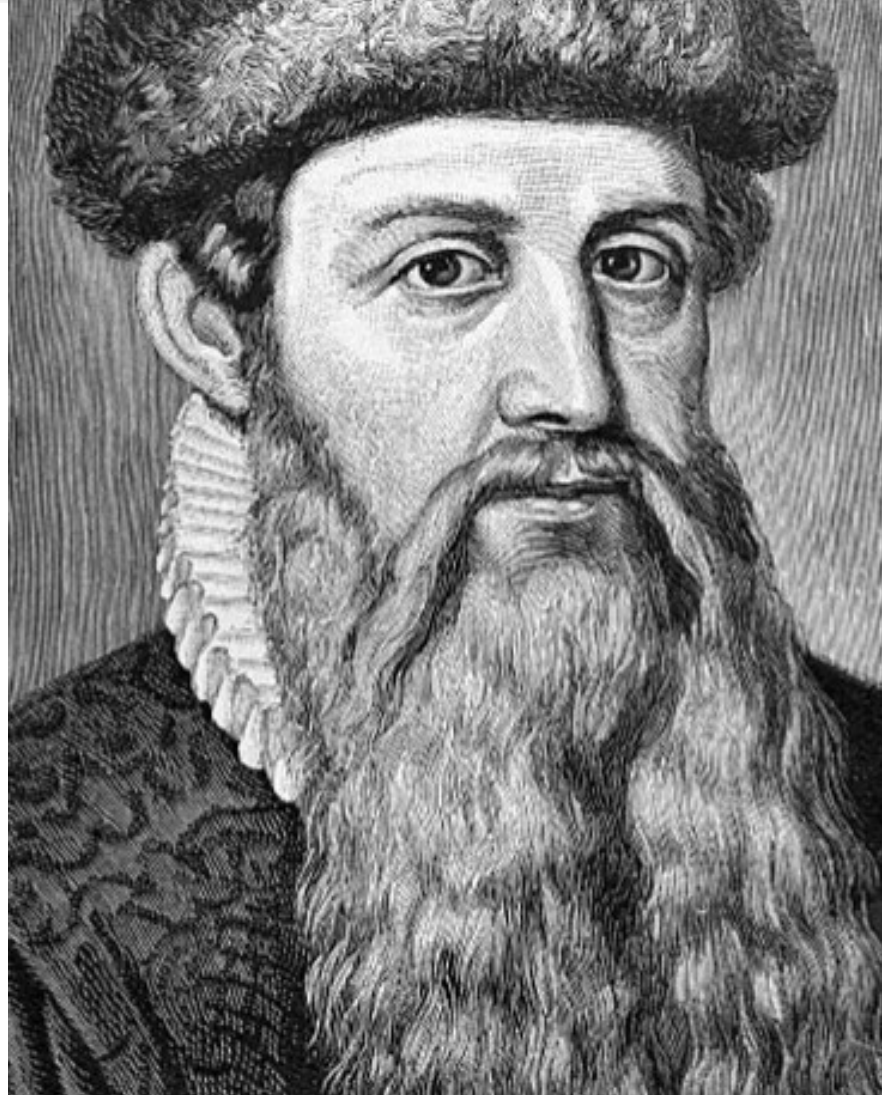
1556: power at the mine



Design knowledge in a notebook



Johannes Gutenberg



Printing as a production system



Paper, printing and technical knowledge

Paper, reusable type, presses and skilled labor made the circulation of drawings and instructions easier.

Technical books allowed designs to travel beyond a single workshop; readers could compare and adapt them.

Printing also supported news, religious debate and wider access to learning.

Navigation, trade and industrial production

Ships, sails, steering and navigational instruments supported longer trading routes.

Maps and reports circulated experience, while longitude remained a difficult practical problem.

Trade and colonial expansion connected resources and markets; industrialization grew within these unequal networks.

Approximately 1750–1850

The first industrial transformation gathered force in Britain and spread unevenly to other regions.

Textiles, coal, iron, water power and steam developed together; their adoption took decades.

The conventional 1760–1820/1840 frame describes a transition, not a single event with universal dates.

Why Britain? Connected conditions

Coal, craft skills, finance and markets supported investment.

Agriculture and transport helped supply food, workers and customers.

Trade and empire connected resources and markets.



Great Britain in northwestern Europe; modern geographic locator

A factory in a global economy

British cotton mills depended on growers, merchants and consumers across continents.

Atlantic slavery tied industrial prosperity to forced labor.

Colonial power also reshaped India's established textile industries.

Administrator's Sale, by Order of the Ordinary.

A PRIME AND ORDERLY GANG OF
68 Long Cotton Field Negroes,
Belonging to the Estate of the late Christopher J. Whaley.

WILBUR & SON
Will sell at PUBLIC AUCTION in Charleston,
At the Mart in Chalmers Street,
On Thursday, Feb. 2d, 1860,
COMMENCING AT ELEVEN O'CLOCK,
THE FOLLOWING GANG OF LONG COTTON NEGROES,
Who are said to be remarkably prime, and will be sold as per Catalogue.

NAMES.	AGES.	NAMES.	AGES.
Jimmy, driver,	30	Carter,	36
Flora, seamstress,	24	Taffy,	13
James,	5	Rachel, (\$ 720,)	8
Charles, (\$ 125,)	1	Jannett,	18
August,	52	Phebe, (\$ 860,)	40
Mathias, (\$ 1,220,)	18	Judy,	8
Sandy,	16	Major,	40
John,	13	Lavinia,	30
Tom,	70	Billy, (\$ 550,)	10
Jack,	88	Tamor,	6
James,	6	Jimmy,	52
Leah,	5	Kate,	46
Flora,	2	Susan,	25
Andrew,	42	Thomas, (\$ 380,)	6
Binah,	40	Kate,	1
Phillis,	20	Edward, coachman,	49
Mary,	15	Amey,	22
Lynus,	10	Teneh, washer,	30
Abram, (\$ 275,)	2	Josephine,	9
Binah,	2 mos.	Sam,	11
Andrew,	29	Isaac,	5
Hagar,	25	William,	1
Dayman,	4	Amey,	27
Cuffy,	21	Louisa, (\$ 750,)	8
Hagar, (\$ 1,320,)	20	Joe,	3
Margaret,	85	Sam,	ruptured, 65
Lucy,	cripple, 60	Andrew,	dropsical, 61
John,	22	Daniel,	70
Ellick, (\$ 1,160,)	18	Lynus,	30
Libby,	19	Lucy,	nurse, 58

TERMS.
One-third Cash; balance in one and two years, secured by bond, and mortgage of the negroes, with approved personal security. Purchasers to pay us for papers.

29

Charleston auction advertisement for enslaved cotton workers, 1860

From fiber to cloth

Spinning turns prepared fibers into yarn; weaving interlaces yarn into fabric.

Speeding up one stage creates pressure to improve the next.

Prepare fibers

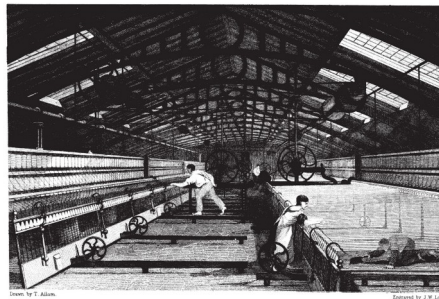
Clean and align



→

Spin yarn

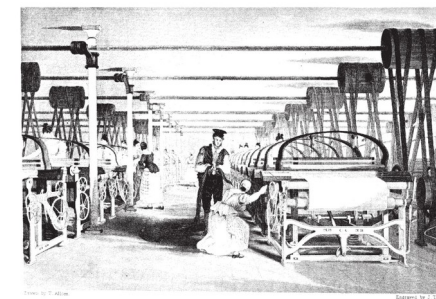
Draw out and twist



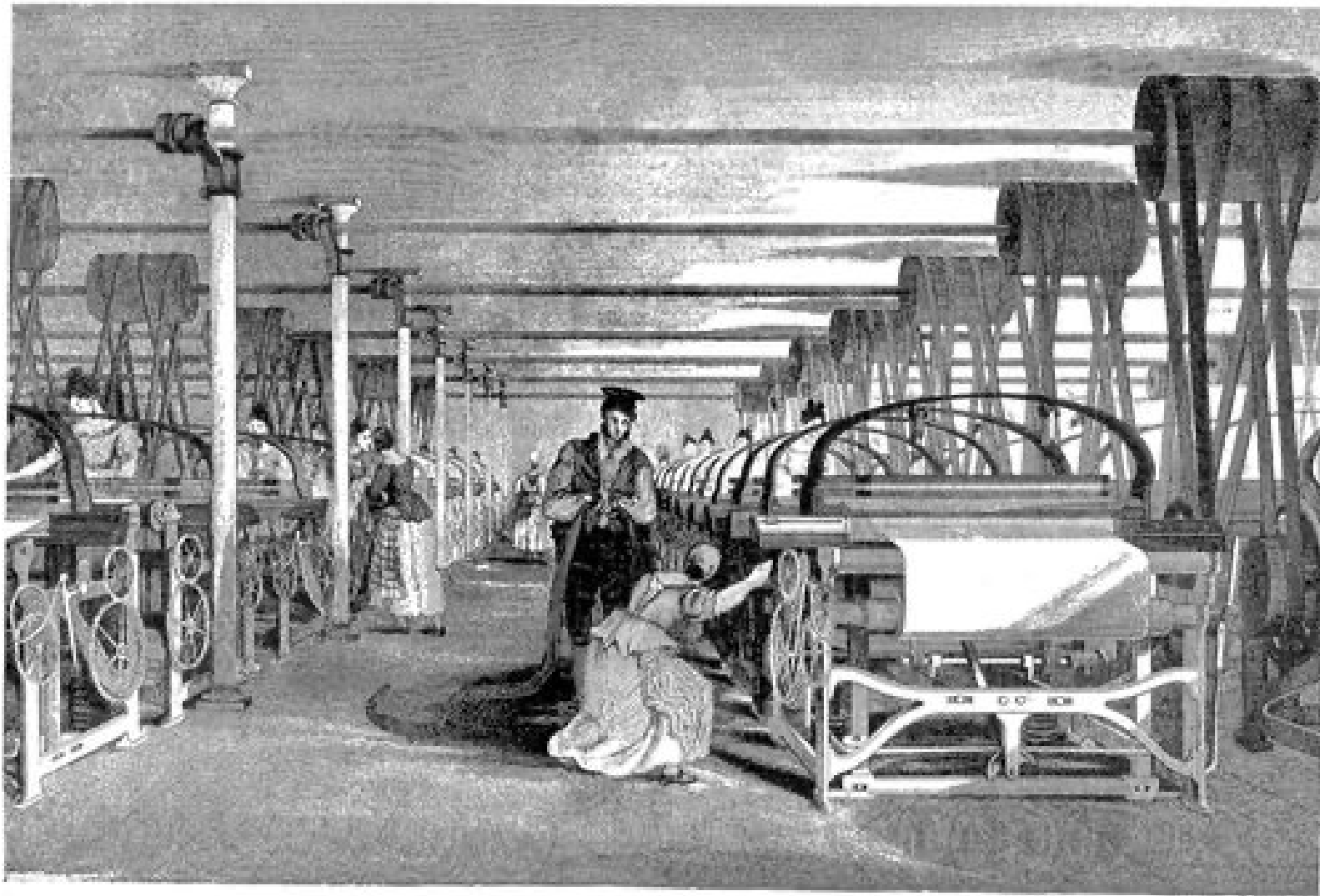
→

Weave cloth

Interlace threads



Textiles



1760s–1770s: increasing the supply of yarn

Hargreaves's spinning jenny let one operator work multiple spindles.

Arkwright's roller-spinning system supported powered production; Crompton's mule combined important features of earlier machines.

More yarn did not automatically mean more cloth: preparation, weaving and markets also had to expand.

Water power and the mill

A waterwheel could drive many machines through shafts and belts.

Reliable water flow and coordinated labor encouraged production at one site.

Water-powered factories preceded widespread steam power.



Waterwheel and mill at Cromford — Chris Allen, CC BY-SA 2.0

Sources of mechanical power

Muscles, wind and flowing water supplied useful motion before steam.

Iranian asbads turn a vertical shaft to drive millstones.

Steam changed where power could be used; fuel, water and maintenance still mattered.



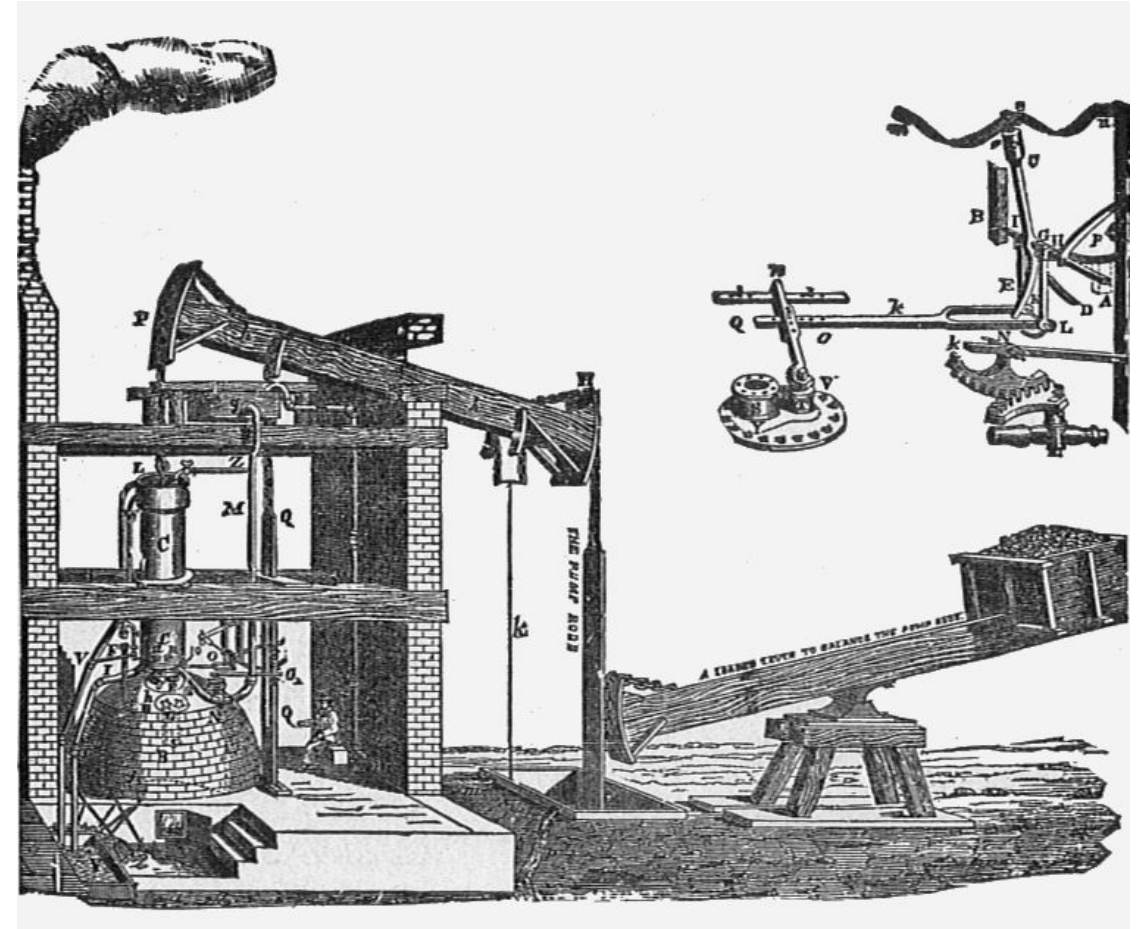
Traditional vertical-axis windmills, Nashtifan, Iran — Ali Vaseghnia, CC BY-SA 4.0

1712: pumping water from mines

Deep mines needed pumps to remove groundwater.

Condensing steam created low pressure beneath the piston.

Air pressure drove the piston down; the beam operated the pump.



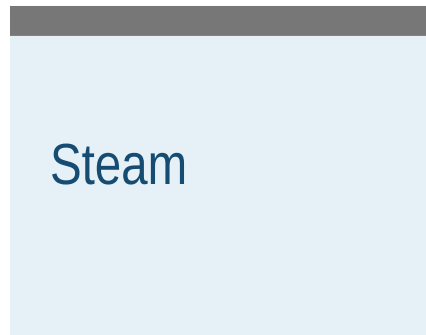
Newcomen atmospheric engine — illustration published in 1904

How an atmospheric engine works

Steam fills the cylinder. Cooling condenses it, lowering the pressure.

Air pressure above the piston supplies the downward working stroke.

1 · Fill with steam



Cool →

2 · Condense; air pushes down

Atmospheric pressure ↓



A beam transfers piston motion to a pump. Simplified cycle.

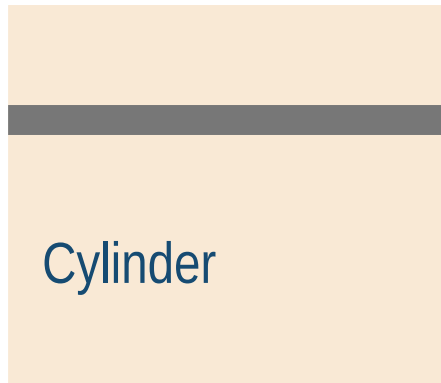
1765–1769: Watt separates hot and cold

Repeatedly heating and cooling the working cylinder wastes fuel.

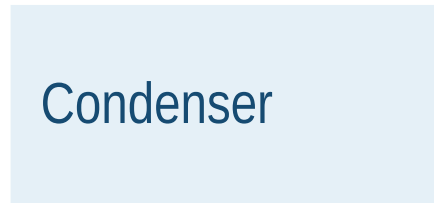
Watt developed a separate condenser in 1765 and patented the improvement in 1769.

Working cylinder stays hot

Separate chamber stays cold

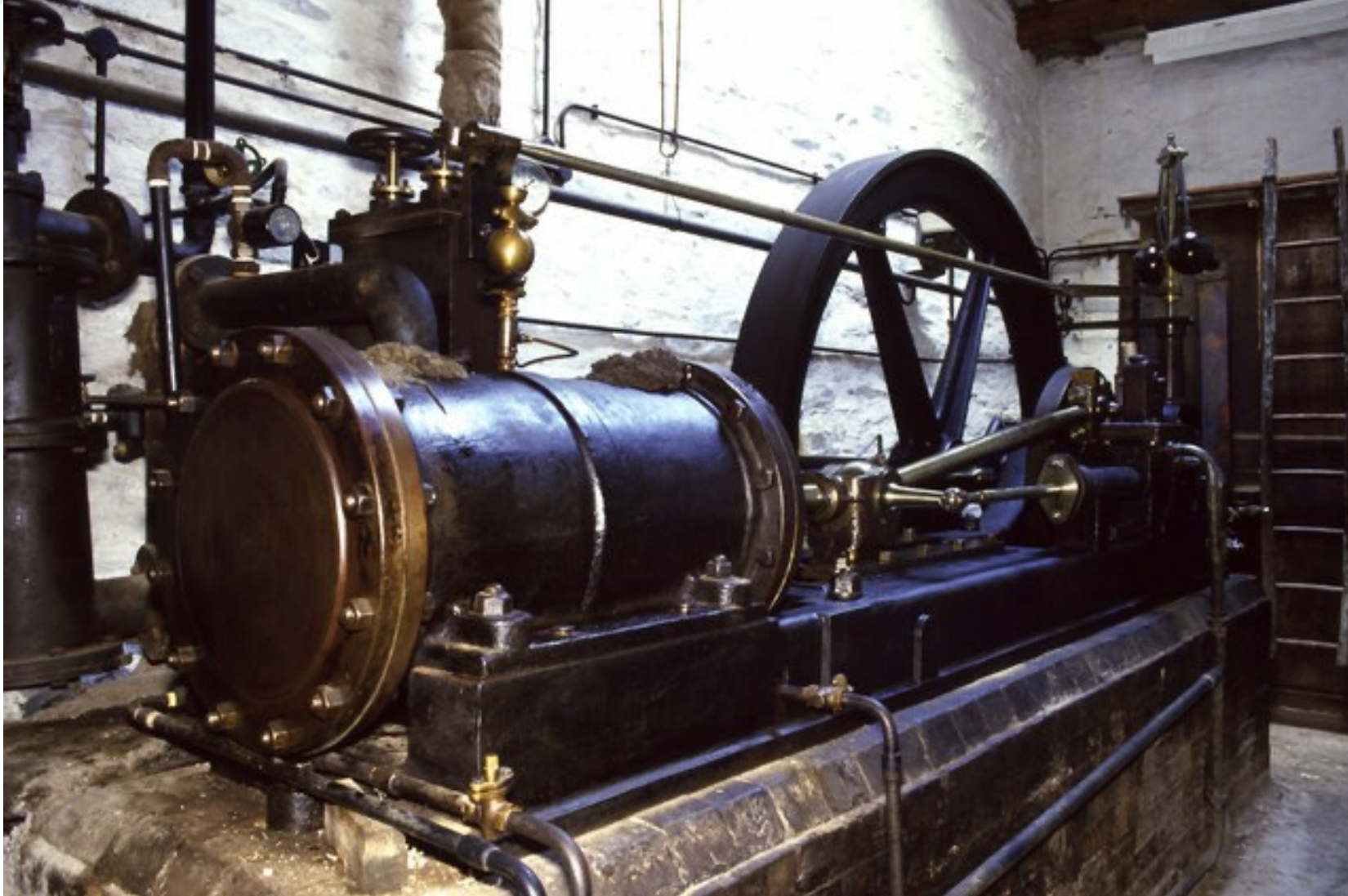


Steam flows →



Less repeated heating and cooling → less fuel wasted

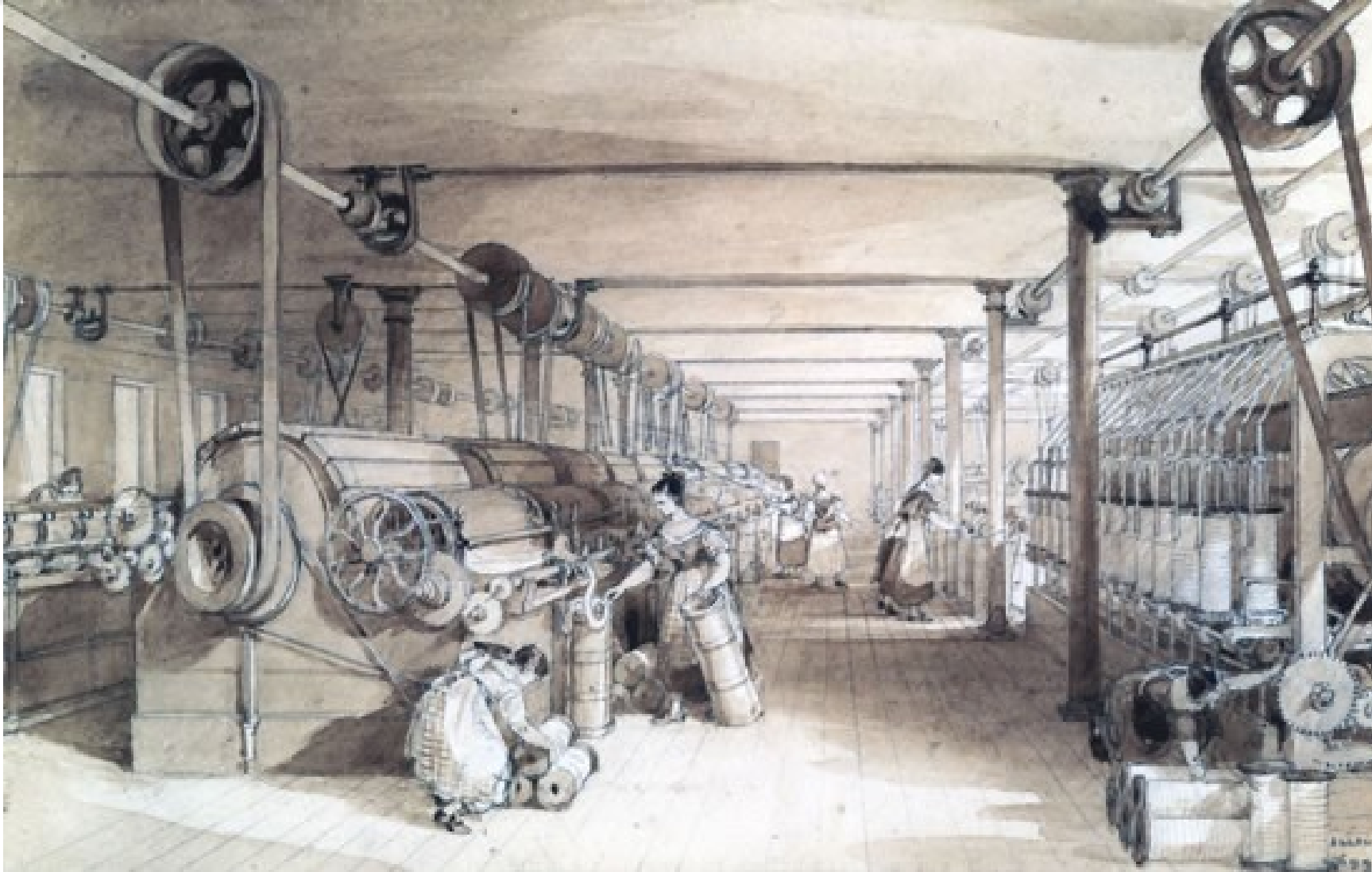
From a piston to rotating machinery



Keeping the engine under control



One engine, many machines



Precision makes machinery practical

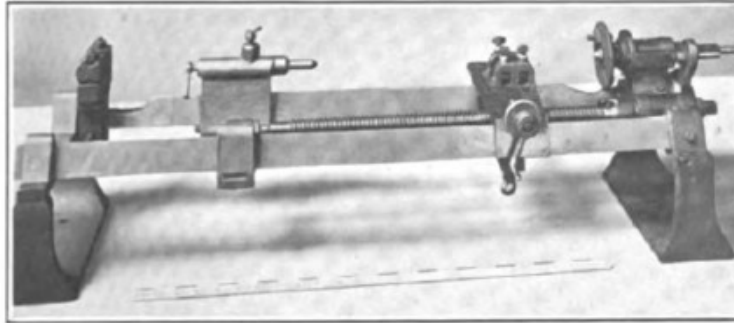


FIGURE 15. MAUDSLAY'S SCREW-CUTTING LATHE
ABOUT 1797

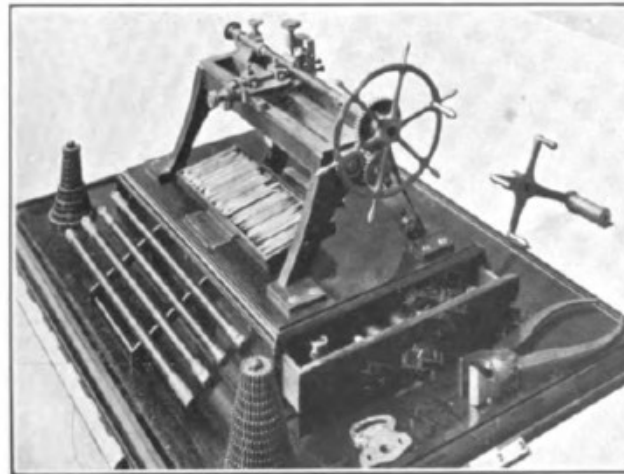


FIGURE 16. MAUDSLAY'S SCREW-CUTTING LATHE
ABOUT 1800

Iron: different materials, different uses

Cast iron can be shaped in molds but is brittle; it suits many housings, pots and structural applications.

Wrought or bar iron can be worked into nails, chains, hinges and other tough components.

Steel became increasingly important, but its later large-scale expansion belongs to the next industrial era.

1709 onward: changing iron production

Coke reduced dependence on wood charcoal as a furnace fuel.

Smelting and refining are different steps; making more iron also required better processes and equipment.

Smelt ore



Refine iron



Make components

Fuel supplies heat; ore becomes iron



Adjust properties for the intended use

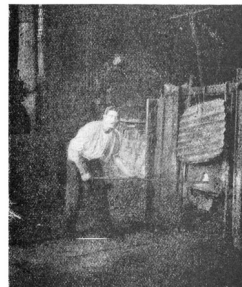
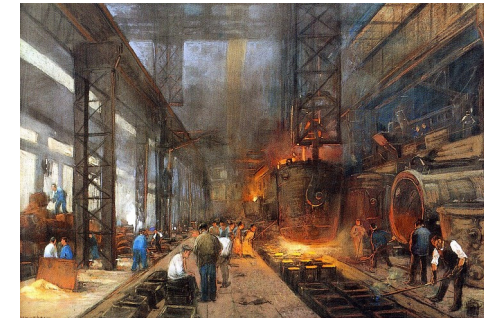


Fig. 8.—Puddler Rabbling a Charge.

Cast, forge or machine the material



Coal, iron and engines reinforce each other

Engines help pump mines. Mines supply fuel. Ironworks supply machinery.

Each improvement creates demand for skills, investment and further improvements.

Coal and mines

Fuel for heat and power



Iron and tools

Materials and accurate parts



Engines and pumps

Drain mines and drive machinery

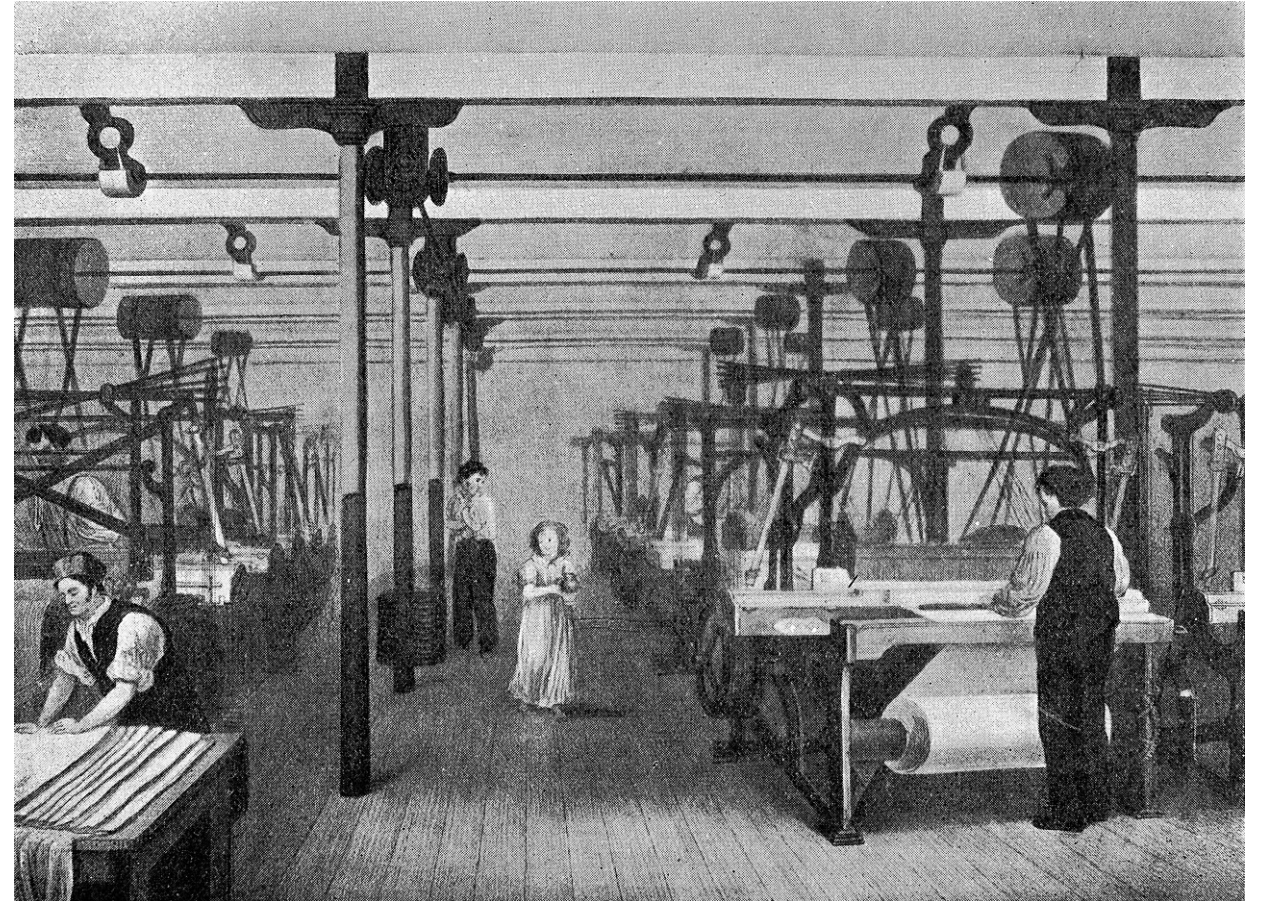
Engines support further mining → the cycle continues

The centralized workplace

Large, expensive machinery and shared power favored a central workplace.

Workers gathered around equipment that required coordinated operation.

Owners organized materials and hours; workers increasingly depended on wages.

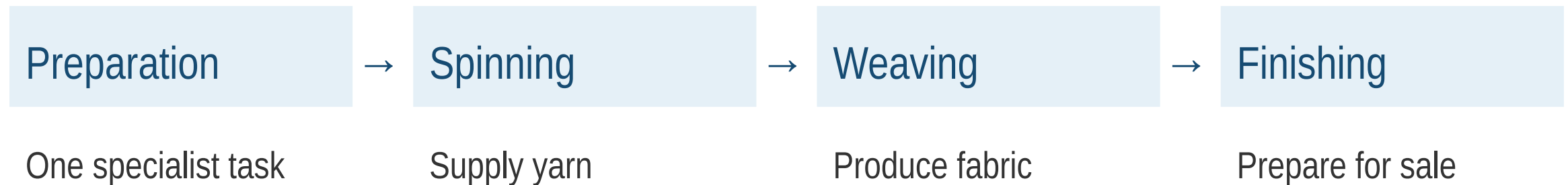


Cotton-factory interior — Wellcome Collection, CC BY 4.0

Division of labor

Each worker specializes in one part of production instead of making the entire product.

Some tasks require shorter training; the process still depends on skilled maintenance and coordination.



A delay in one operation can limit the whole process.

Standardization and interchangeability

Matching parts need compatible diameter, pitch and thread form.

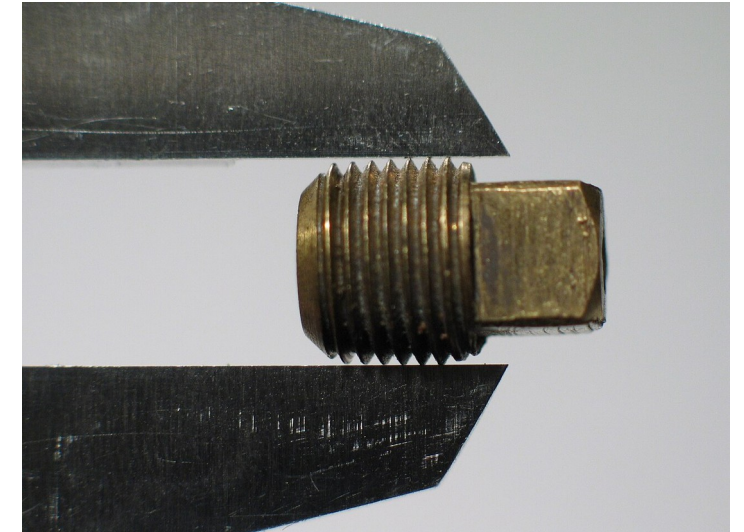
Standardization makes replacement and repair easier; similar-looking parts may not fit.



Vintage nuts and bolts



Metric • fine • inch • Whitworth



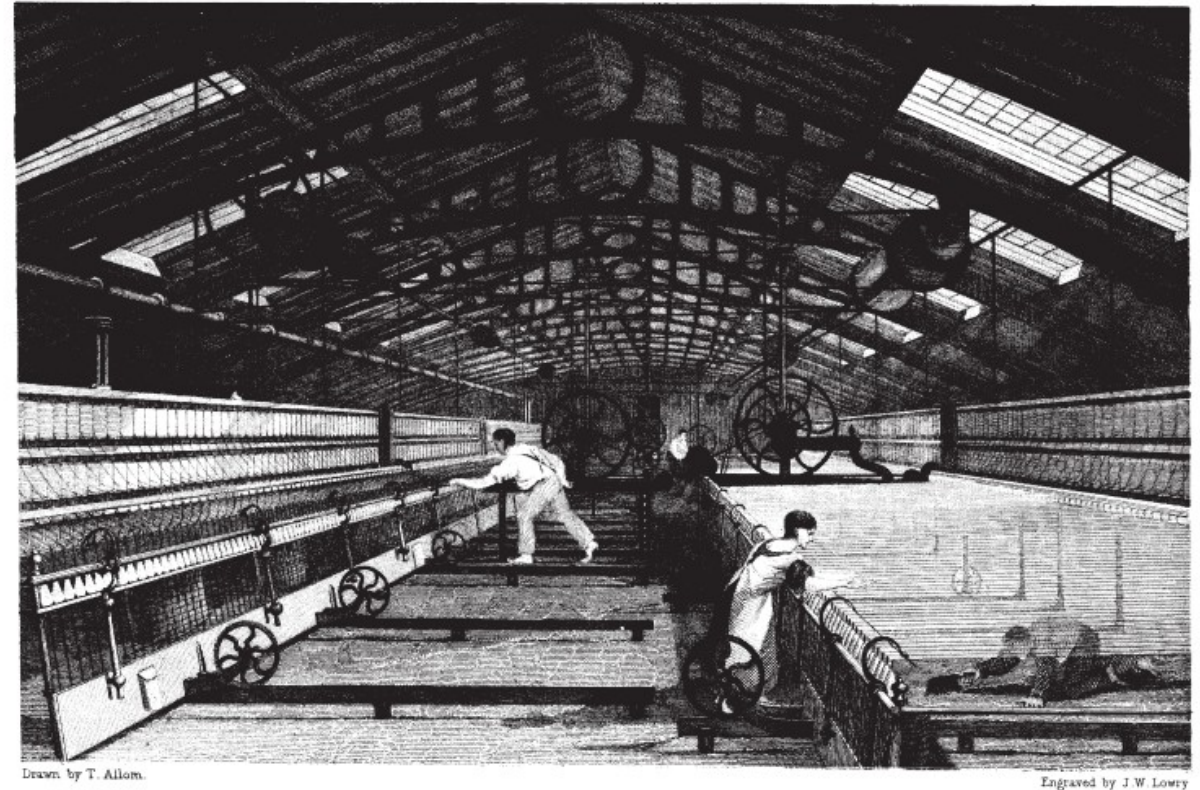
Tapered pipe thread

Skills, clocks and bargaining power

Some jobs required less training; others demanded new mechanical skills.

Shared machinery set a common schedule and pace.

Pay, hours and safety shaped the benefits of factory work.

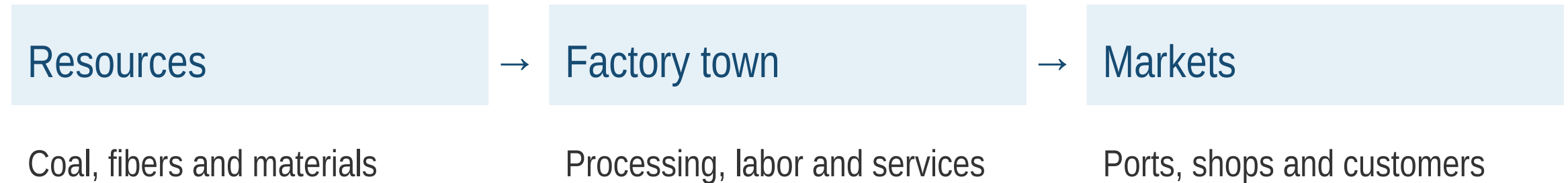


Workers and machinery in a spinning mill — Baines, 1835

Transport connects the system

Fuel, raw materials and finished goods have to move.

Canals and later railways connected places with different resources and functions.



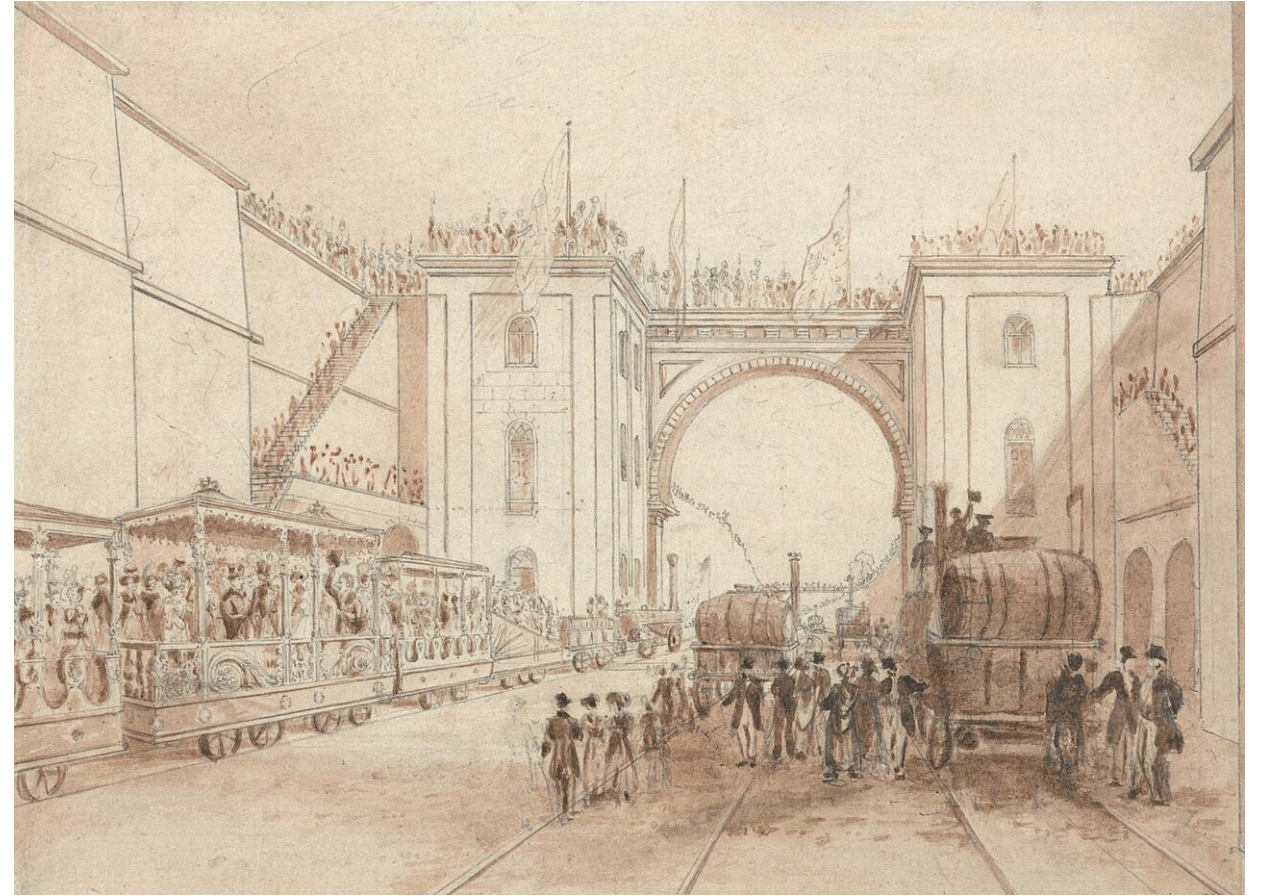
Roads, canals, railways and shipping connect the stages.

1830: railways and wider markets

The railway opened in 1830, linking Liverpool's port with Manchester.

Faster transport connected markets, factories and supplies.

Tracks, stations, capital and maintenance made the service possible.



Opening of the Liverpool and Manchester Railway — Isaac Shaw, 1830; Yale Center for British Art

Cities grow around work

Industrial jobs drew people toward towns, increasing demand for housing, food and services.

Population growth could outpace clean water, drainage and safe accommodation.

Urban growth created opportunity and serious health burdens at the same time.

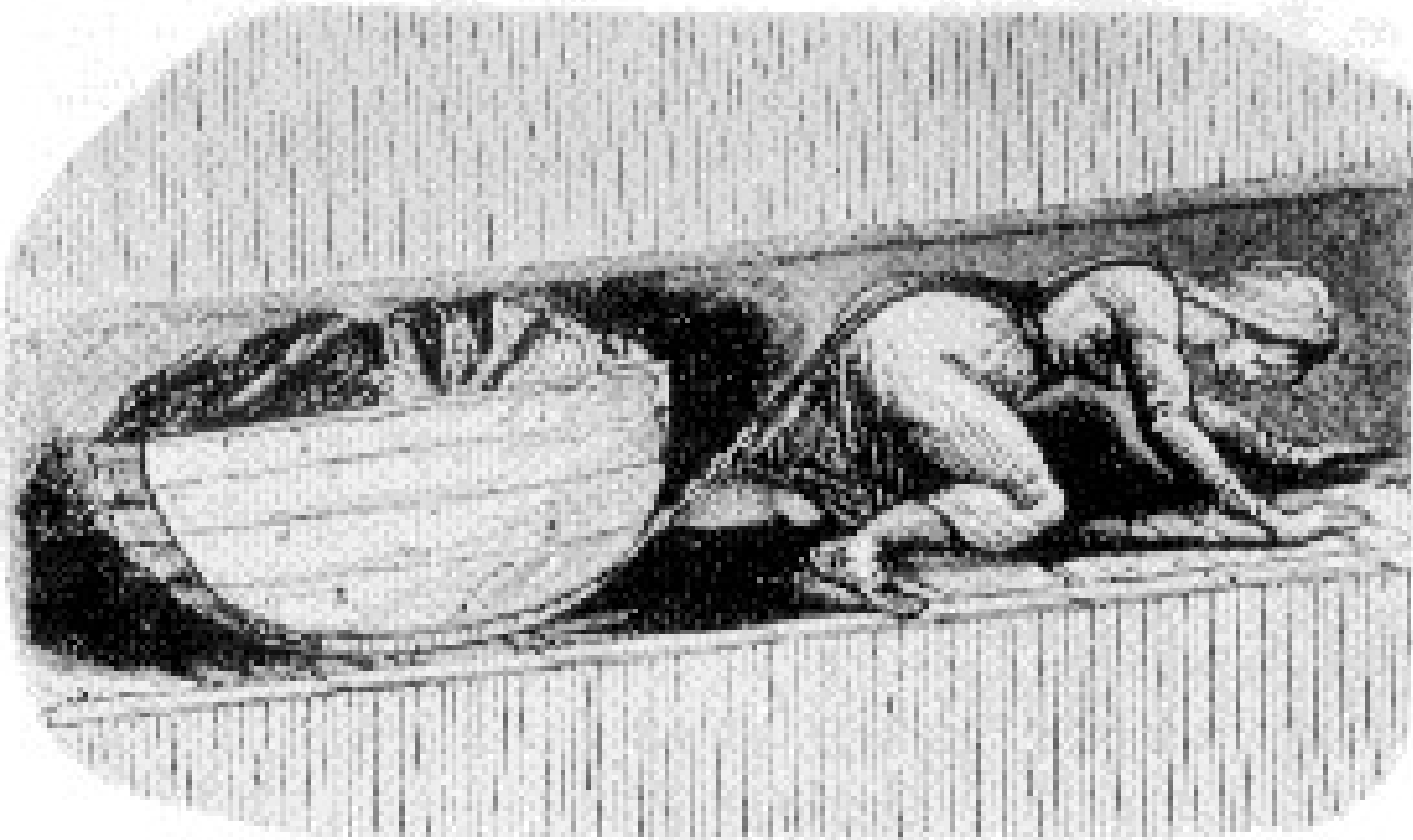
Higher output, uneven living standards

Industrialization changed everyday life and accompanied sustained growth in production, population and average incomes.

Historians debate when ordinary workers gained substantially: wages, health, housing and working hours changed at different rates.

Long-run improvements were profound, but early benefits differed across places, occupations and households.

Children at work



Why were children employed?

Households needed income, and employers sought labor at low cost.

Children worked in mills, mines and other settings, often with serious risks to health and education.

Child labor existed before factories; industrial organization changed its scale, setting and visibility.

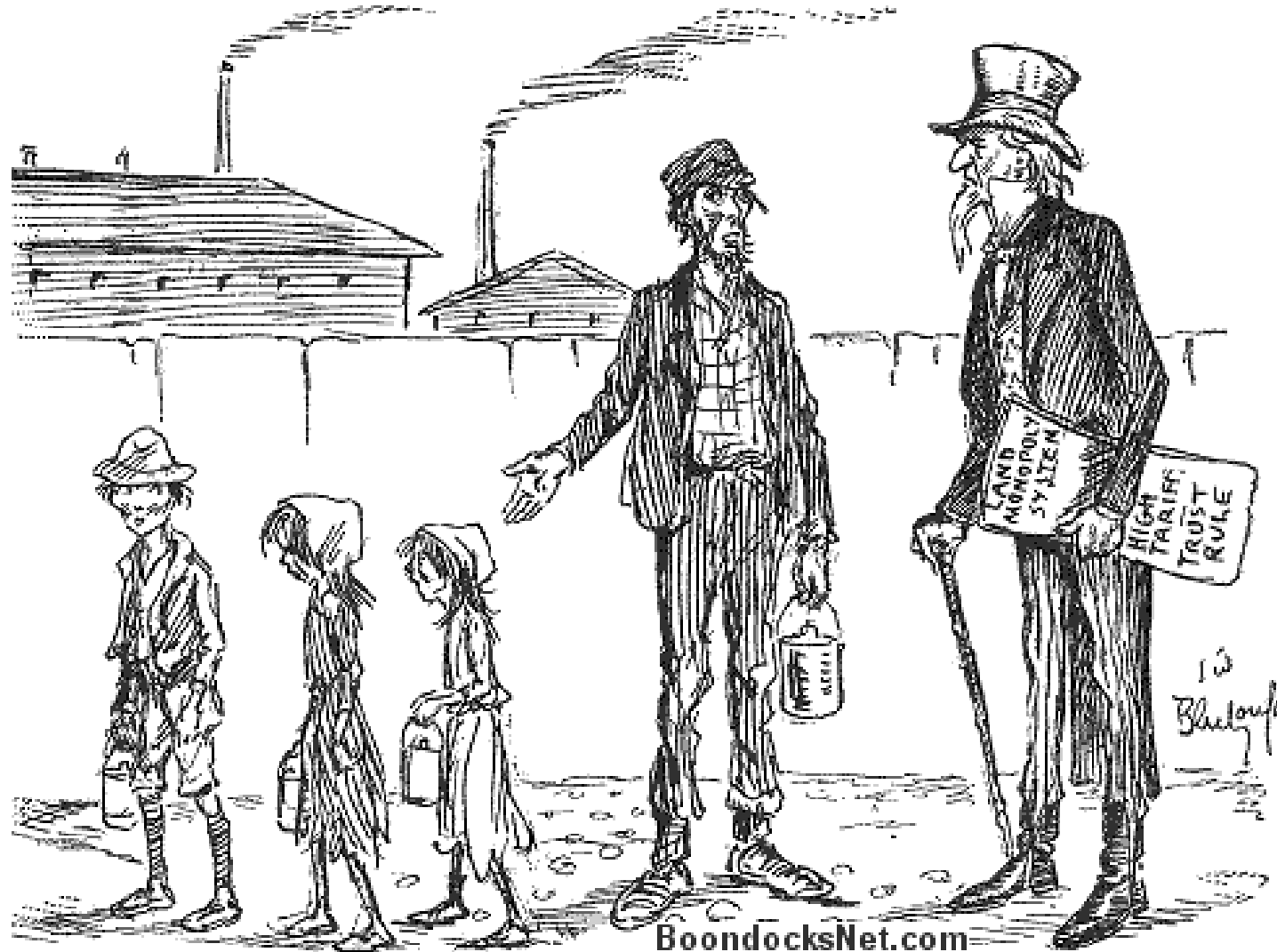
1909: child labor continued



1911: faces behind industrial output



Social movements and reform



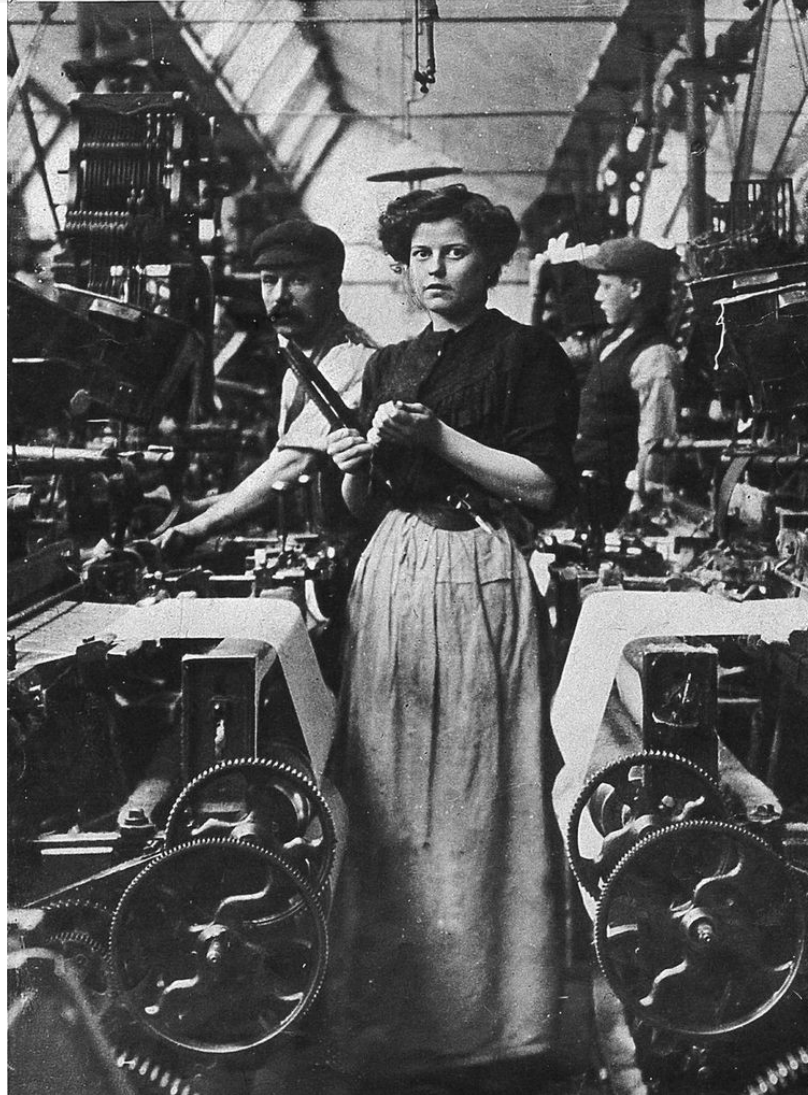
1833: laws need enforcement

The British Factory Act restricted child labor in covered textile factories and required schooling for younger children.

It introduced factory inspectors, making enforcement a government responsibility.

Its scope was limited: passing a law did not immediately remove exploitation.

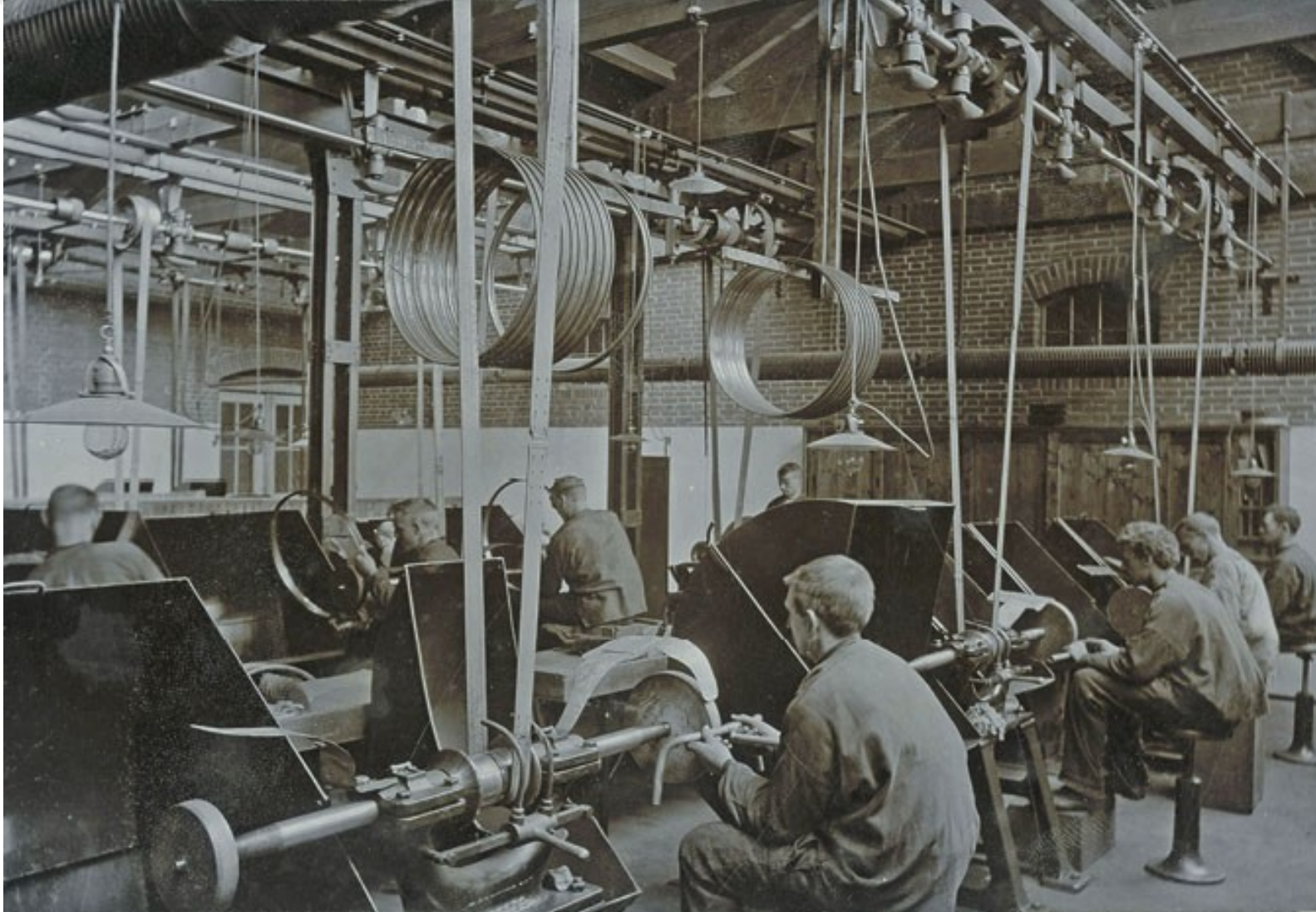
Working conditions



Labor inside the industrial system



Holland: the machine shop



Working life inside the factory

Moving belts and crowded workspaces exposed workers to injury.

Dust, long hours and relentless machinery affected health and daily life.

Pay, training and the power to negotiate shaped workers' opportunities.

Share of Total World Manufacturing Output (Percentage)^[161]

	1750	1800	1860	1880	1900
Europe	23.2	28.1	53.2	61.3	62.0
United States	0.1	0.8	7.2	14.7	23.6
Japan	3.8	3.5	2.6	2.4	2.4
The Rest of the World	73.0	67.7	36.6	20.9	11.0

Read the table carefully

These are estimated shares of world manufacturing, not income per person or living standards.

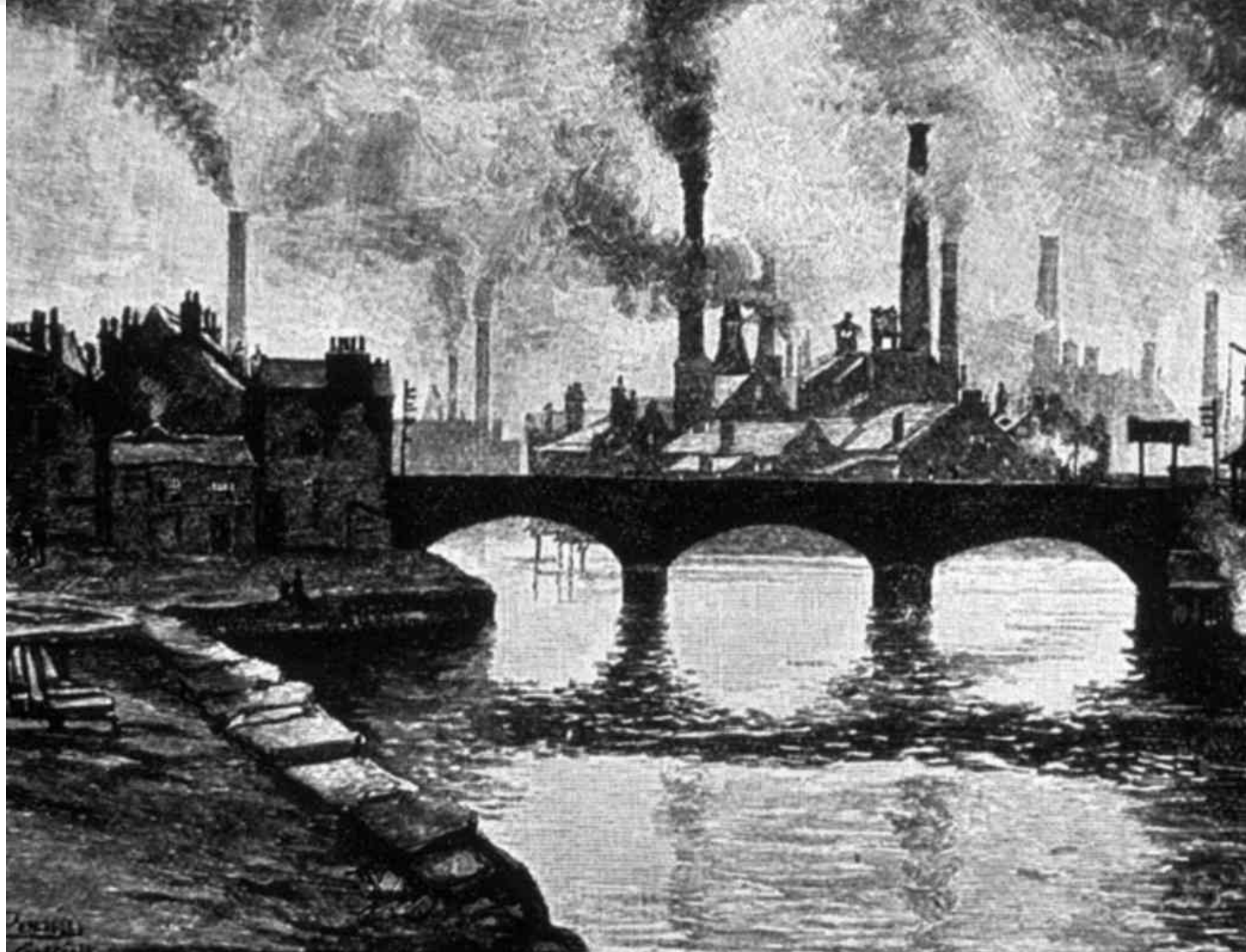
A falling share does not by itself prove that absolute output fell.

The table extends to 1900: it shows a longer transformation beyond the first industrial period.

Pollution



The industrial landscape



Benefits and costs beyond the factory

Smoke and waste affected people who did not choose to work in the factory.

Private production costs could omit damage to public health, water and nearby homes.

Regulation and public infrastructure helped determine who bore those costs.

Industrial growth was uneven



From early factories to new industries

Mechanized textiles and steam did not produce a smooth, uninterrupted rise in prosperity.

Innovation, investment and markets developed at different rates; crises and unemployment remained possible.

Later steel, electricity and chemistry opened further changes. Assembly-line production follows later still.

Did science simply produce industry?

Craft skill, practical experiment and business organization were central to early industrial machinery.

Working engines raised questions about heat and efficiency; theory and technology could influence each other.

An invention becomes industrial capacity through manufacture, operation, repair and repeated improvement.

Review: explain with a connection

Why can a faster spinning machine fail to increase cloth output?

Why did Watt's separate condenser make an important difference?

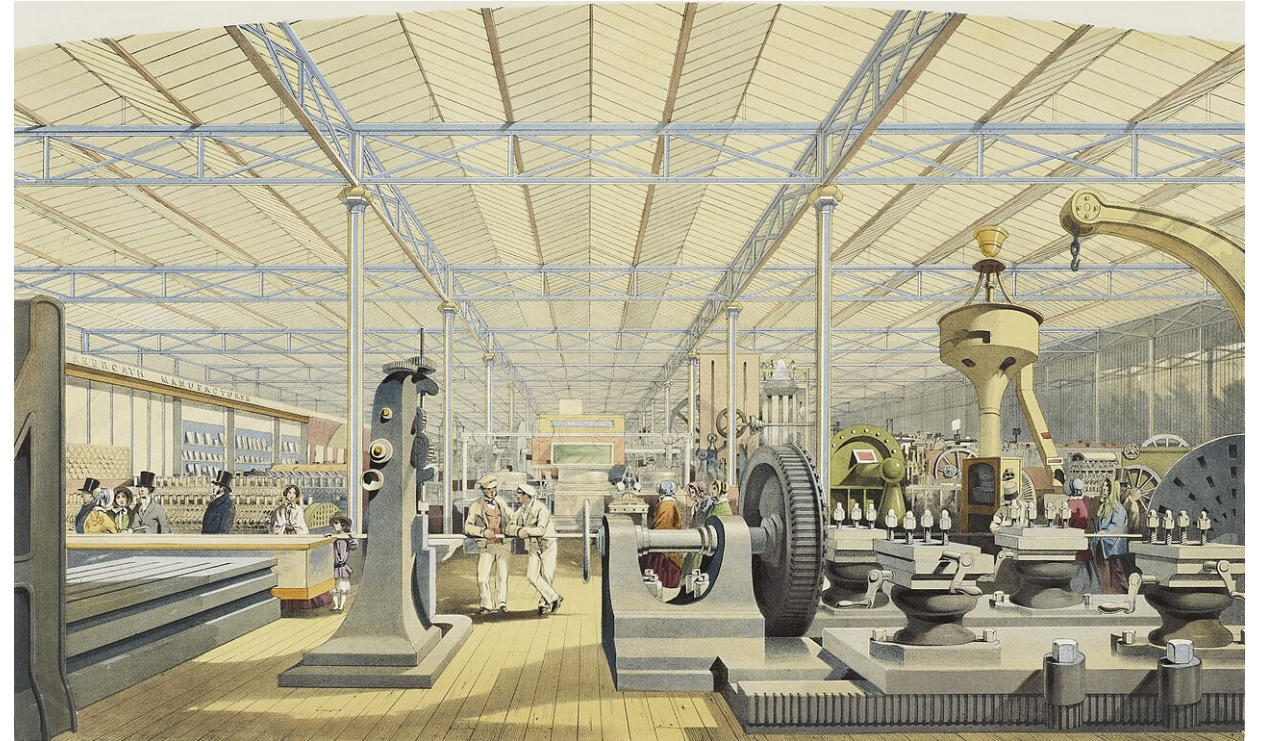
How can industrial output rise while some workers' lives remain difficult?

Model reasoning

Output depends on the connected production process.

Watt's condenser reduced repeated heating and cooling, saving fuel.

Higher output and better working lives did not always advance together.



Moving machinery at the Great Exhibition of 1851 — published 1854

Next: electricity, chemistry and systems

Steam and factories changed production and work.

The next lecture follows steel, chemistry, electricity and the infrastructure connecting them.

Keep asking: what must work around an invention for it to become useful at scale?

Reference: historical iron estimates

Year	Charcoal iron	Coke iron
1720	20,500	400
1750	24,500	2,500
1788	14,000	54,000
1806	7,800	250,000

Tons as reported in the historical series; original statistical source and unit definition unverified.

Reference: interpreting labor estimates

Numbers depend on age limits, industries, location and the meaning of “working.”

A factory sample cannot establish a national proportion.

Use dated photographs, inspection evidence and appropriately defined statistics together.

Sources and further reading

Science and Technology in World History, chapter on industrialization.

Oxford Big Ideas, chapter 5; Joel Mokyr, The Second Industrial Revolution, 1870–1914.

Museum collections, Library of Congress photographs and Parliament's Factory Act history are linked in the reading.