

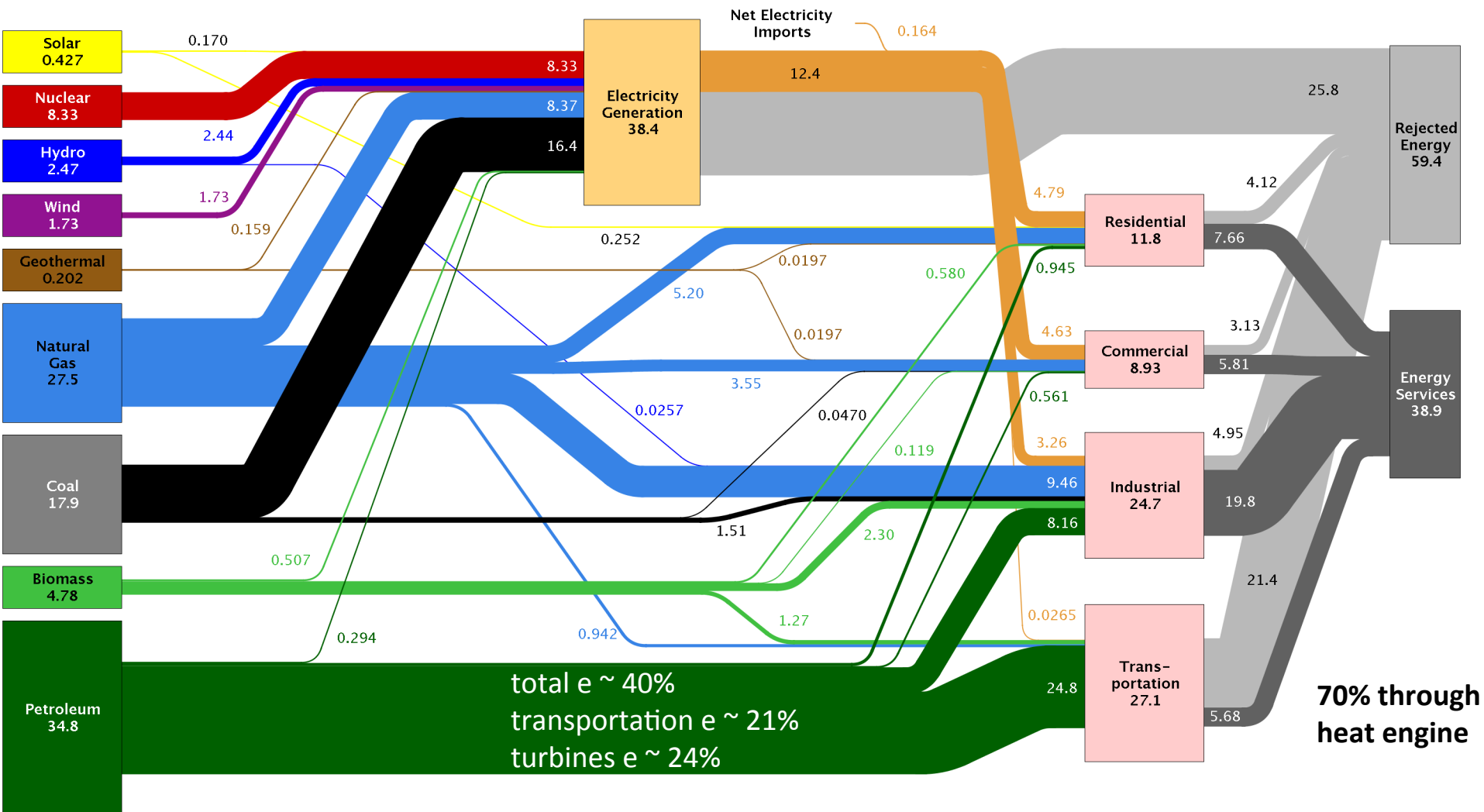
GEOS 24705 ENST 24705 ENSC 21100

Lecture 8

The Industrial Revolution and the
transformation to the modern
energy system

Most of U.S. energy use is lost as waste heat

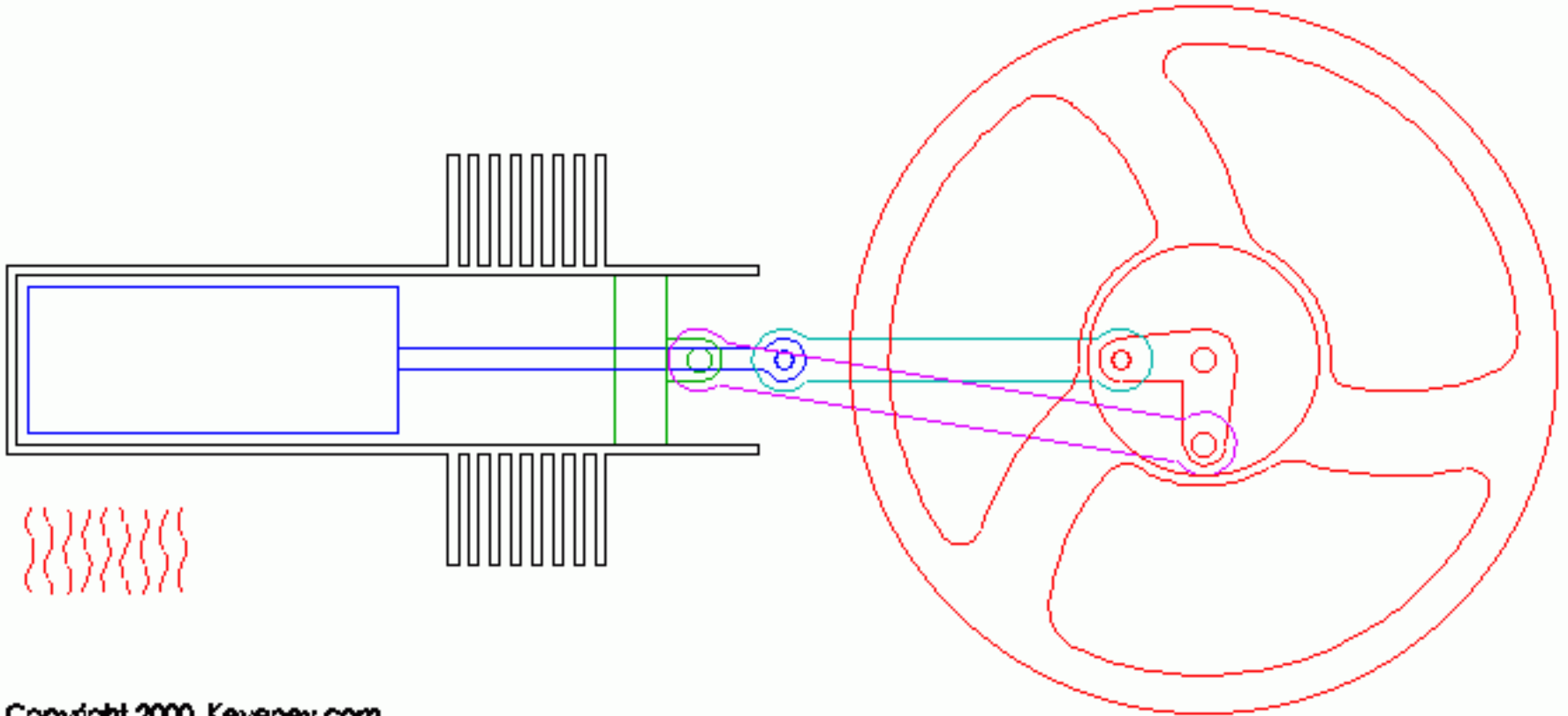
Estimated U.S. Energy Use in 2014: ~98.3 Quads



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Carnot-style “air engines” are in use

- gas only
- closed cycle
- external combustion



Themes for today

- The Industrial Revolution and the development of heat engines are related but not the same
 - industrialization started before the heat engine
 - the heat engine ultimately allowed greater industrialization
- Industrialization produced profound social & economic upheaval
- The upheaval was amplified by limitations in energy technology

Mills had been mechanized and centralized since Medieval times



*Grindstone, 1700s, U.S.
from Hamilton, "The Village Mill
in Early New England"*



Yates gristmill, North Carolina U.S.

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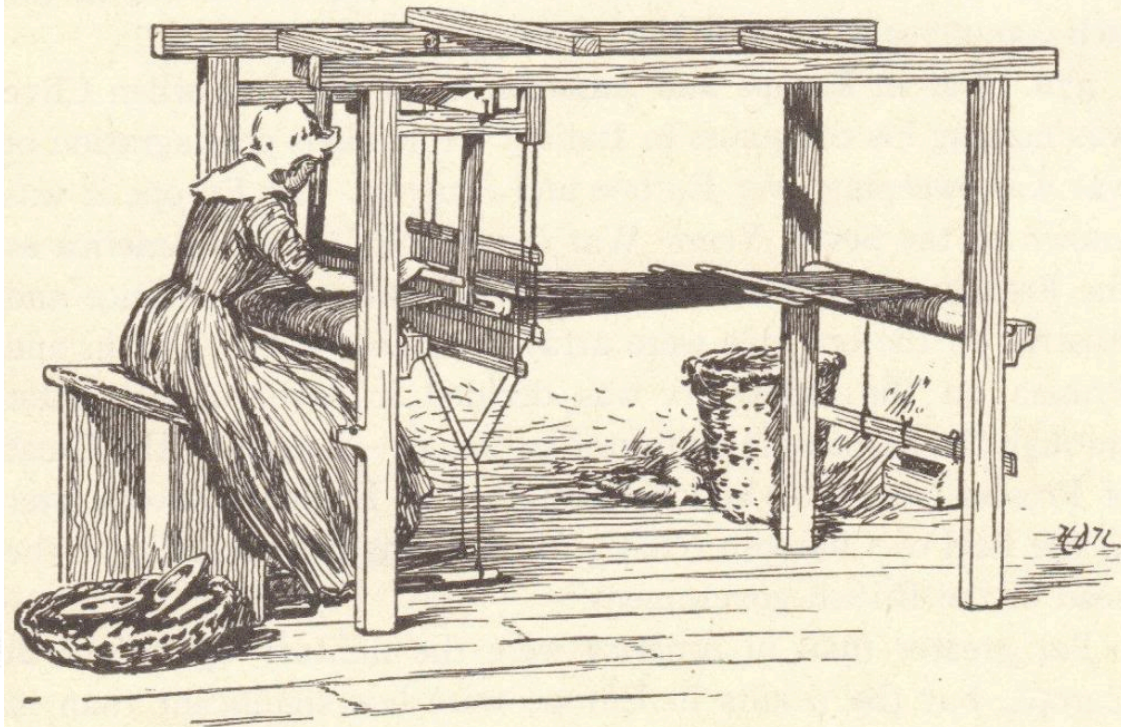
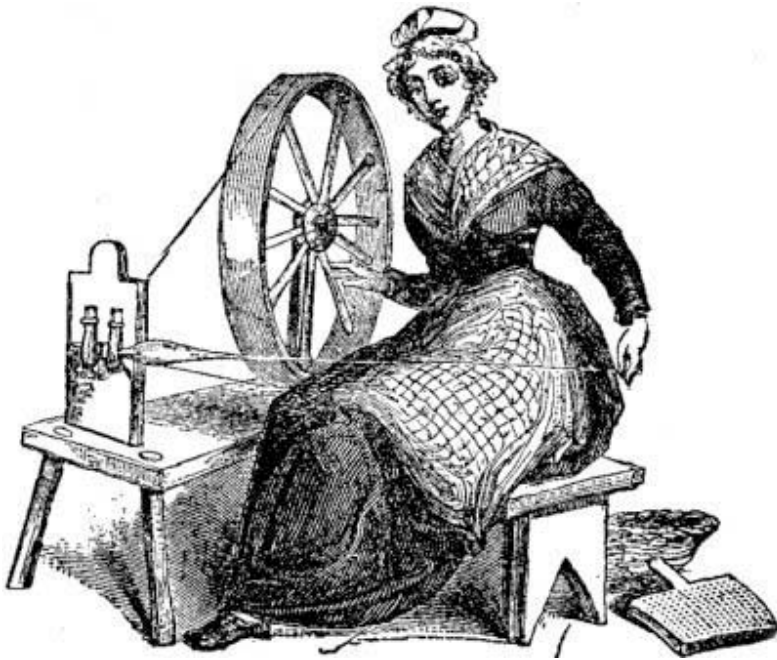


*Grindstone, 1700s, U.S.
from Hamilton, "The Village Mill
in Early New England"*

Rock Run gristmill, Maryland U.S.

Textiles were still a home industry in the mid-1770s

but extremely repetitive motions are well suited to mechanization



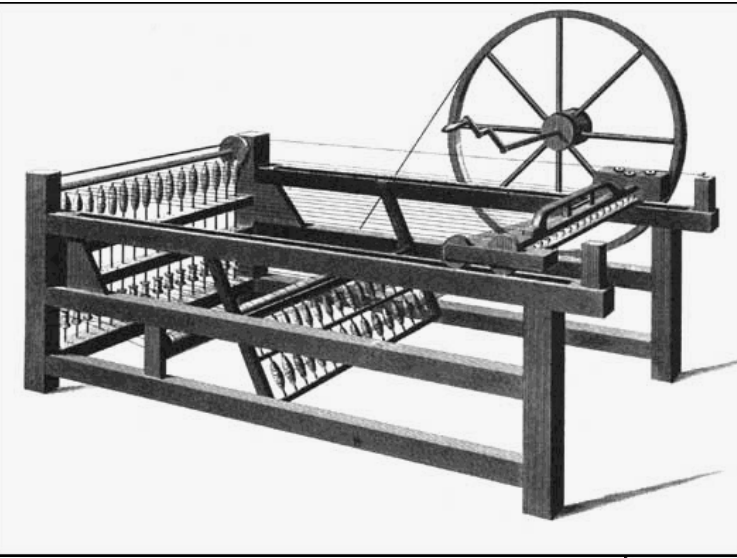
A HAND LOOM, SUCH AS WAS USED BEFORE 1785

Source: unknown

Jersey Spinning Wheel. From: *The Story of the Cotton Plant*, Frederick Wilkinson, 1912, via Gutenberg.org

over 6 spinners to make thread for 1 weaver as looms improved in 1730s

Spinning was mechanized to meet thread demand

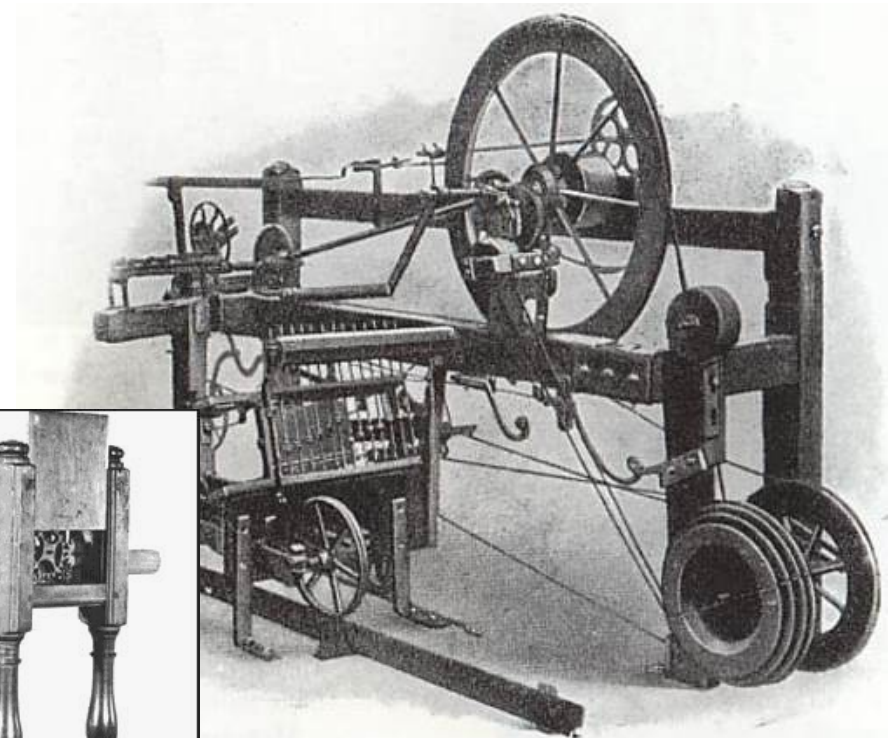
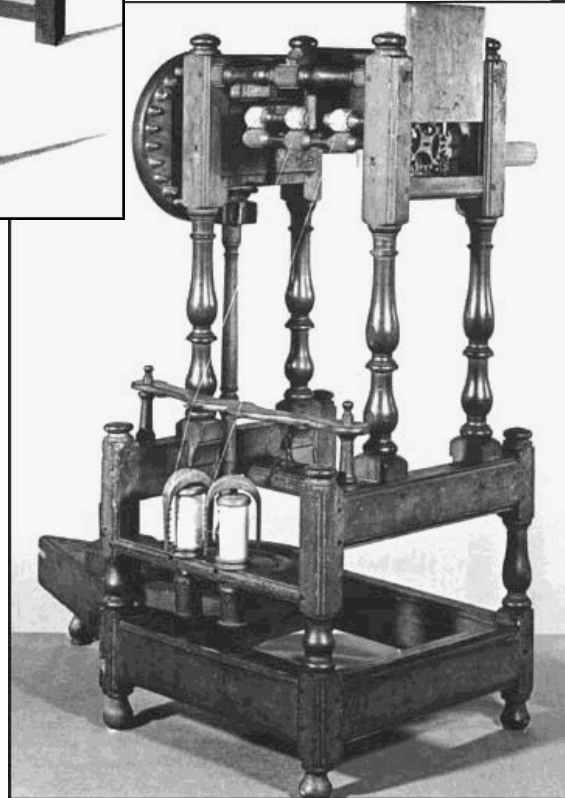


Spinning jenny, 1764
James Hargreaves

power: human

“Water frame” 1769
John Kay, Richard Arkwright

power: horses, then water



Spinning mule, 1779
Samuel Crompton

Power: water
fully automated by 1830

Mechanization of spinning benefits weavers...

from Radcliffe on weaving, 1828....

From the year 1770 to 1788 a complete change had gradually been effected in the spinning of yarns, - that of wool had disappeared altogether, and that of linen was also nearly gone, - cotton, cotton, cotton, was become the almost universal material for employment, the hand wheels, with the exception of one establishment were all thrown into lumber-rooms, the yarn was all spun on common jennies, the carding for all numbers...was done on carding engines.... In weaving no great alteration had taken place during these 18 years...

The next fifteen years, viz. from 1788 to 1803, which fifteen years I will call the golden age of this great trade, which has been ever since in a gradual decline.... new weavers' cottages with loom-shops rose up in every direction; all immediately filled, and when in full work the weekly circulation of money as the price of labour only rose to five times the amount ever before experienced in this sub-division, every family bringing home weekly 40, 60, 80, 100, or even 120 shillings per week! ! !

From William Radcliffe,

"Origin of the New System of Manufacture, Commonly Called Power loom Weaving", 1828

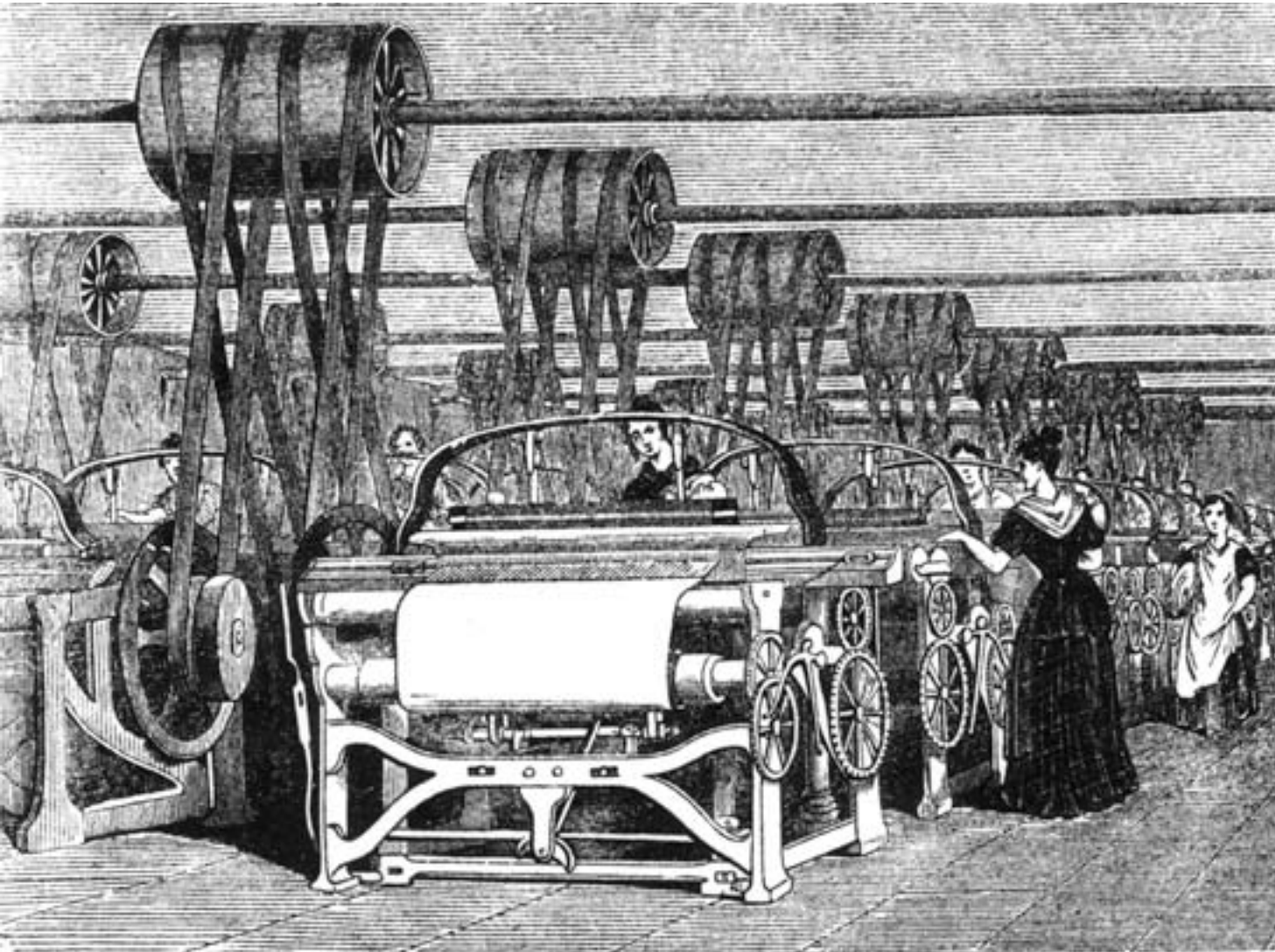
.....but then comes to weaving as well

In 1785, the Rev. E. Cartwright invented a Loom to be worked by water or steam... A factory for Steam Looms was built in Manchester, in 1806. Soon afterwards two others were erected at Stockport, and about 1809, a fourth was completed in Westhoughton....

Before the invention of the Dressing Frame, one Weaver was required to each Steam Loom, at present a boy or girl, fourteen or fifteen years of age, can manage two Steam Looms, and with their help can weave three and a half times as much cloth as the best hand Weaver

*From Richard Guest, Compendious History of the Cotton Manufacture
(Manchester 1823)*

Weaving mechanization came next



Power loom, 1787
Edmund Cartwright

Power: water

by 1829 there are nearly 50,000 power looms in England, water- and steam-powered

But steam engines used mostly in mines and ironworks at this time

Impact: major social disruption...home weaving could no longer compete. Rural livelihoods were cut off, forcing migration

Power looms, 1844
Source: Getty Images

Even in boom years mechanization produces income disparity

from Radcliffe on weaving, 1828....

Although our family and some others in the neighbourhood during the latter half of the time, earned from three to four fold-wages to what the same families had heretofore done, yet, upon the whole, the district was not much benefited by the change; for what was gained by some families who had the advantage of machinery, might, in a great measure, be said to be lost to the others

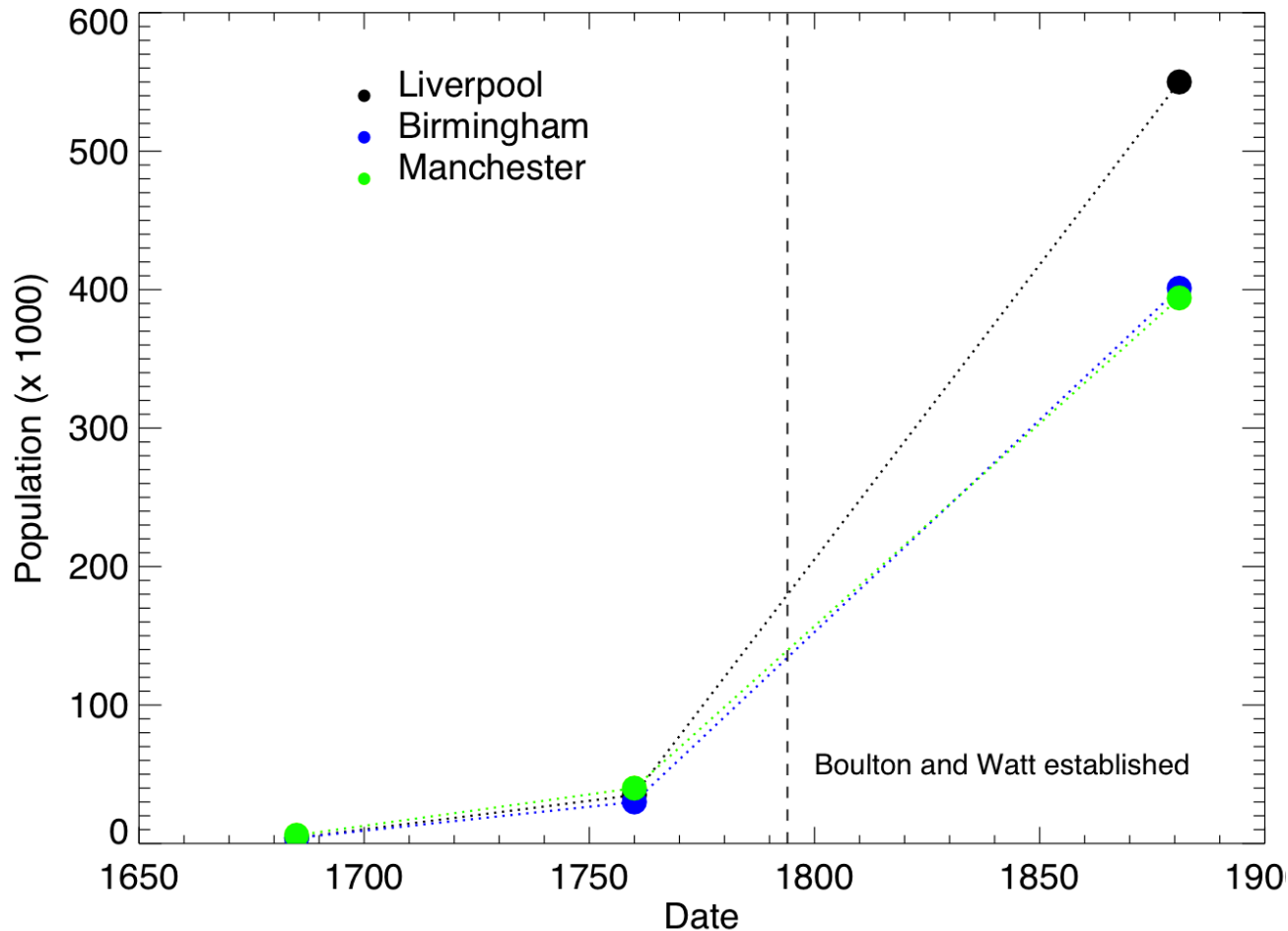
....One of the formidable consequences of this change now began to make its appearance, the poor's rate, which previous to this change had only been known in a comparatively nominal way .. Relief to persons who could not get employment, or bastardy, were alike unknown on their books...

From William Radcliffe,

“Origin of the New System of Manufacture, Commonly Called Power loom Weaving”, 1828

Rapid depopulation of countryside, move to cities

1696: 10% population urban / 1881: 70% urban



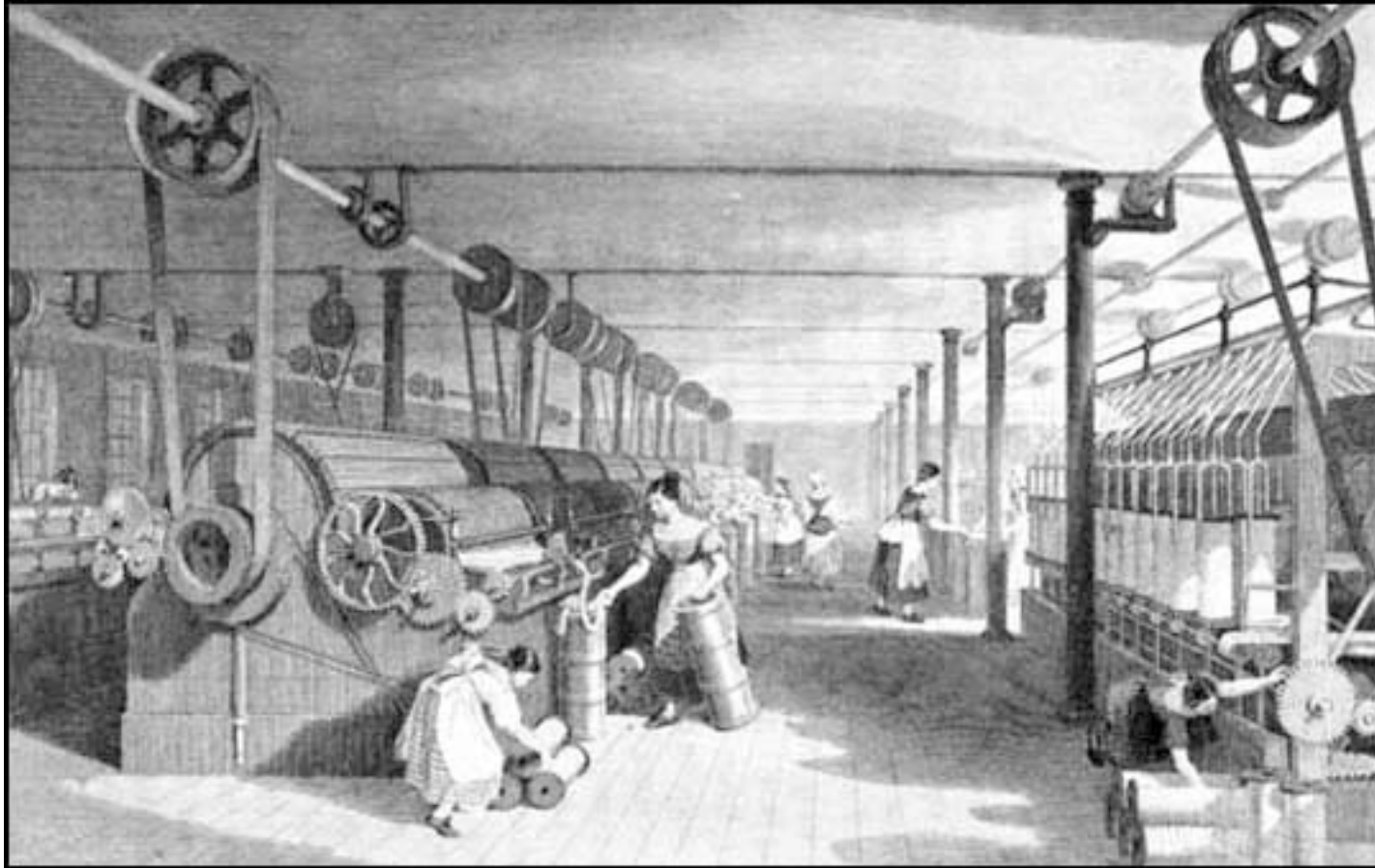
Source: Data from Toynbee, "Lectures on the Industrial Revolution in England, 1884, in turn drawn from a. Macaulay's History of England c. 3. b. Defoe's Tour (1725) c. Arthur Young (1769) d. Macpherson's Annals of Commerce (1769) e. Levi's History of British Commerce

By mid-1800s, water power superseded by coal → steam



Manchester from Kerstal Moor, 1840. *William Wyld*. *Painting of Manchester, England*.

Textile production in England changed social structure of labor

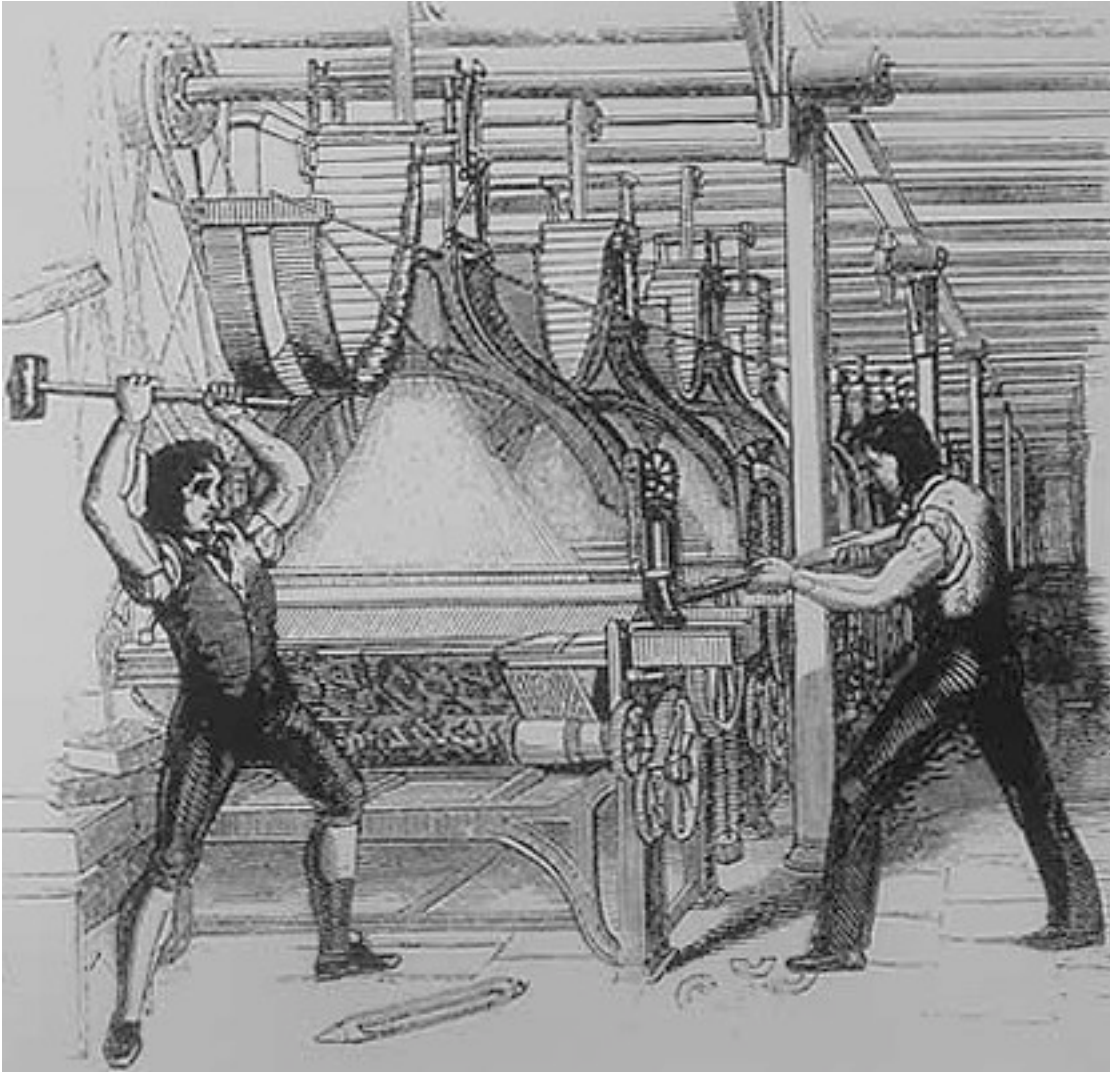


*Looms,
England,
early 1800s,
source
unknown*

Women and children left the home to work, hired because:

- cheap labor
- small hands were valuable in operating machinery
- strength no longer required

The backlash against industrialization was strong



“Luddites” smashing a loom (“frame-breaking”), ca. 1812, *source unknown*

Ned Ludd breaks two knitting frames in 1779, becoming a folk hero

“Protection of Stocking Frames, etc. Act”, 1788
penalty: 7-14 years
transportation to colonies

“Luddites” began organized acts of sabotage of industrial system, 1811-1812

“Frame-Breaking Act”, 1812
penalty: death

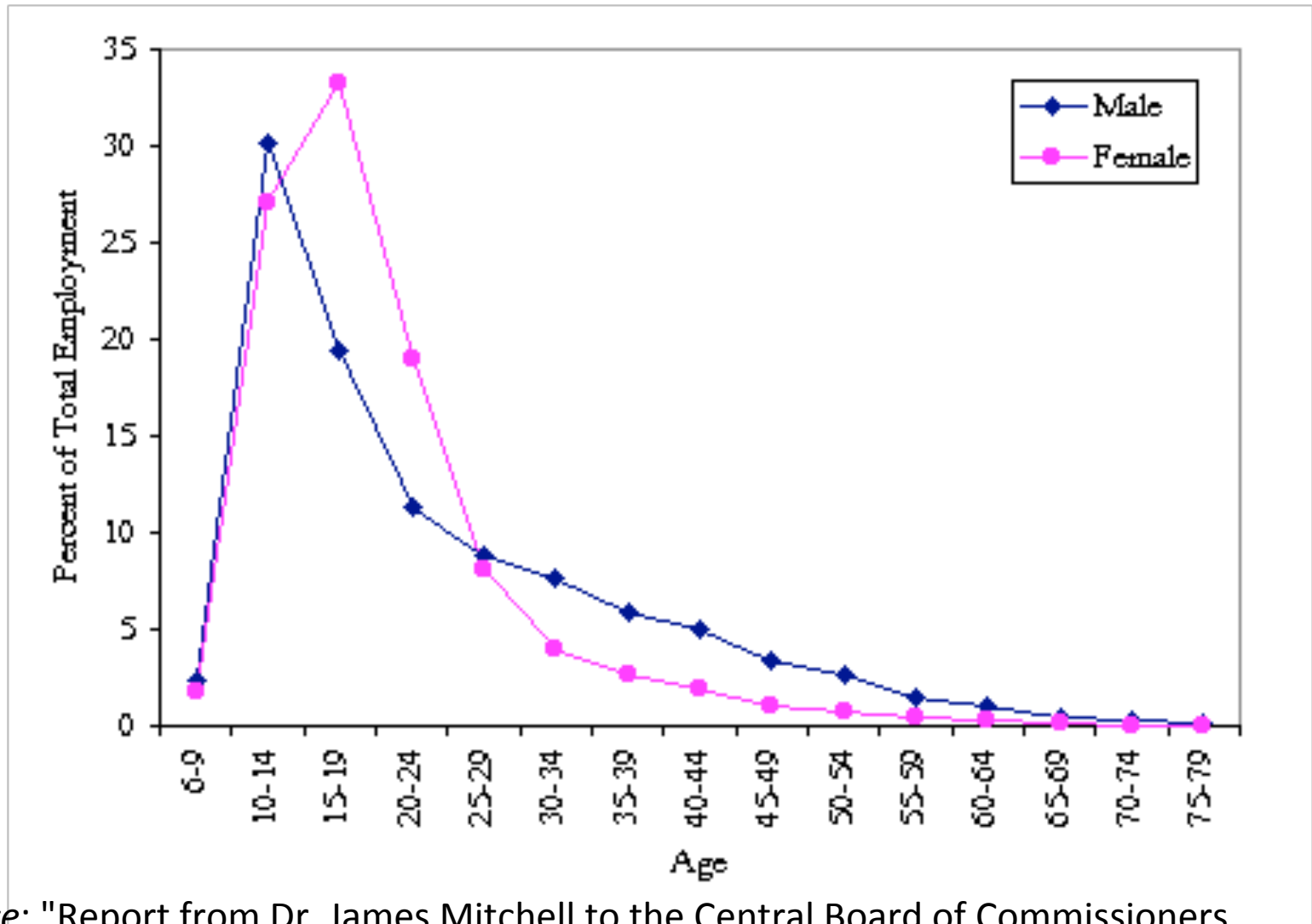
Much of mill labor was performed by children



Lewis Hine,
children
working in a
textile
factory in
Cherryville,
N.C.

Children were sent to the mills by their parents, much discussion of why. Lack of money as wages are dropping? Lack of child care with parents in factories? Greed?

By early 1800s, **most** factory workers are children



Source: "Report from Dr. James Mitchell to the Central Board of Commissioners, respecting the Returns made from the Factories, and the Results obtained from them." *British Parliamentary Papers*, 1834 (167) XIX. (from Burnette, Joyce, EH.net)

Labor conditions prompts the first child labor laws

- **1802:** Health and Morals of Apprentices Act orders ventilation and cleanliness
- **1815:** Robert Owen suggests children under age 10 should not work in factories
- **1819:** Cotton Mills and Factories Act forbids employing children under 9, children 9-16 years old can work no more than 12 hours/day + 9 hours on Saturday (69 hour week!)
- **1831:** Labor in Cotton Mills Act: limit to 12 hours/day extends to age 18, no night work for anyone under 21
- **1832:** Labor of Children... in Factories Act 1832 (Sadler's Bill) extends protection to all textile factories, not just cotton. Limit reduced to 10 hours/day.
- *....prompts backlash by employers, further legislation stalls for about a decade.*

The fight is the "Ten Hour Movement" – can children work more than 10 hours/day or not?

Only in late 1800s are protections extended to children outside the textile industry