GEOS 24705 / ENST 24705 / ENSC 21100

2018

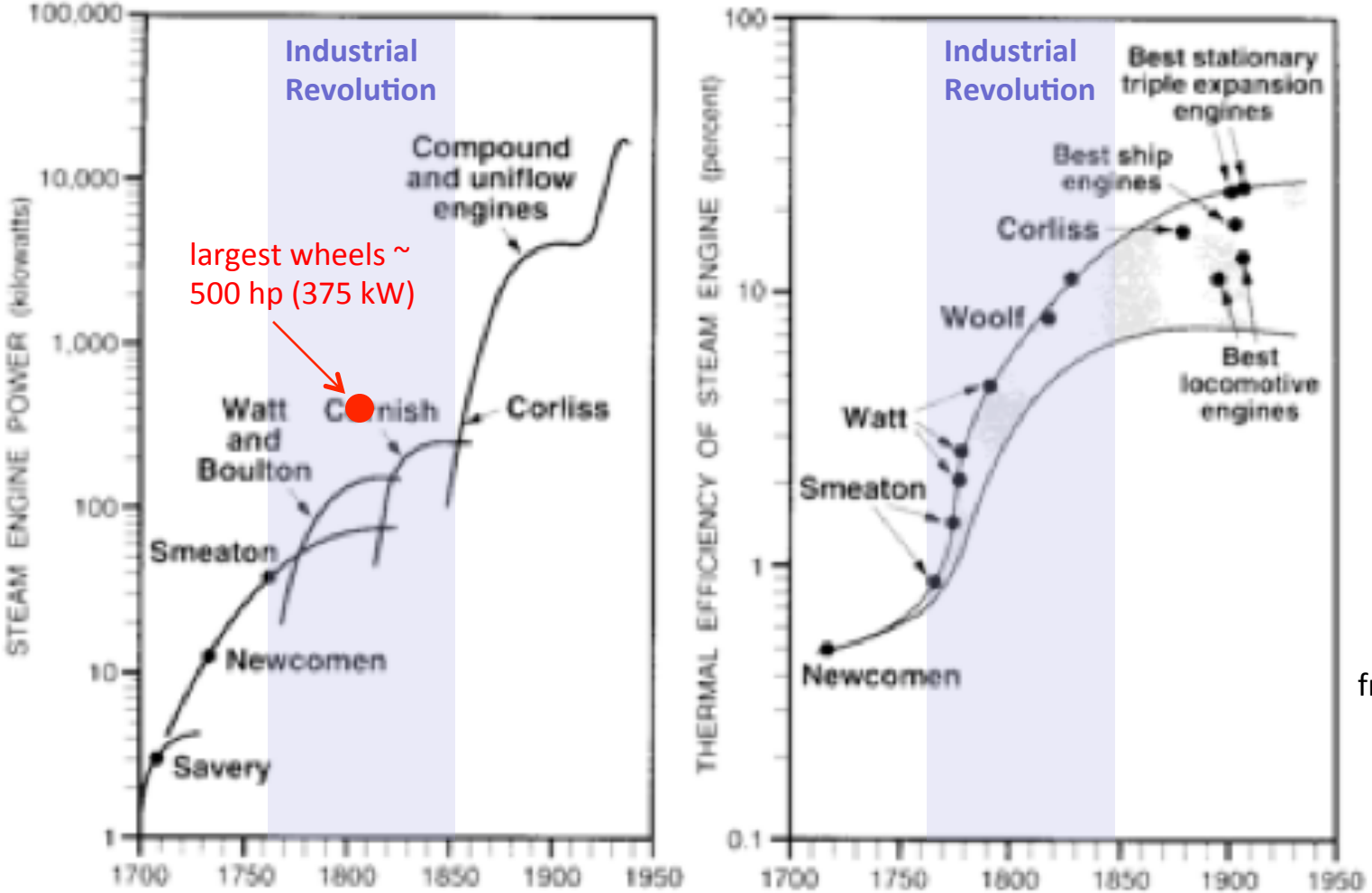
Lecture 8

The industrial revolution, the impact of heat engines on the U.S.

Industrial Revolution isn't tied simply to heat engine evolution

Steam doesn't overtake water power in British factories til ~1820s-30s

Why even then? Water power is cheaper AND wheels more powerful



from V. Smil

FIGURE 5.3 The rising power and improving efficiency of the best steam engines, 1700–1930. *Sources:* Plotted from data in Dickinson (1939) and von Tunzelmann (1978).

Mills had been mechanized & centralized since Medieval times

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

Yates gristmill, North Carolina U.S.

Larger wheels can provide power for mechanized factories

Laxey water wheel, 72.5 ft dia.

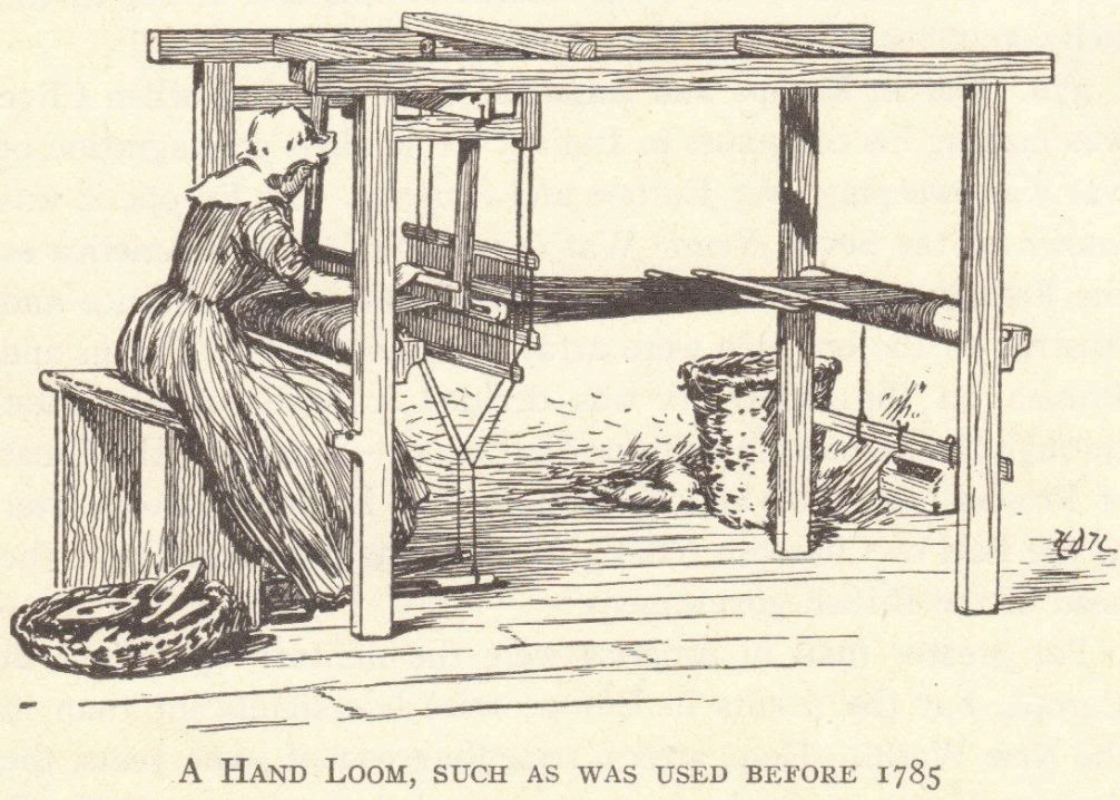
~ 200 hp (150 kW)

Built 1854, for pumping mines

Textiles were a home industry in the mid-1770s
(only milling had been mechanized)

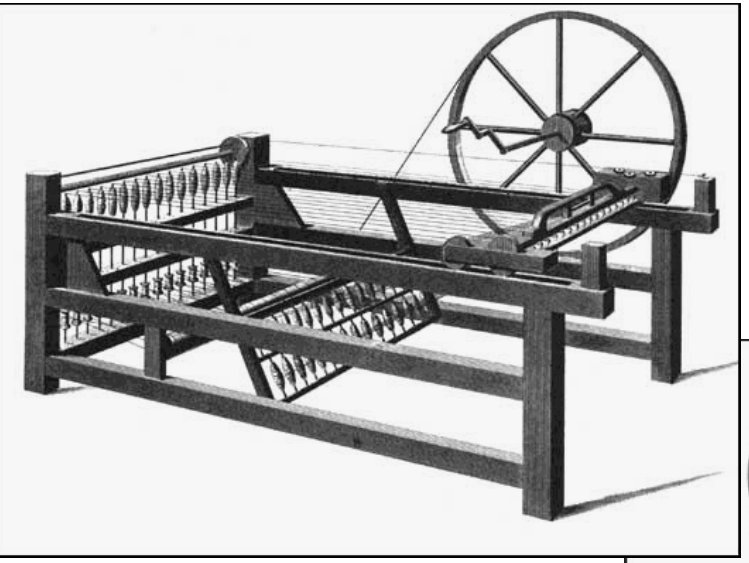
but extremely repetitive motions are well suited to mechanization

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



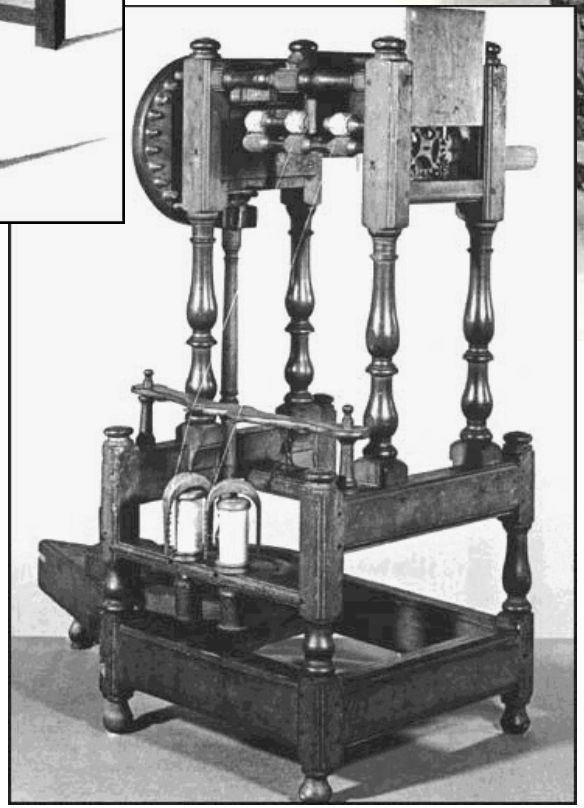
Source: unknown

Spinning was mechanized first, happened quickly



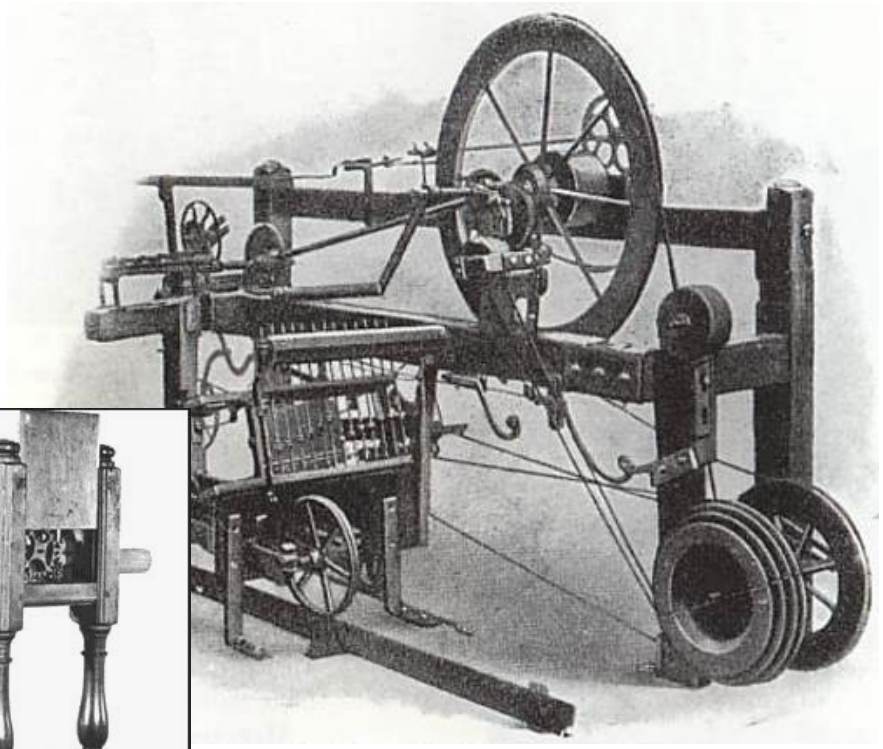
Spinning jenny, 1764
James Hargreaves

power: human



"Water frame" 1769
John Kay, Richard Arkwright

power: horses, then water



Spinning mule, 1779
Samuel Crompton

Power: water
fully automated by 1830

Home weavers benefit from mechanization of spinning

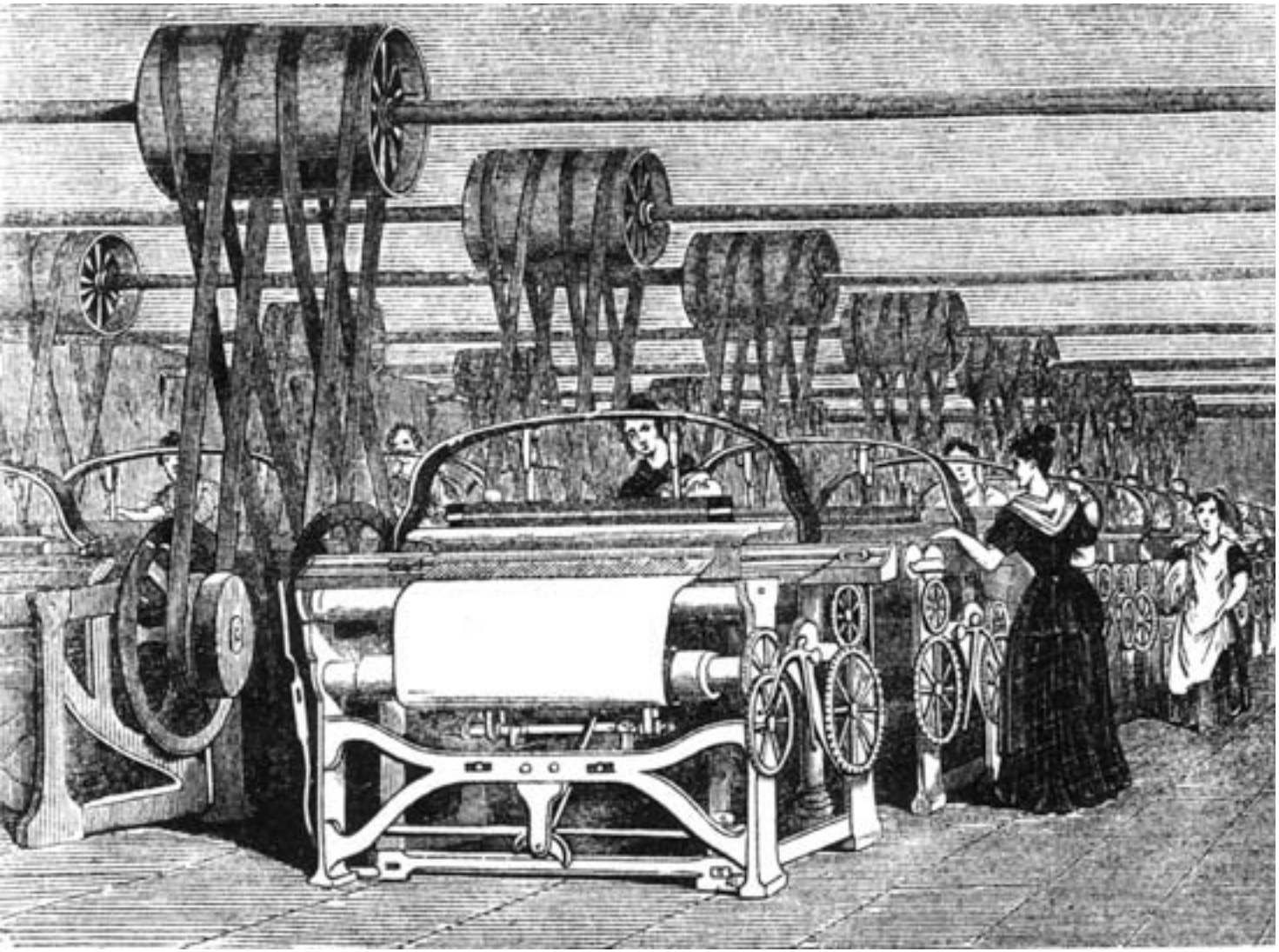
from Radcliffe on weaving....

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! ! I

From William Radcliffe,
"Origin of the New System of Manufacture, Commonly Called Power Loom Weaving", 1828

Weaving mechanization came next



Power loom, 1787
Edmund Cartwright

Power: water

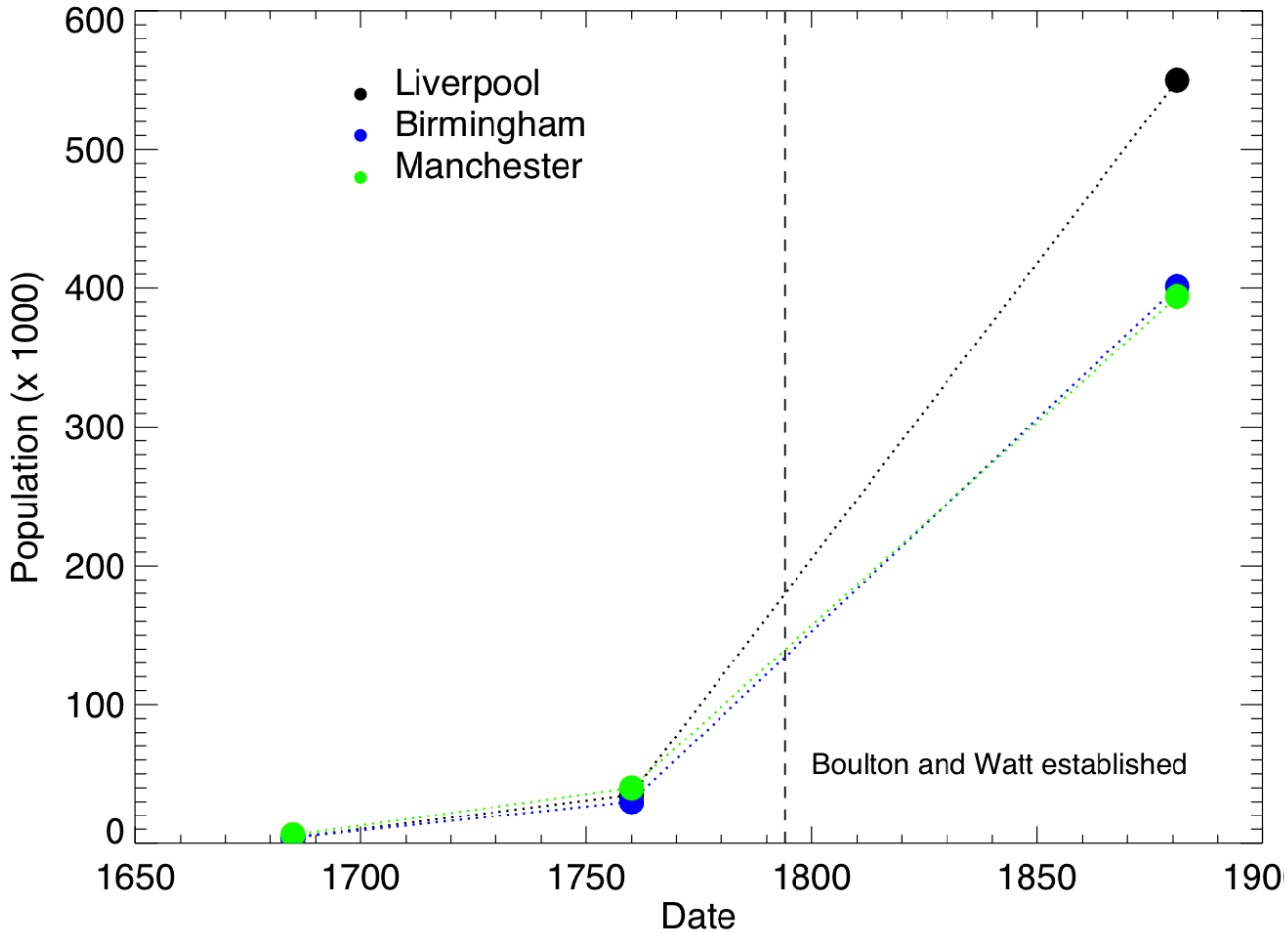
by 1829 there are nearly 50,000 power looms in England

Led to major social disruption…home weaving could no longer compete. Rural livelihoods were cut off, forcing migration

Power looms, 1844
Source: Getty Images

Cities grow rapidly as people move there

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

Cities become unhealthier as coal overtakes water power

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

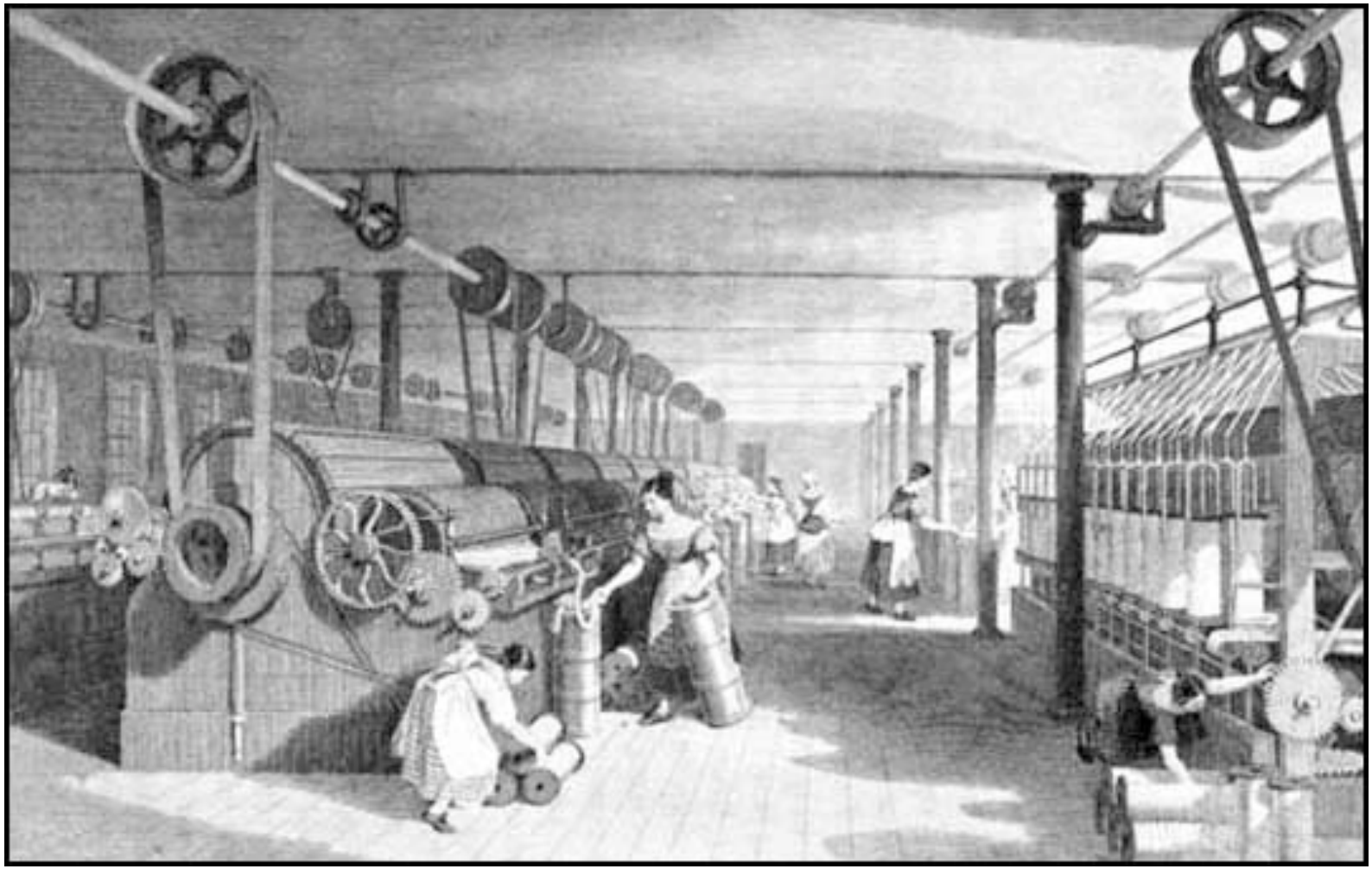
Mechanization reduces labor needs, allows children to work

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)

Textile production in England changed social structure of labor



Women and children left the home to work: women were cheap labor, small hands were valuable in operating machinery, and strength not required.

Looms, England, early 1800s, source unknown

Mechanization produces income disparity

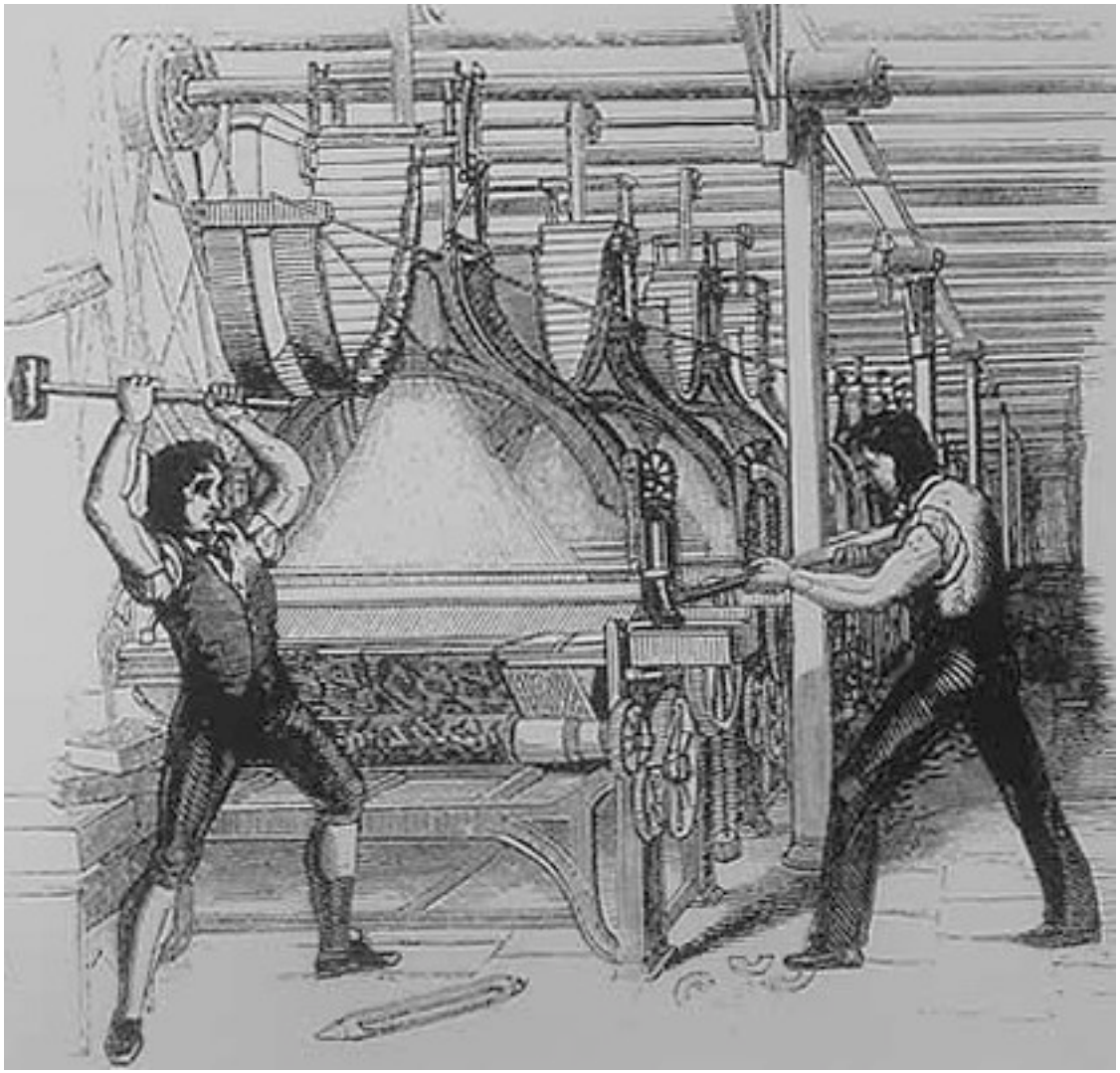
from Radcliffe on weaving, 1828....

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

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

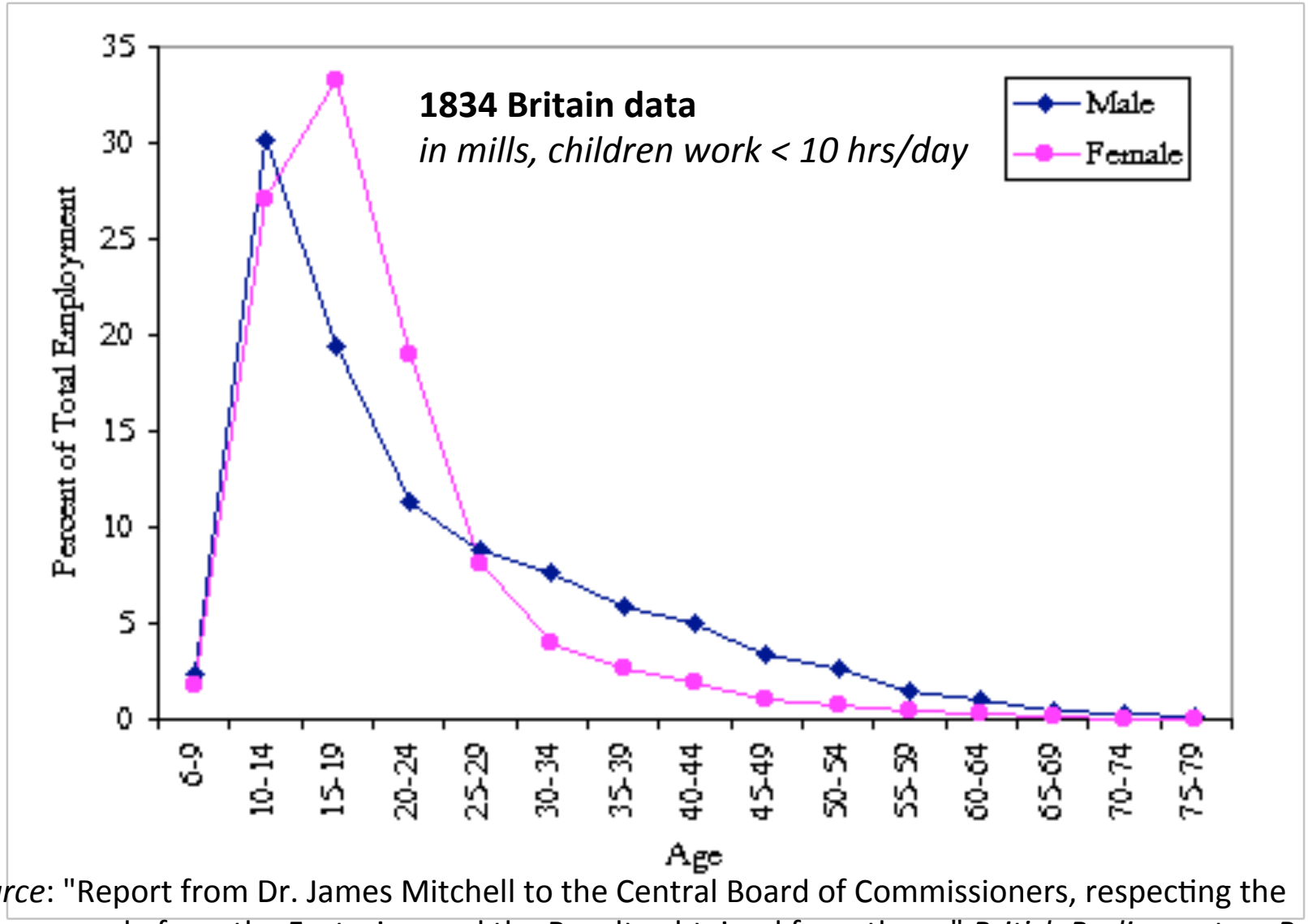
"Frame-Breaking Act", 1812
penalty: death

Much of mill labor was performed by children

Lewis Hine, children working in a textile factory in Cherryville

Children were sent to the mills by their parents, perhaps caught in wage trap – child labor lowered wages, which meant children must labor...

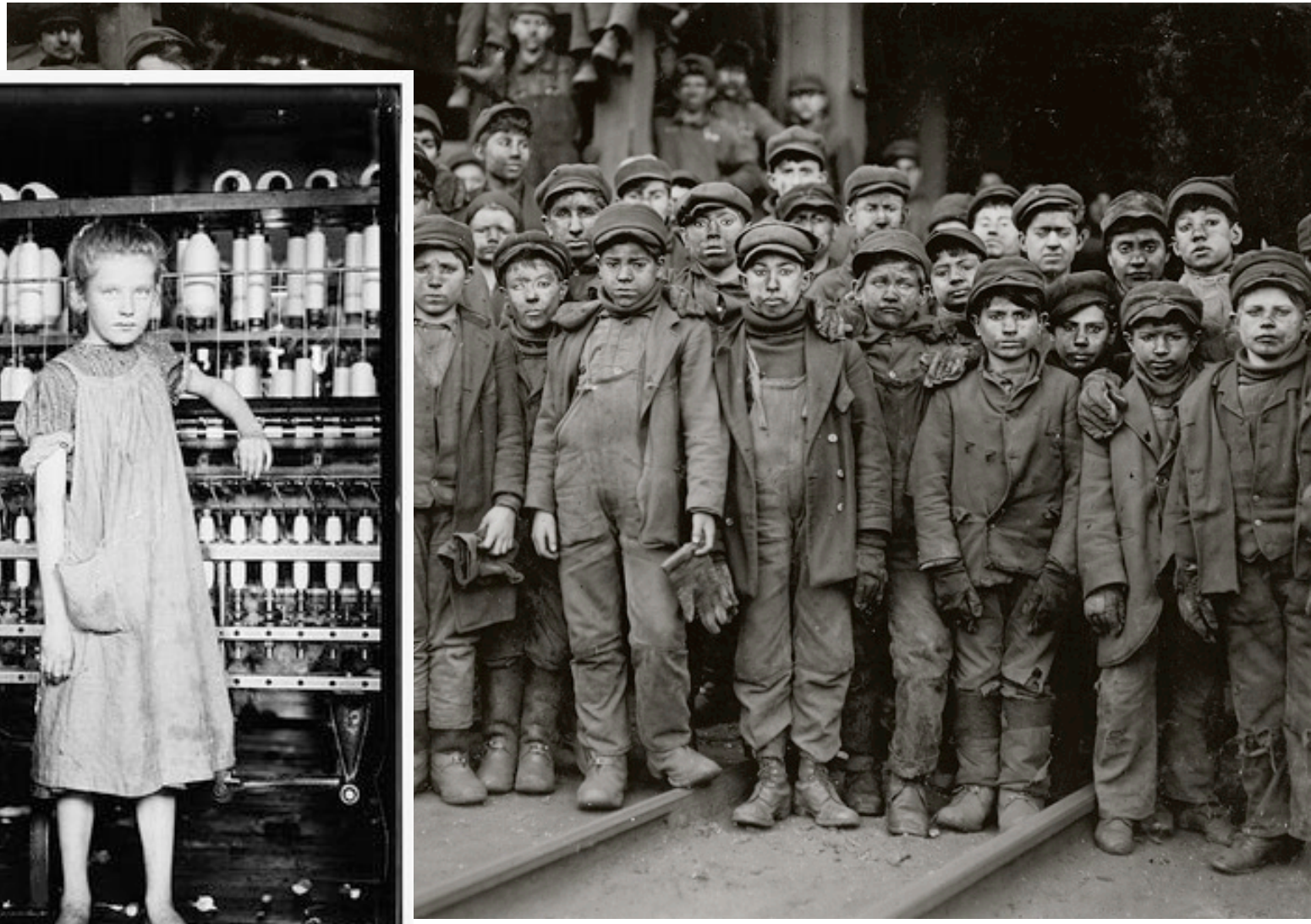
But soon ***most*** factory workers are children



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)*

Note date: U.S. replicates British history 50-100 years later

Lewis Hine, 1912, *Addie Card, 12 years, Spinner in N. Pownal Spinning Mill*



Lewis Hine, 1911, *Breaker boys working in Ewen Breaker of Pennsylvania Coal Co.*

Labor conditions prompts the first child labor laws in U.K.

- **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, those 9-16 years old can work only 69 hour weeks: 12 hours/day + 9 hours on Saturday
- **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.
- *....this prompts backlash by employers, further legislation stalls for about a decade.*
- *Only in late 1800s are protections extended to children in non-textile industries*

The "Ten Hour Movement" – should children work more than 10 hours/day?

In U.S., nearly a century behind...

- **1811:** Francis Cabot Lowell commits industrial espionage in Britain, steals plans
- **1814:** Lowell builds first U.S. textile mills in Massachusetts, hires local girls
  By 1840s, striking workers are fired, hire immigrants, conditions worsen.
- **1842:** first state labor law (Massachusetts children under 12 can't work > 10 hrs)
  by 1899, 28 states have some kind of child labor laws, 17 have none
- **1900:** 18% of children between ages 10-15 are working
- **1908:** Lewis Hine becomes photographer for National Child Labor Committee
- **1924**: failed attempt to pass constitutional amendment banning child labor
- **1938:** Fair Labor Standards Act, 1st federal limits on child labor in some industries
  max 12 hour days for all, children under 16 can't work during school hours
- **1944:** U.S. Supreme Court rules that government can regulate child labor

Several things to consider

1) What does mill layout tell you about the economics of industrial production?

2) What trends in political and economic thought conditions occurred in mid-1800s Britain?

3) Why are these two things related?

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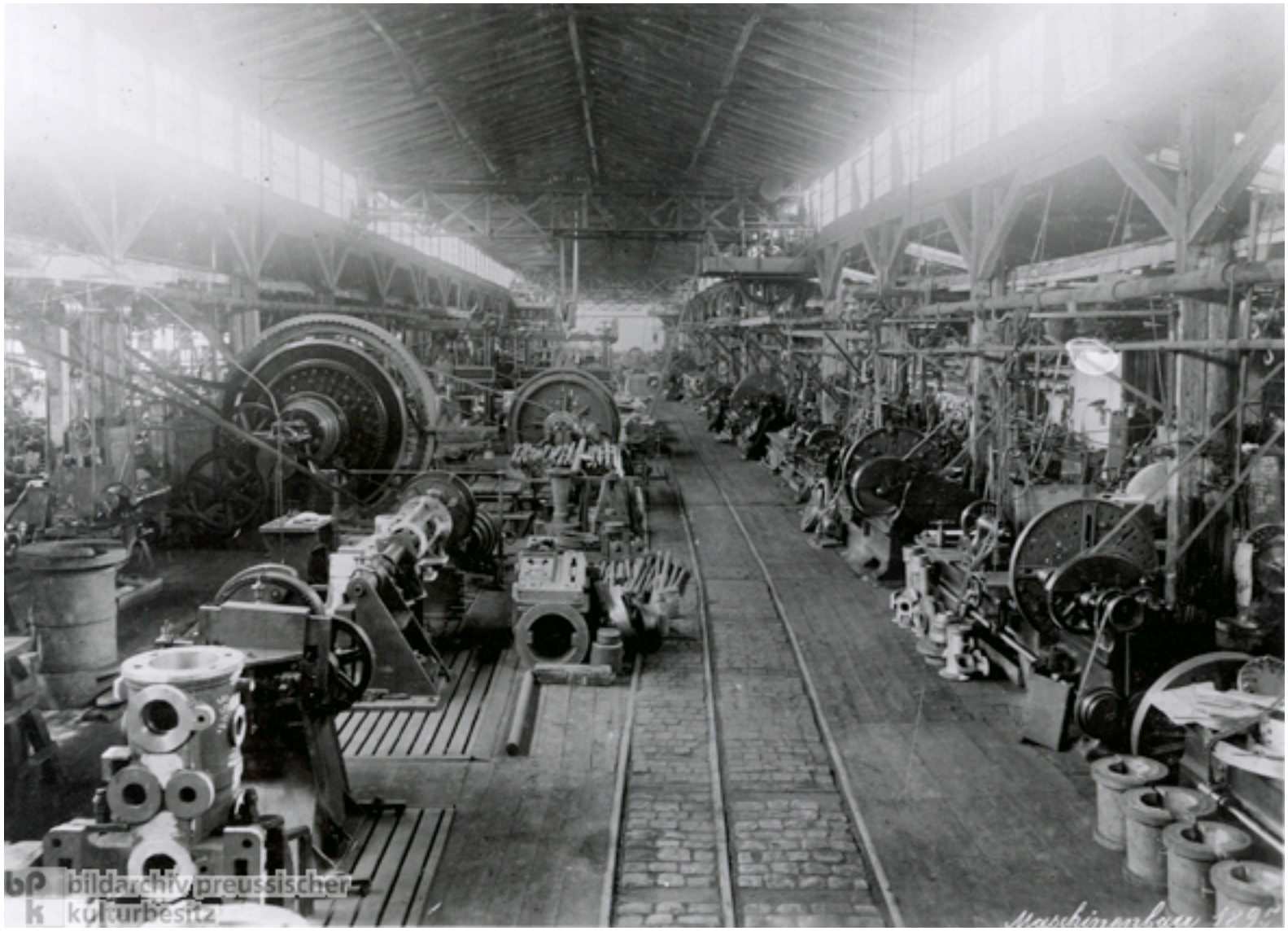
1800s: Mechanization comes to other industries



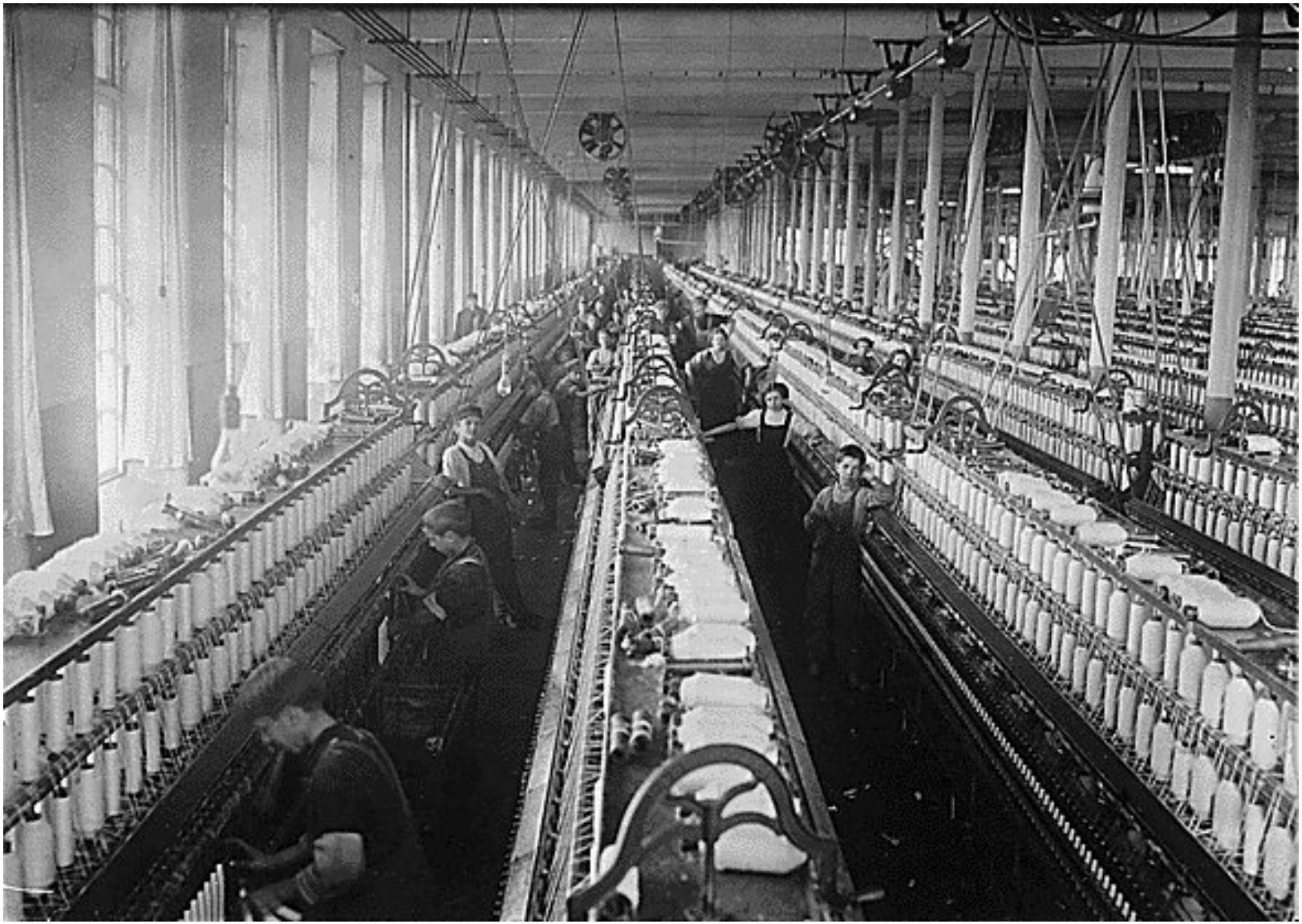
German machine shop driven by single steam engine

(© Bildarchiv Preußischer Kulturbesitz)

1800s: Mechanization comes to other industries

Machine shop, likely late 1800s *(source unknown)*

Spinning mills retain same layout, get larger



Spinning mill

(Photo: Lewis Hine, lik. 1911)

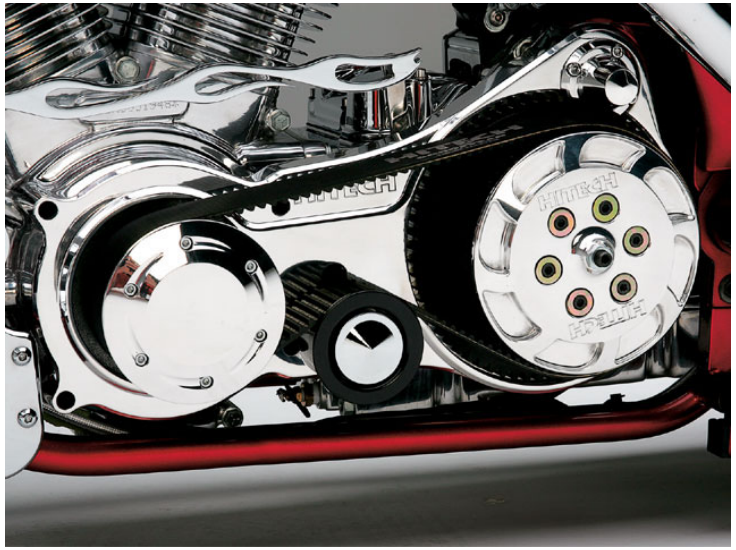
Belts transport rotational motion over long distances

Restored textile mill at Lowell, MA.
Photo Paul Marotta / Getty Images

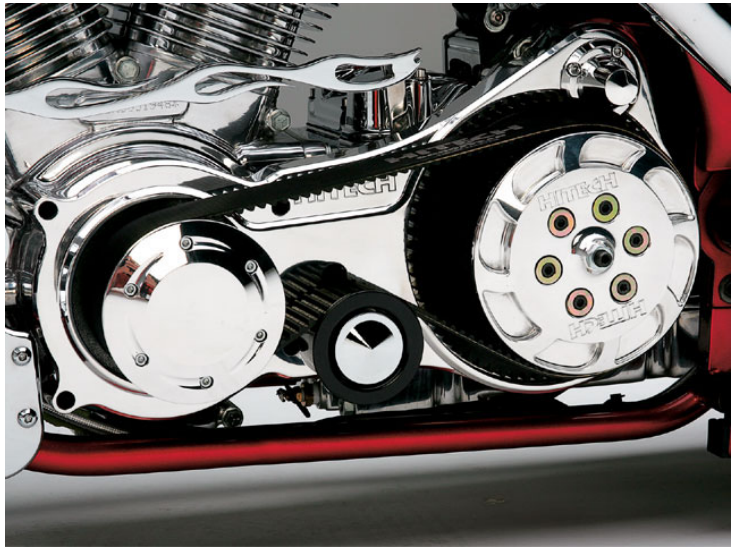
Bill Mill No. 1 in Macon, GA, 1909
Photo Lewis Hine

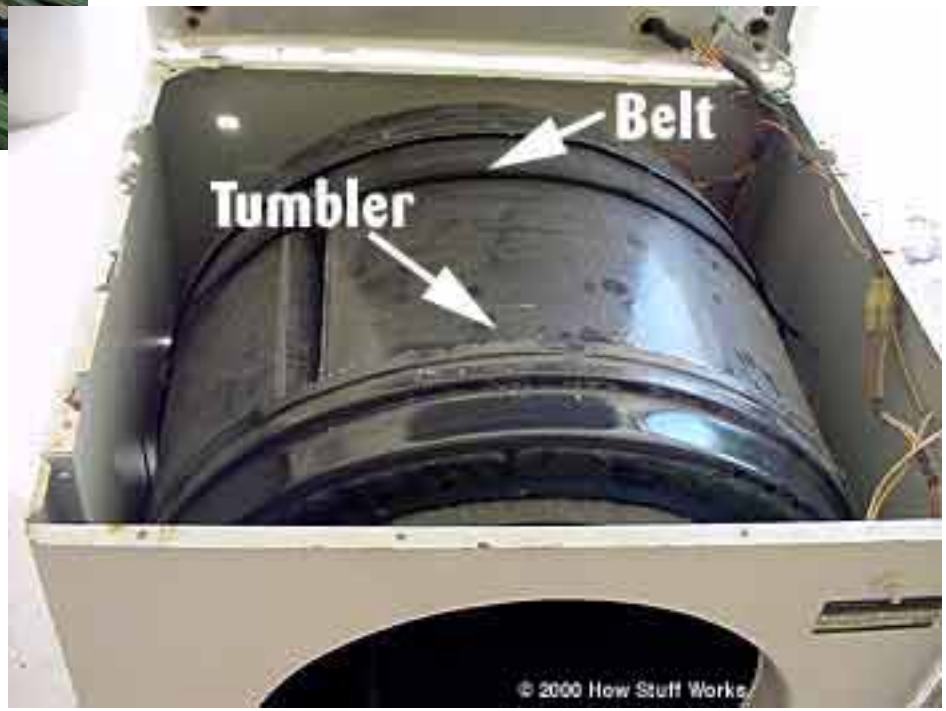
Belt and chain drives in modern life

Belt and chain drives in modern life



Belt and chain drives in modern life





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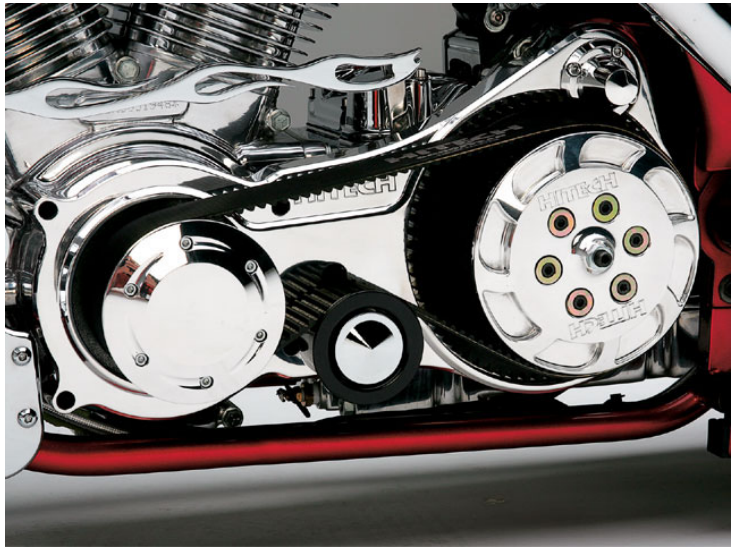

What does this mean for economic organization in the 1800s?

- No hand-worker could compete with mechanization and use of industrial power. All production in factories.
- Because kinetic energy can't be carried over long distances, every factory had to have its own power source
- *Therefore:* to be a producer you had to own your own power plant
- *Therefore:* capital required to start a business was extremely high. High labor productivity only possible with big capital investment.

Several things to consider

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Writing about the working class in Britain

1) Engels, *"The Condition of the Working Class in England", 1844*

   written after 2-year stay in Manchester


Die Lage
der
arbeitenden Klasse
in
England.

Nach eigner Anschauung und authentischen Quellen
von
Friedrich Engels.

Leipzig.
Verlag von Otto Wigand.
1845.

Evolves to general theories of the working class

1) Engels, *"The Condition of the Working Class in England", 1844*

   written after 2-year stay in Manchester

2) Marx & Engels, *"The Communist Manifesto", 1848*

   written jointly, Engels is in Manchester, Marx in Brussels

Manifest

der

Kommunistischen Partei.

Veröffentlicht im Februar 1848.

Proletarier aller Länder vereinigt Euch!

London.

Gedruckt in der Office der „Bildungs-Gesellschaft für Arbeiter"
von J. E. Burghard.

46, Liverpool Street, Bishopsgate.

Marx and Engels in Britain

1) Engels, *"The Condition of the Working Class in England", 1844*

   written after 2-year stay in Manchester

2) Marx & Engels, *"The Communist Manifesto", 1848*

   written jointly, Engels is in Manchester, Marx in Brussels

1850, Marx moves to London

supported by Engels, visits Manchester
writes for *New York Daily Tribune*

The former Red Dragon pub in Manchester where Marx and Engels hung out

Marx and Engels in Britain

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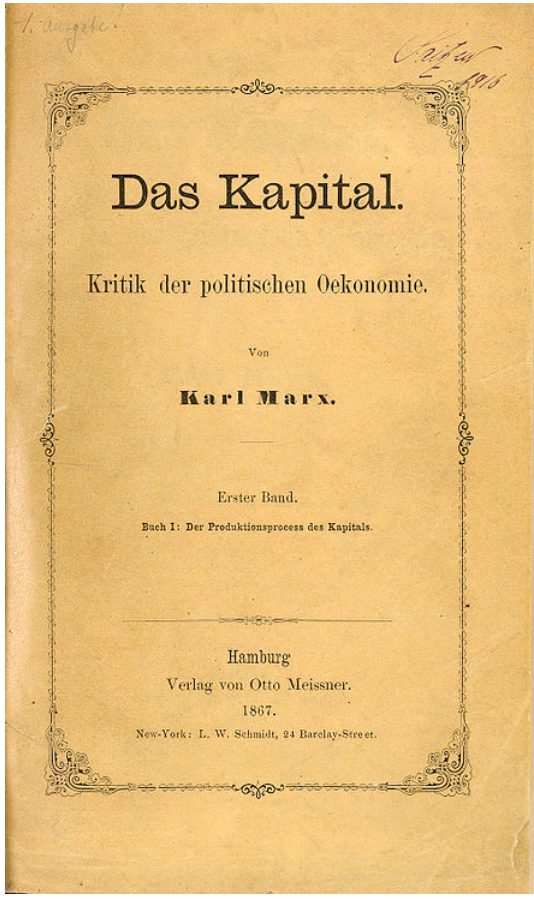
3) Marx, *"Capital", 1872-1894*

   written in London



Das Kapital.

Kritik der politischen Oekonomie.

Von

Karl Marx.

Erster Band.

Buch I: Der Produktionsprocess des Kapitals.

Hamburg
Verlag von Otto Meissner.
1867.
New-York: L. W. Schmidt, 24 Barclay-Street.

The two technological leaps of the Industrial Revolution that bring in the modern energy era *(100 years separate)*

1. ***"Heat to Work"***

   Chemical energy → mechanical work via mechanical device

   Use a temperature gradient to drive motion

   Allows use of stored energy in fossil fuels

   Allows expansion of industrial production, factories in cities

   Late 1700's: commercial adoption of steam engine

2. ***Efficient transport of energy: electrification***

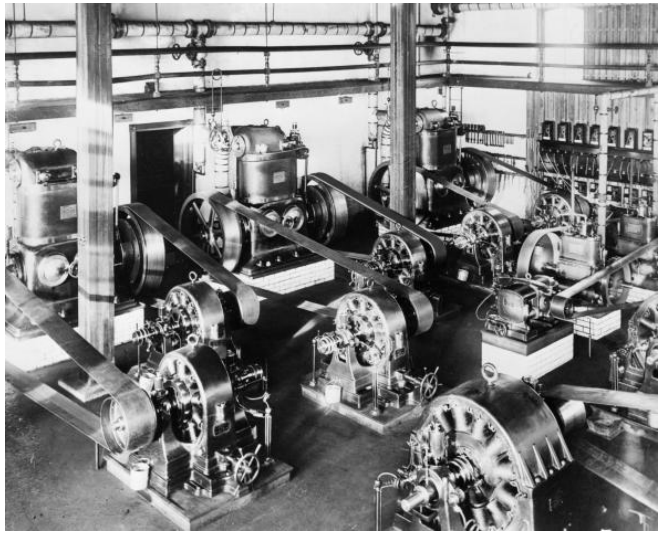
   Mechanical work → electrical energy → mech. work

   Allows central generation of power

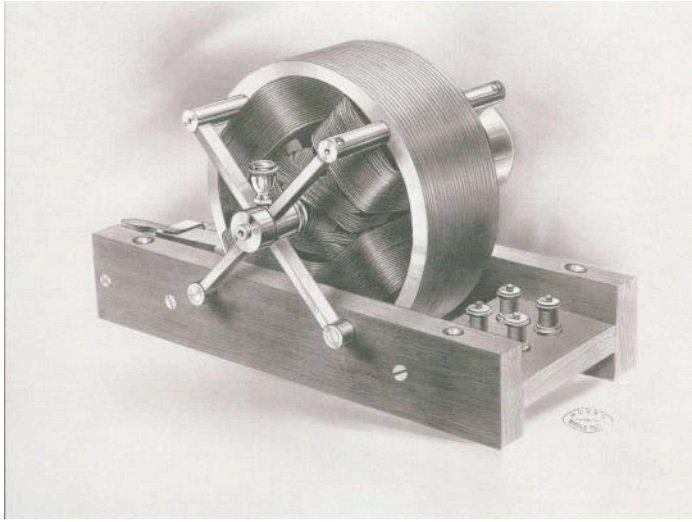
   Late 1800's: rise of electrical companies

A generator and a motor provide a way to move kinetic energy from one location to another

Kinetic ------(generator)----------> Electrical --------(motor)--------> Kinetic

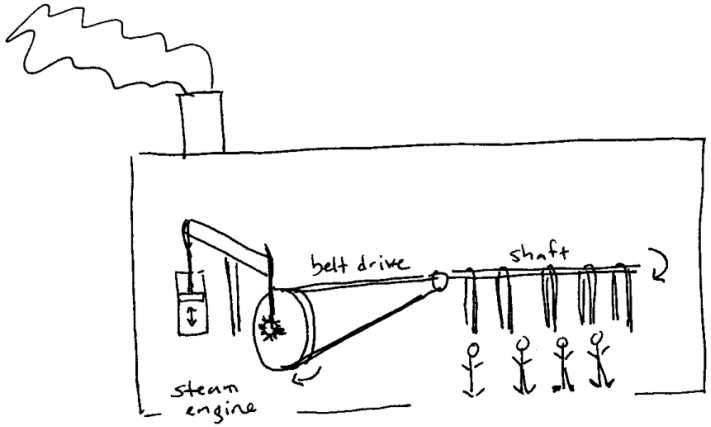


Westinghouse generators, 1888

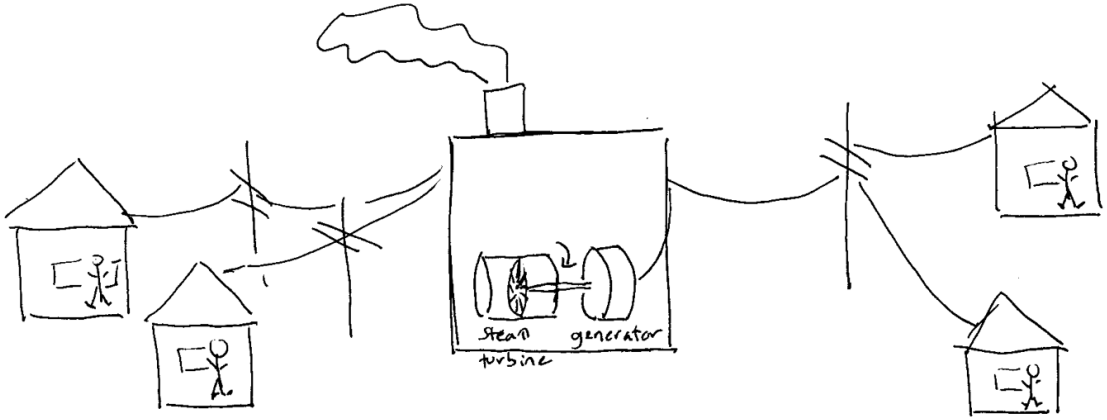


Tesla induction motor, 1888

Can electric motors reduce the terrible capital requirements of the 19th century?



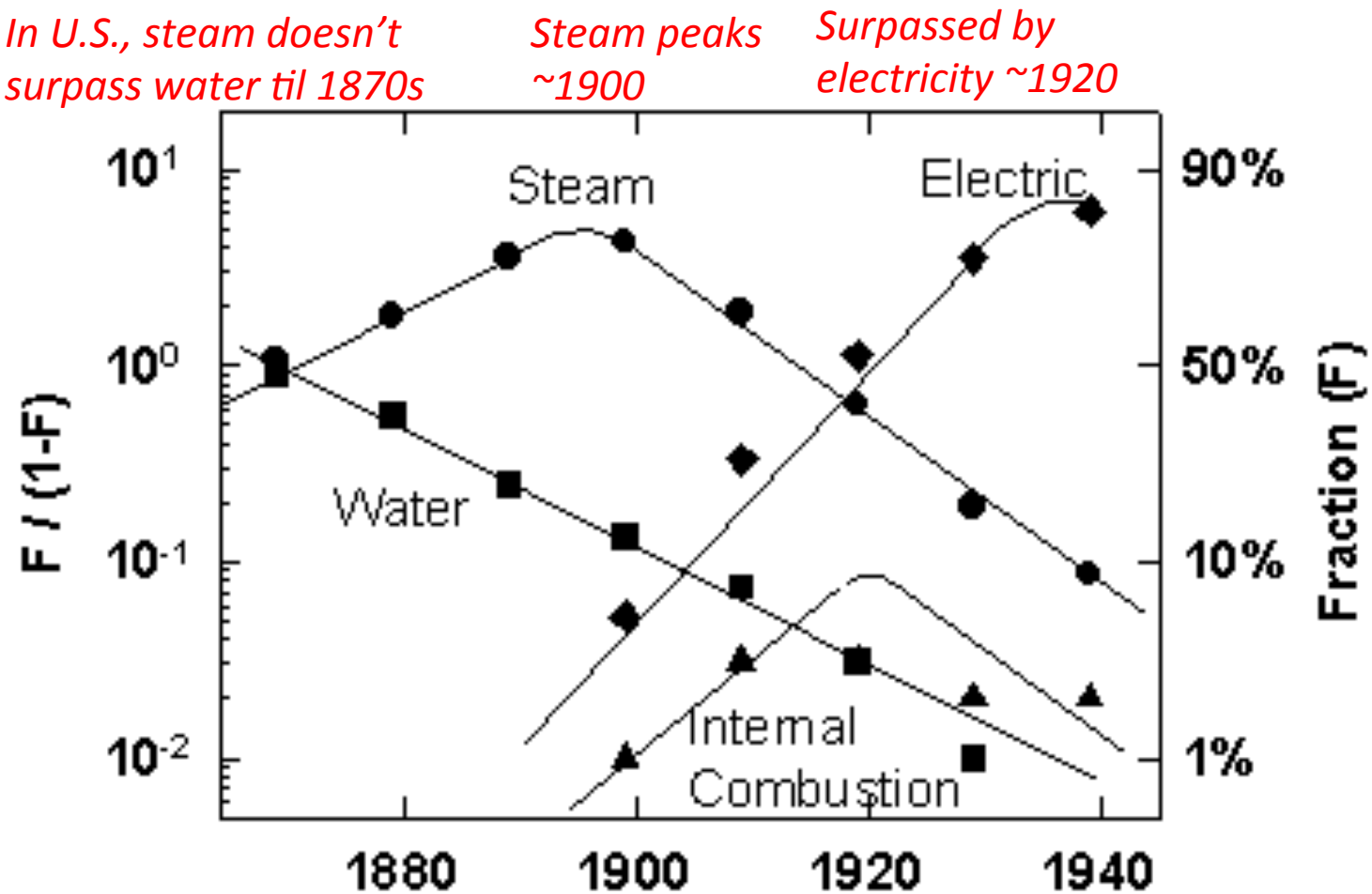
Pre-electrification – must own power plant, all workers in one place. Power = power



Post-electrification – dispersed work possible, and workers now own the means of production (if utilities are public).

Main use of electricity is take rotational motion in one place and "move" it somewhere else

In U.S., electricity quickly (~50 years) becomes **dominant means of delivering kinetic energy** for factories and motors



Sources of Power for Mechanical Drives in the United States.

Data Source: Warren D. Devine, Jr., "From Shafts to Wires: Historical Perspective on Electrification," *Journal of Economic History* 43 (1983): 347_372; Table 3, p. 351.
From: Ausubel, J. Daedalus 125(3):139-169, 1996.

For most of 1800s, U.S. had little industry and abundant water-power

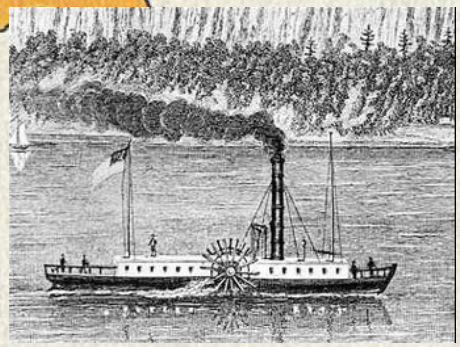
revolutionary impact of heat engines in U.S. history comes via transportation instead

Steam is important in **1810** North America

OREGON COUNTRY
LOUISIANA
PURCHASE
LOUISIANA TERRITORY 1805
1803
(Spain)
ILLINOIS TERR 1809
MICH TERR 1805
IND TERR (1809)
OHIO 1803
MISSISSIPPI TERR (1804)
ORLEANS TERR 1804

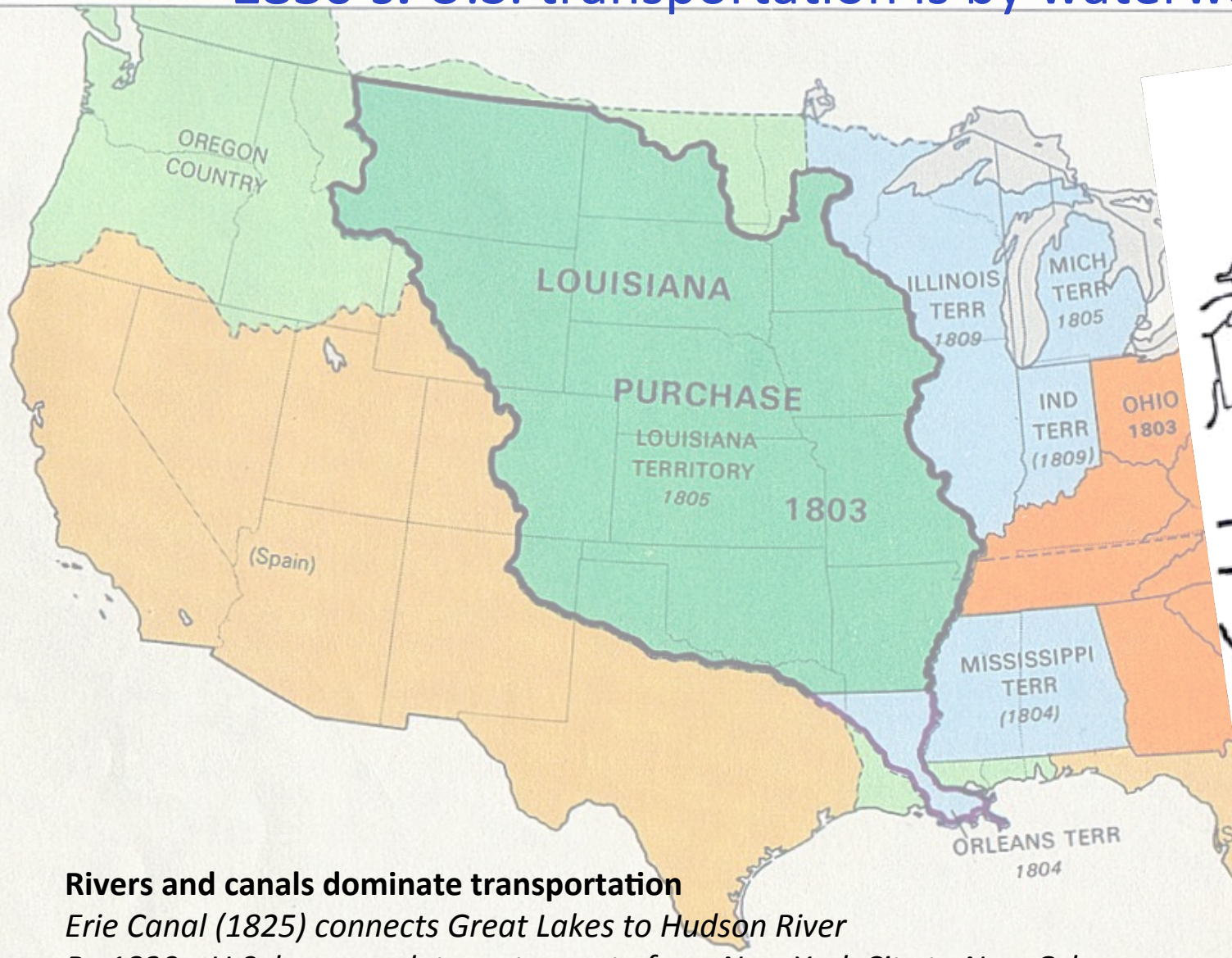
Boats before trains

First U.S. trial of steam boat 1787,
Philadelphia (Fitch), patent 1791
Fulton begins submarine 1793 (in France)
Fulton's first steamboat in U.S. 1807, traveled NYC → Albany
First steam boat on Mississippi 1811
Steam boats dominate rivers by 1830s



Fulton's *"Clerment"*, 1811

1830's: U.S. transportation is by waterway



Rivers and canals dominate transportation

Erie Canal (1825) connects Great Lakes to Hudson River

By 1830s, U.S. has complete water route from New York City to New Orleans

.. and U.S. is world's largest cotton producer

siana purchased from France

1830 map of railways in U.S.

Rivers and canals dominate transportation

Erie Canal (1825) connects Great Lakes to Hudson River

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.. and U.S. is world's largest cotton producer

1840 map of railways in U.S.

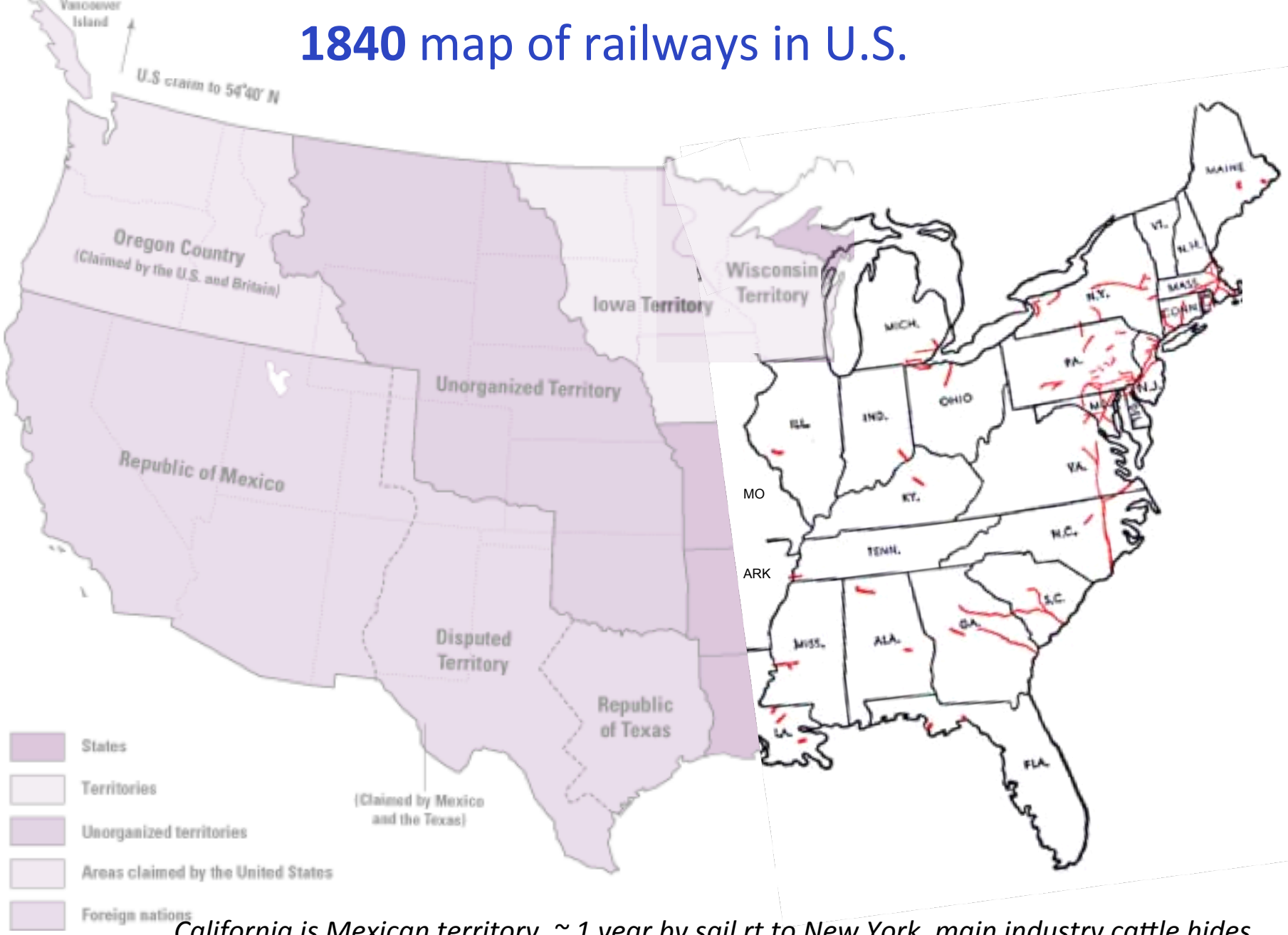
Rivers and canals dominate transportation

Railroads help get crops to water, steamboats are still key

Betw. 1830-1840, add Ark. and Mich. to get 26 states. Florida still a territory.

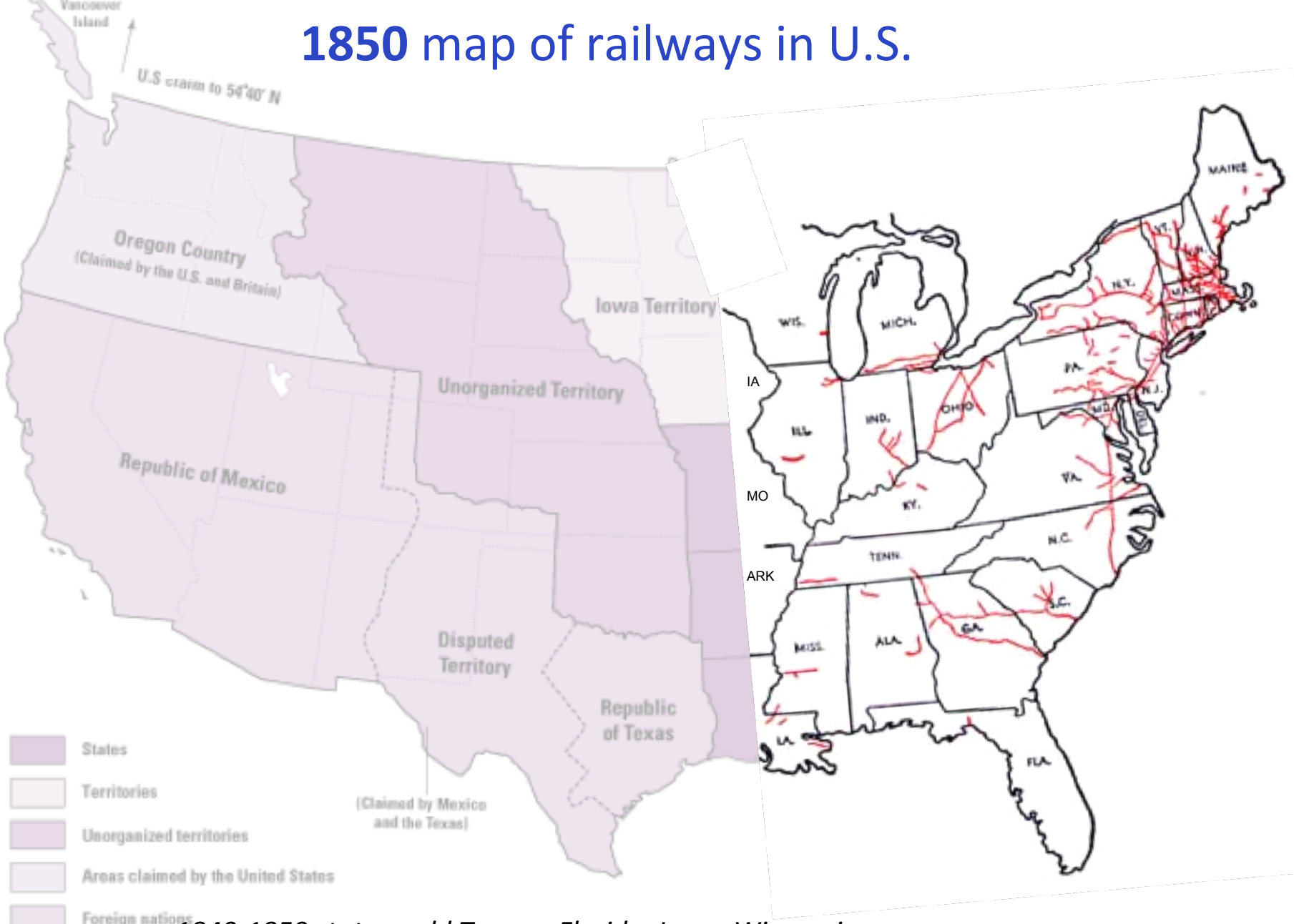
Steamboats in popular imagination: Mark Twain's "Tom Sawyer", "Huckleberry Finn" set in 1840s

1840 map of railways in U.S.



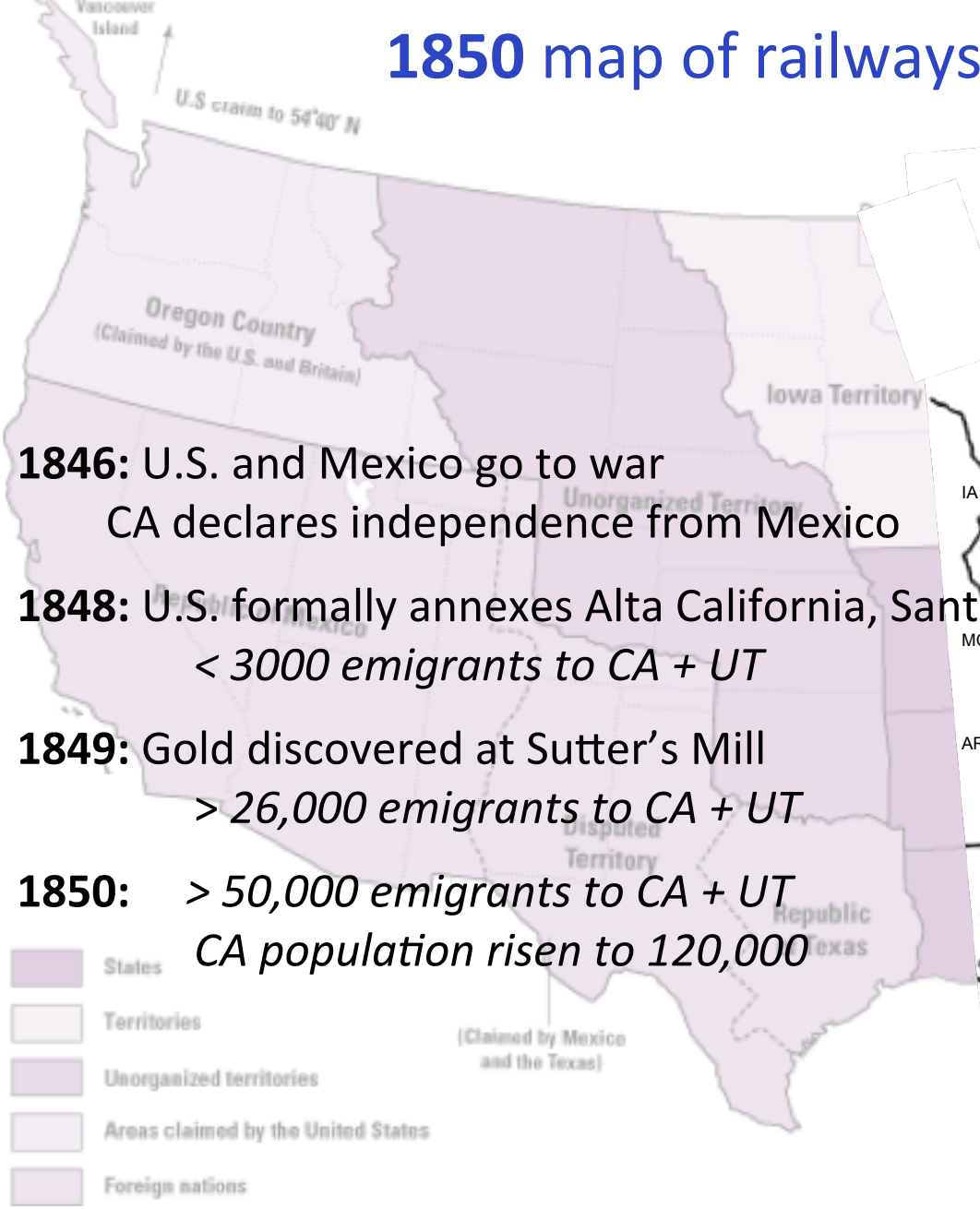
California is Mexican territory, ~ 1 year by sail rt to New York, main industry cattle hides.
Total population about 8,000 non-Indian, San Francisco < 200 people

1850 map of railways in U.S.



1840-1850 states: add Texas + Florida, Iowa, Wisconsin.
California still Mexican til 1846

1850 map of railways in U.S.

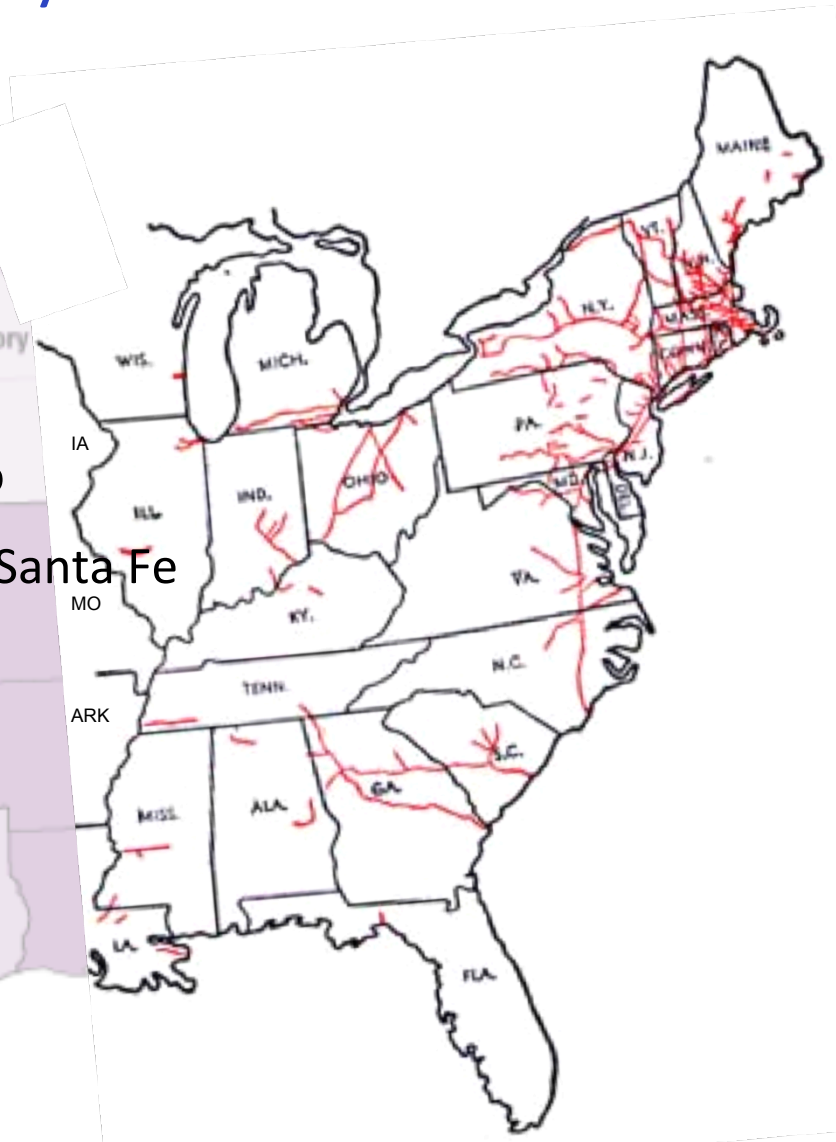


1846: U.S. and Mexico go to war
CA declares independence from Mexico

1848: U.S. formally annexes Alta California, Santa Fe
< 3000 emigrants to CA + UT

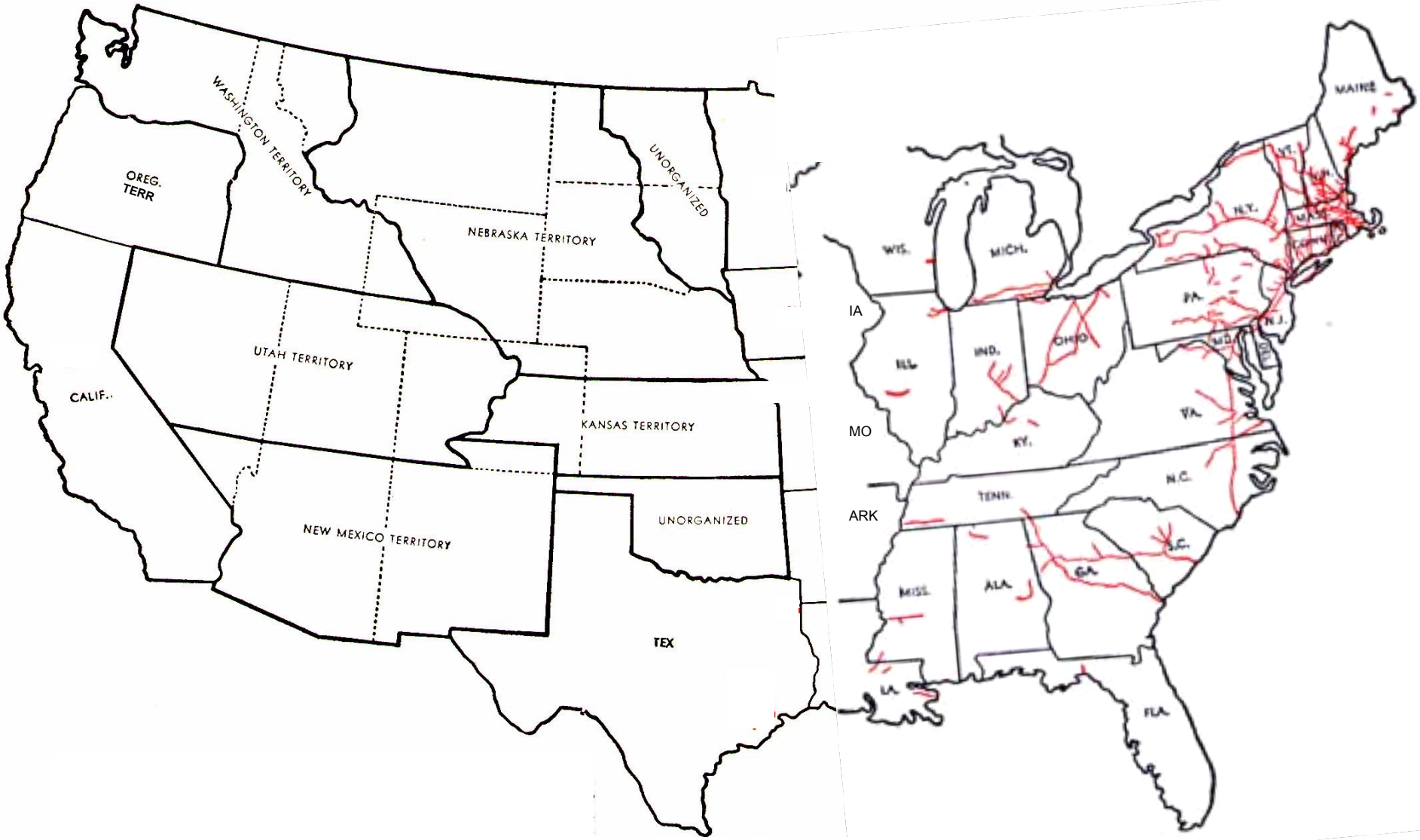
1849: Gold discovered at Sutter's Mill
> 26,000 emigrants to CA + UT

1850: *> 50,000 emigrants to CA + UT*
CA population risen to 120,000



Statistics from Hill, "The Oregon Trail, Yesterday and Today"

1850 map of railways in U.S.

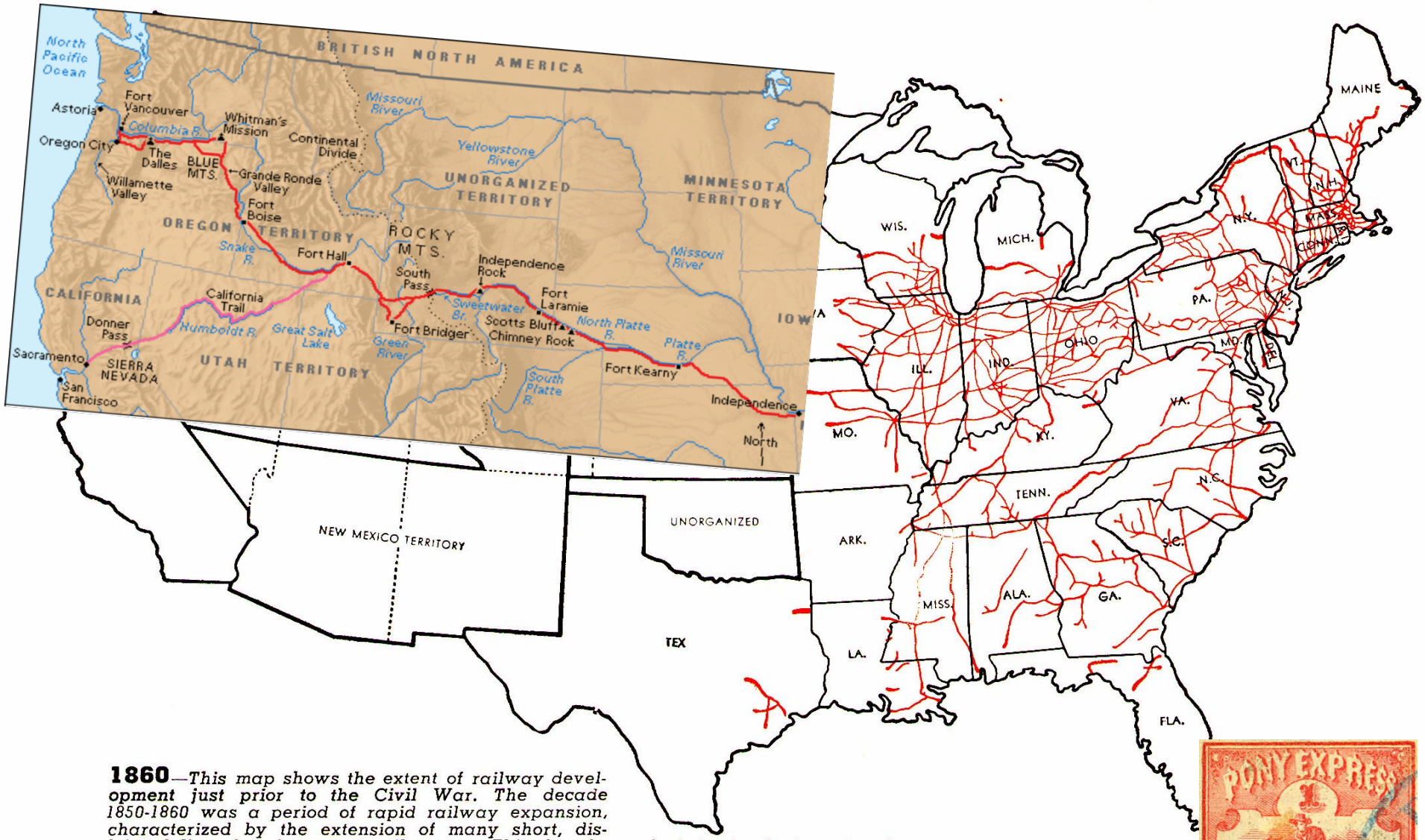


1850s: "frontier" actually middle of country: states in West and East, territories in between

1850 map of railways in U.S.

1850s: beginning of "Pioneer era": walk 4-6 months

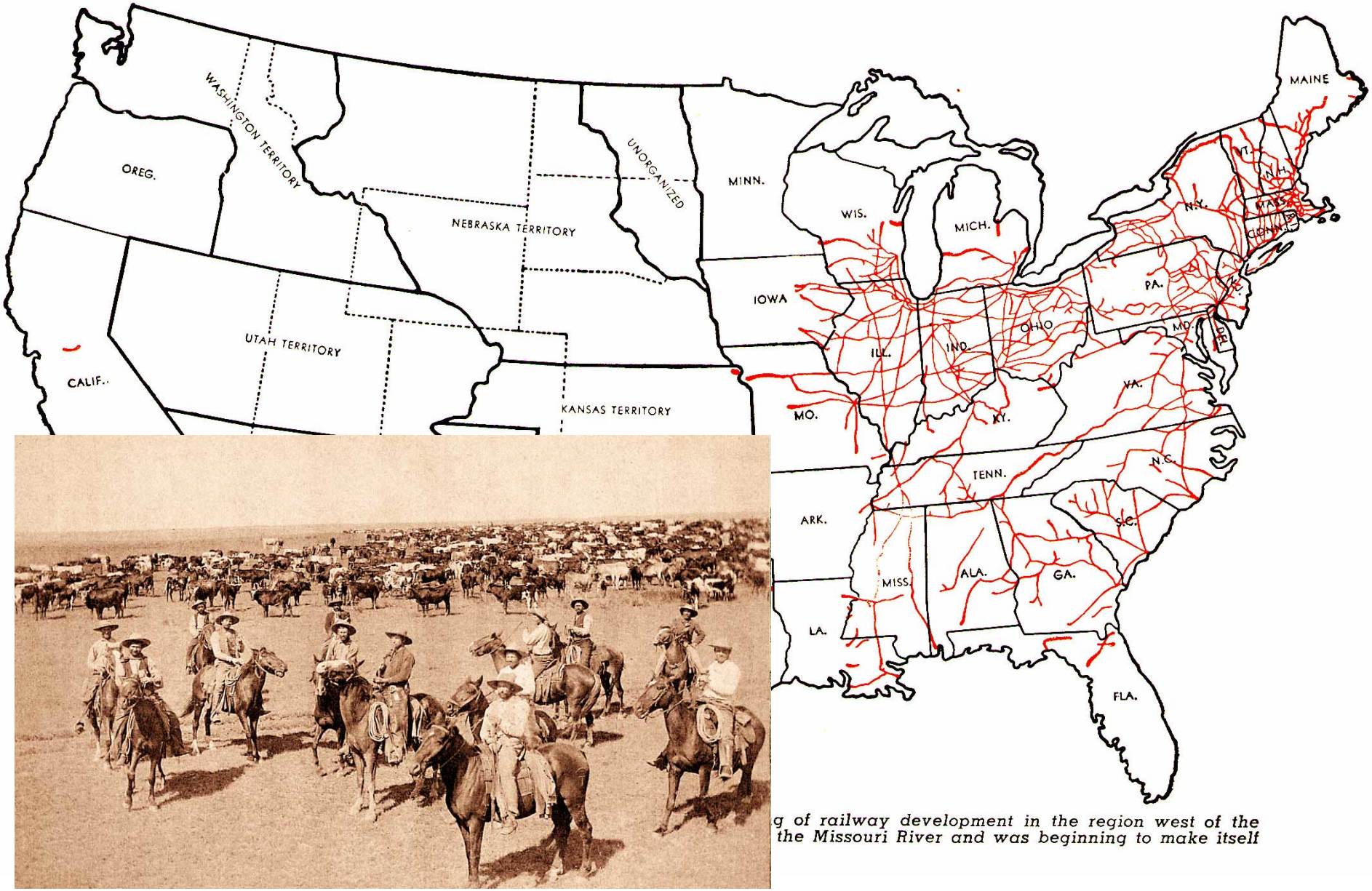
1860 map of railways in U.S.



1860—*This map shows the extent of railway development just prior to the Civil War. The decade 1850-1860 was a period of rapid railway expansion, characterized by the extension of many short, disjointed lines into important rail routes. This decade marked the beginning of railway development in the region Mississippi River. By 1860, the "Iron Horse" had penetrated westward to the Missouri River and was beginning to felt in Iowa, Arkansas, Texas, and California.*

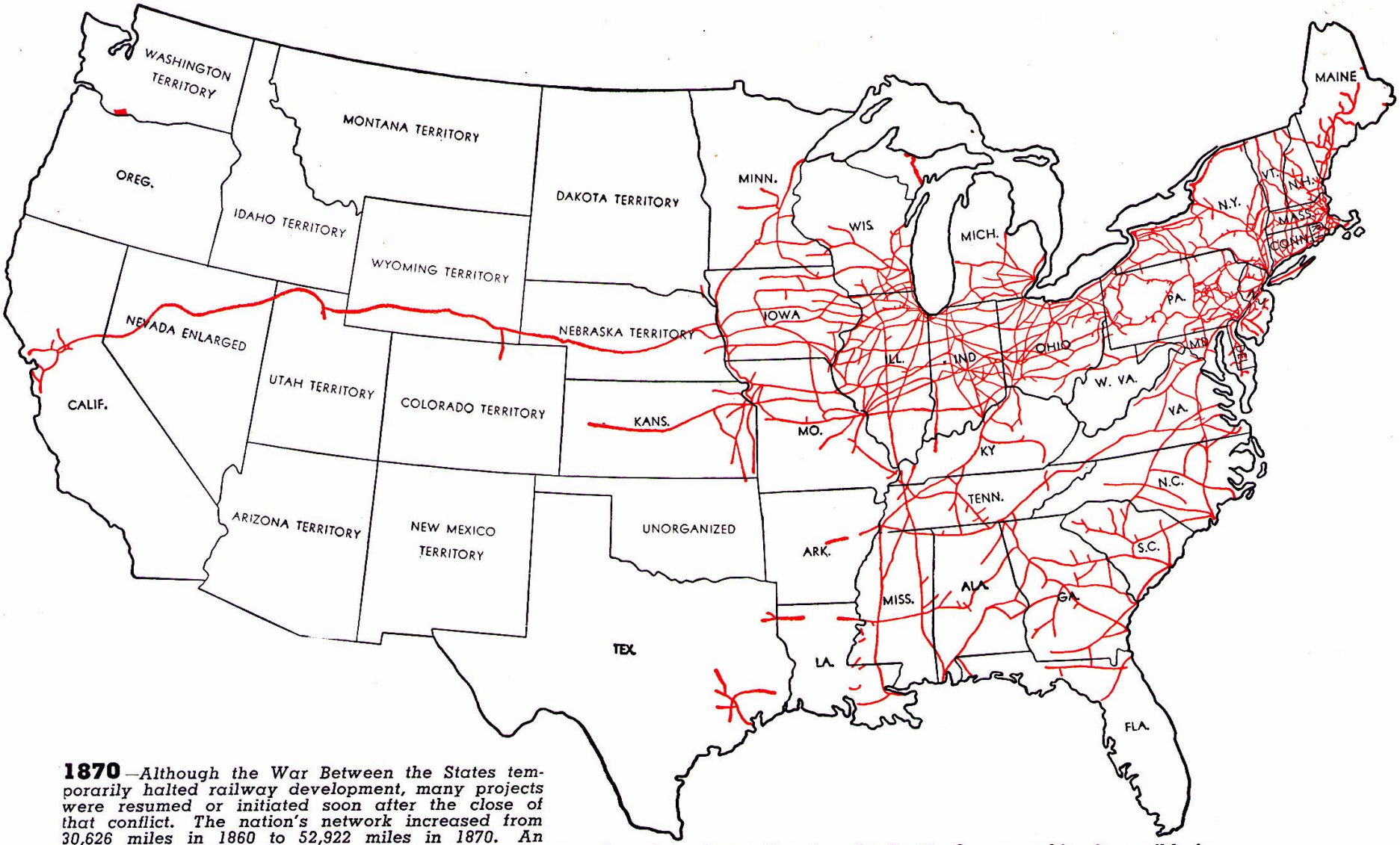
1860-61: Pony Express carries mail from St. Joseph MO to Sacramento CA, 7 days

1860 map of railways in U.S.



1860s: "cowboy era" of cattle drives begins: first meatpacking plant in Chicago, 1865

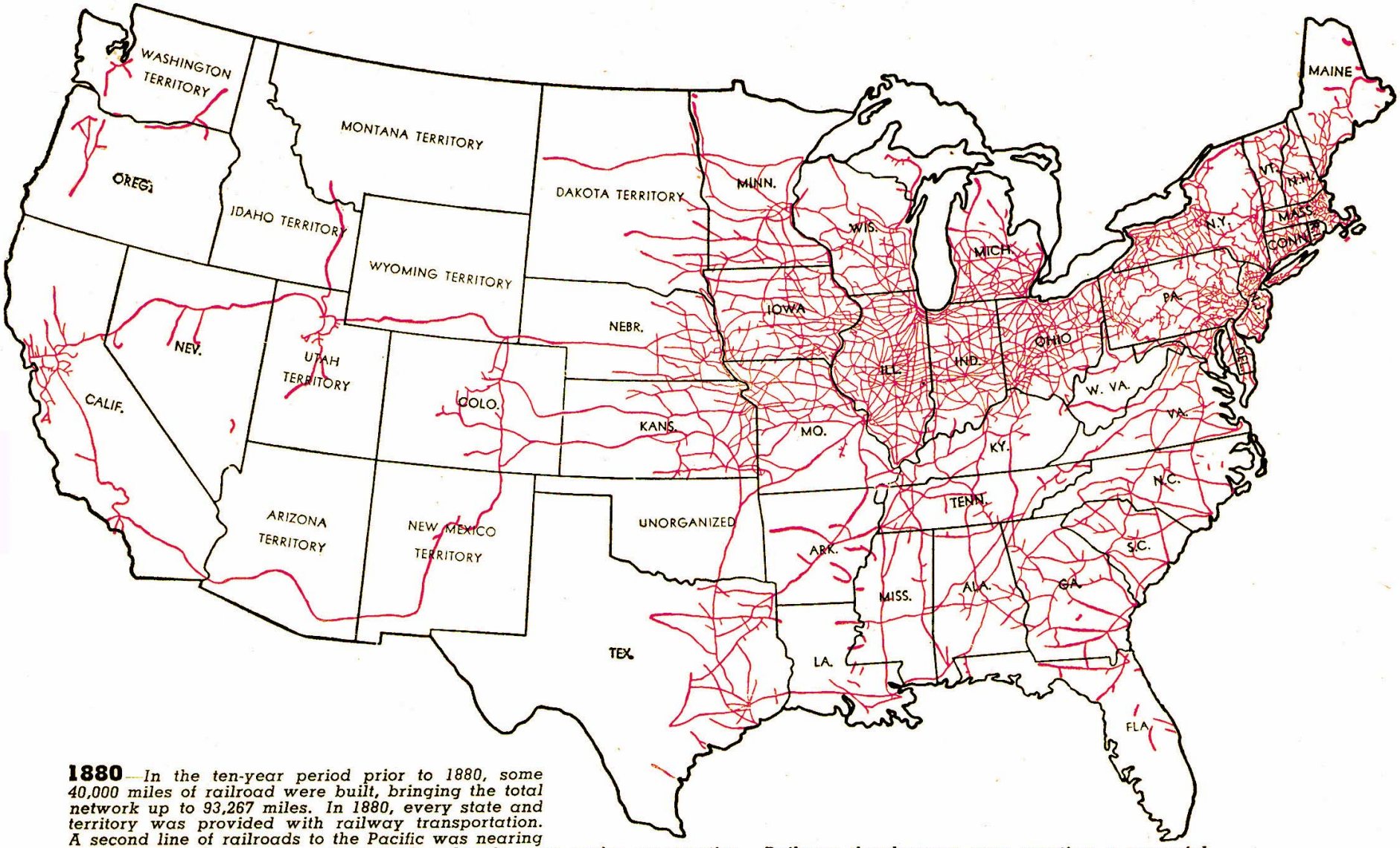
1870 map of railways in U.S.



1870—*Although the War Between the States temporarily halted railway development, many projects were resumed or initiated soon after the close of that conflict. The nation's network increased from 30,626 miles in 1860 to 52,922 miles in 1870. An outstanding development of the decade was the construction of the first railroad to the Pacific Ocean, making it possible for the first time to travel all the way across the country by rail. Railway development in the Mississippi and Missouri valleys was especially notable during this period.*

1870s: cattle drives to Abilene & Dodge City KS, barbed wire introduced, range wars begin

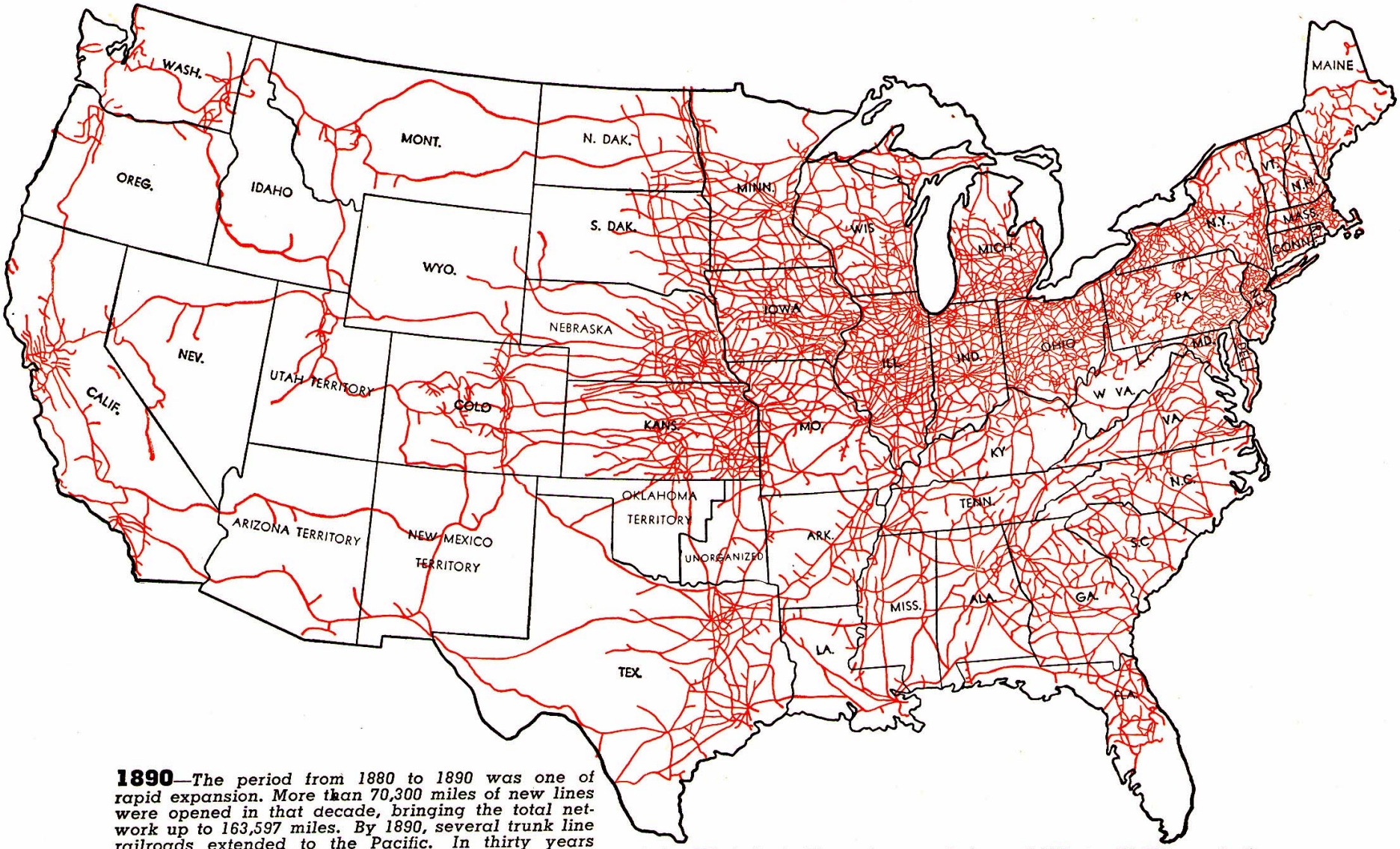
1880 map of railways in U.S.



1880—*In the ten-year period prior to 1880, some 40,000 miles of railroad were built, bringing the total network up to 93,267 miles. In 1880, every state and territory was provided with railway transportation. A second line of railroads to the Pacific was nearing completion, and other transcontinental railroads were under construction. Railway development was exerting a powerful influence upon immigration and agricultural and industrial growth throughout the country.*

1880s: cowboy era is ending, first meatpacking plants W. of Chicago

1890 map of railways in U.S.



1890—*The period from 1880 to 1890 was one of rapid expansion. More than 70,300 miles of new lines were opened in that decade, bringing the total network up to 163,597 miles. By 1890, several trunk line railroads extended to the Pacific. In thirty years from 1860 to 1890, the total mileage of the region west of the Mississippi River increased from 2,175 to 72,389, and the population of that area increased fourfold.*

1890: frontier is declared closed