Range of Materials & Processes in a Tractor

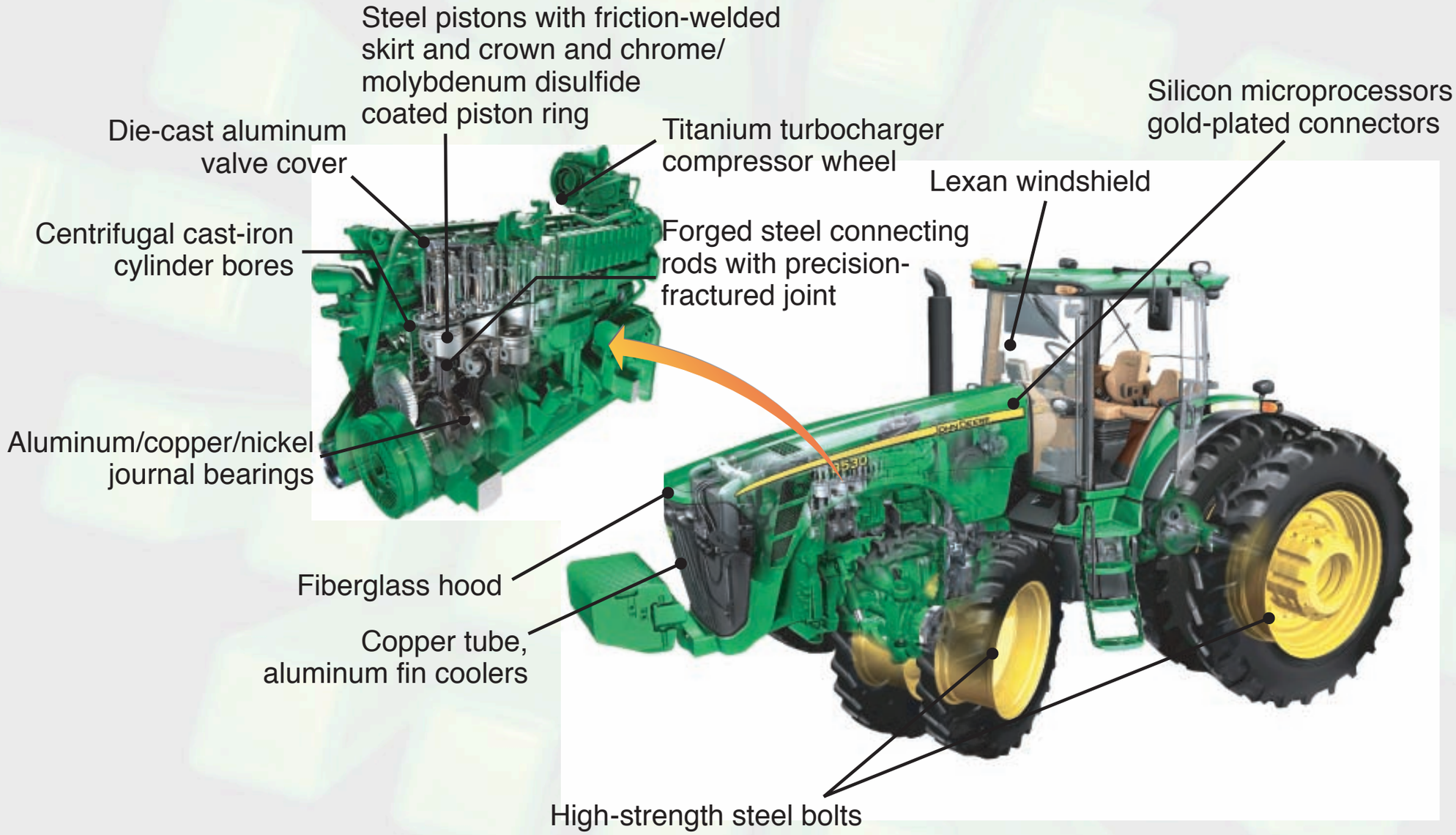

FIGURE 1.1 Model 8430 tractor, with detailed illustration of its diesel engine, showing the variety of materials and processes incorporated. *Source:* Courtesy of John Deere Company.

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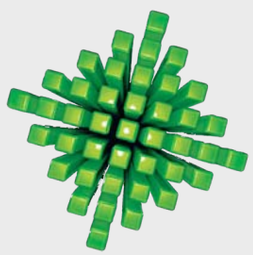
History of Manufacturing

TABLE 1.1

Historical Development of Materials and Manufacturing Processes

Period	Dates	Metals and casting	Various materials and composites	Forming and shaping	Joining	Tools, machining, and manufacturing systems
	Before 4000 B.C.	Gold, copper, meteoric iron	Earthenware, glazing, natural fibers	Hammering		Tools of stone, flint, wood, bone, ivory, composite tools
	4000–3000 B.C.	Copper casting, stone and metal molds, lost-wax process, silver, lead, tin, bronze		Stamping, jewelry	Soldering (Cu-Au, Cu-Pb, Pb-Sn)	Corundum (alumina, emery)
Egypt: 3100 B.C. to 300 B.C. Greece: 1100 B.C. to 146 B.C. Roman Empire: 500 B.C. to 476 A.D. Middle Ages: 476 to 1492 Renaissance: 14th to 16th centuries	3000–2000 B.C.	Bronze casting and drawing, gold leaf	Glass beads, potter's wheel, glass vessels	Wire by slitting sheet metal	Riveting, brazing	Hoe making, hammered axes, tools for ironmaking and carpentry
	2000–1000 B.C.	Wrought iron, brass				
	1000–1 B.C.	Cast iron, cast steel	Glass pressing and blowing	Stamping of coins	Forge welding of iron and steel, gluing	Improved chisels, saws, files, woodworking lathes
	1–1000 A.D.	Zinc, steel	Venetian glass	Armor, coining, forging, steel swords		Etching of armor
	1000–1500	Blast furnace, type metals, casting of bells, pewter	Crystal glass	Wire drawing, gold- and silversmith work		Sandpaper, windmill-driven saw
	1500–1600	Cast-iron cannon, tinplate	Cast plate glass, flint glass	Water power for metalworking, rolling mill for coinage strips		Hand lathe for wood
	1600–1700	Permanent-mold casting, brass from copper and metallic zinc	Porcelain	Rolling (lead, gold, silver), shape rolling (lead)		Boring, turning, screw-cutting lathe, drill press



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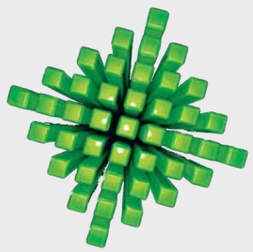
History of Manufacturing (cont.)

TABLE 1.1

Historical Development of Materials and Manufacturing Processes (cont.)

Period	Dates	Metals and casting	Various materials and composites	Forming and shaping	Joining	Tools, machining, and manufacturing systems
Industrial Revolution: 1750 to 1850	1700–1800	Malleable cast iron, crucible steel (iron bars and rods)		Extrusion (lead pipe), deep drawing, rolling		
	1800–1900	Centrigufal casting, Bessemer process, electrolytic aluminum, nickel steels, babbitt, galvanized steel, powder metallurgy, open-hearth steel	Window glass from slit cylinder, light bulb, vulcanization, rubber processing, polyester, styrene, celluloid, rubber extrusion, molding	Steam hammer, steel rolling, seamless tube, steel-rail rolling, continuous rolling, electroplating		Shaping, milling, copying lathe for gunstocks, turret lathe, universal milling machine, vitrified grinding wheel
	1900–1920		Automatic bottle making, bakelite, borosilicate glass	Tube rolling, hot extrusion	Oxyacetylene; arc, electrical-resistance, and thermit welding	Geared lathe, automatic screw machine, hobbing, high-speed-steel tools, aluminum oxide and silicon carbide (synthetic)
WWI	1920–1940	Die casting	Development of plastics, casting, molding, polyvinyl chloride, cellulose acetate, polyethylene, glass fibers	Tungsten wire from metal powder	Coated electrodes	Tungsten carbide, mass production, transfer machines
WWII	1940–1950	Lost-wax process for engineering parts	Acrylics, synthetic rubber, epoxies, photosensitive glass	Extrusion (steel), swaging, powder metals for engineering parts	Submerged arc welding	Phosphate conversion coatings, total quality control
	1950–1960	Ceramic mold, nodular iron, semiconductors, continuous casting	Acrylonitrile-butadiene-styrene, silicones, fluorocarbons, polyurethane, float glass, tempered glass, glass ceramics	Cold extrusion (steel), explosive forming, thermomechanical processing	Gas metal arc, gas tungsten arc, and electroslag welding; explosion welding	Electrical and chemical machining, automatic control



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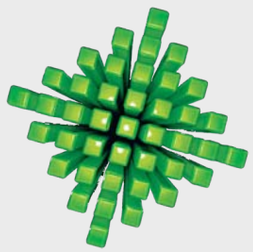
History of Manufacturing (conc.)

TABLE 1.1

Historical Development of Materials and Manufacturing Processes (cont.)

Period	Dates	Metals and casting	Various materials and composites	Forming and shaping	Joining	Tools, machining, and manufacturing systems
	1960–1970	Squeeze casting, single-crystal turbine blades	Acetals, polycarbonate, cold forming of plastics, reinforced plastics, filament winding	Hydroforming, hydrostatic extrusion, electroforming	Plasma-arc and electron-beam welding, adhesive bonding	Titanium carbide, synthetic diamond, numerical control, integrated circuit chip
Space Age	1970–1990	Compacted graphite, vacuum casting, organically bonded sand, automation of molding and pouring, rapid solidification, metal-matrix composites, semisolid metalworking, amorphous metals, shape-memory alloys (smart materials), computer simulation	Adhesives, composite materials, semiconductors, optical fibers, structural ceramics, ceramic-matrix composites, biodegradable plastics, electrically conducting polymers	Precision forging, isothermal forging, superplastic forming, dies made by computer-aided design and manufacturing, net-shape forging and forming, computer simulation	Laser beam, diffusion bonding (also combined with superplastic forming), surface-mount soldering	Cubic boron nitride, coated tools, diamond turning, ultraprecision machining, computer-integrated manufacturing, industrial robots, machining and turning centers, flexible-manufacturing systems, sensor technology, automated inspection, expert systems, artificial intelligence, computer simulation and optimization
Information Age	1990–2000s	Rheocasting, computer-aided design of molds and dies, rapid tooling	Nanophase materials, metal foams, advanced coatings, high-temperature superconductors. machinable ceramics, diamondlike carbon	Rapid prototyping, rapid tooling, environmentally friendly metalworking fluids	Friction stir welding, lead-free solders, laser butt-welded (tailored) sheet-metal blanks, electrically conducting adhesives	Micro- and nano-fabrication, LIGA (a German acronym for a process involving lithography, electroplating, and molding), dry etching, linear motor drives, artificial neural networks, six sigma

Source: J.A. Schey, C.S. Smith, R.F. Tylecote, T.K. Derry, T.I. Williams, S.R. Schmid, and S. Kalpakjian.



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Manufacturing Importance

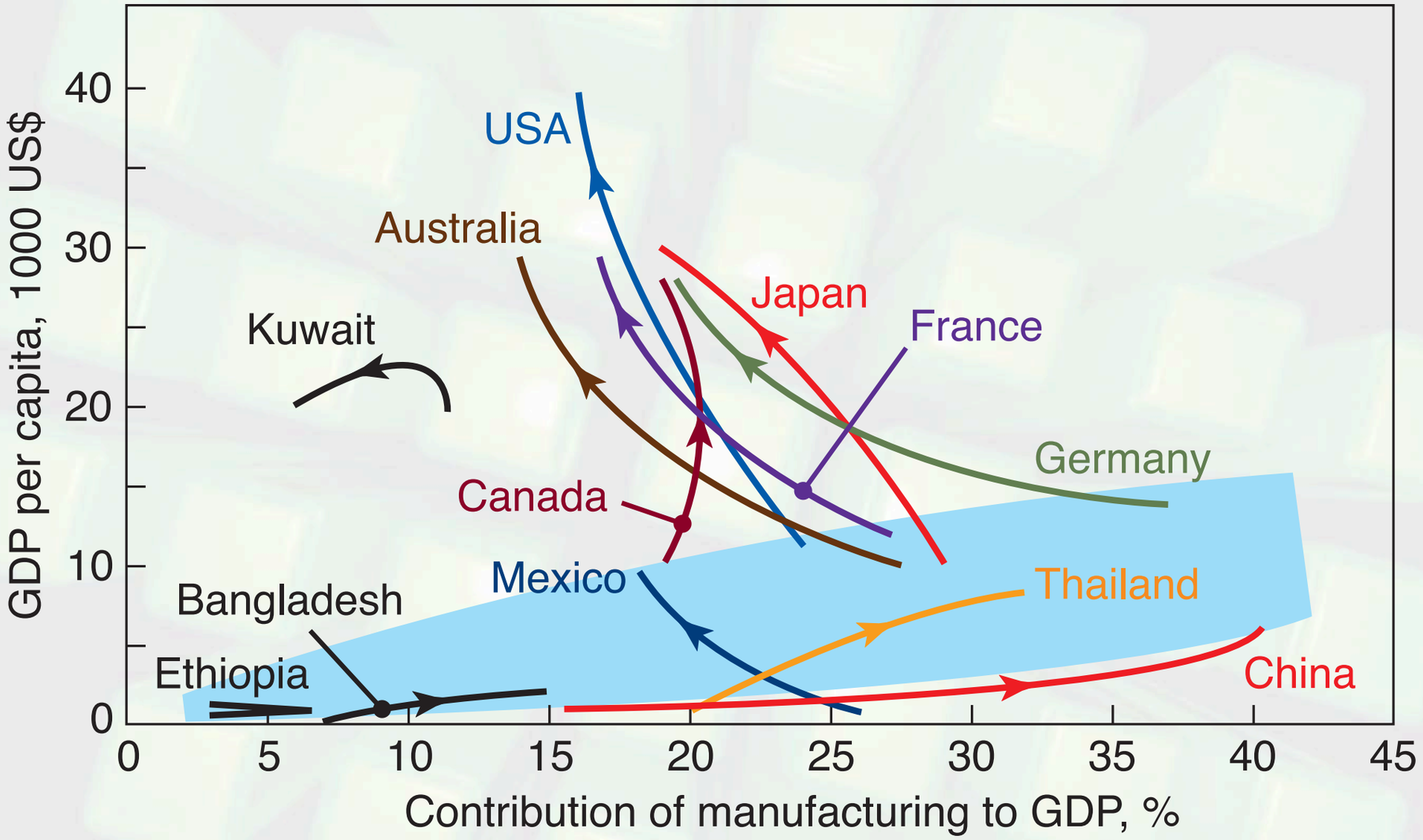

FIGURE 1.2 Importance of manufacturing to national economies. The trends shown are from 1982 until 2006. *Source:* After J.A. Schey with data from the *World Development Report*, World Bank, various years.

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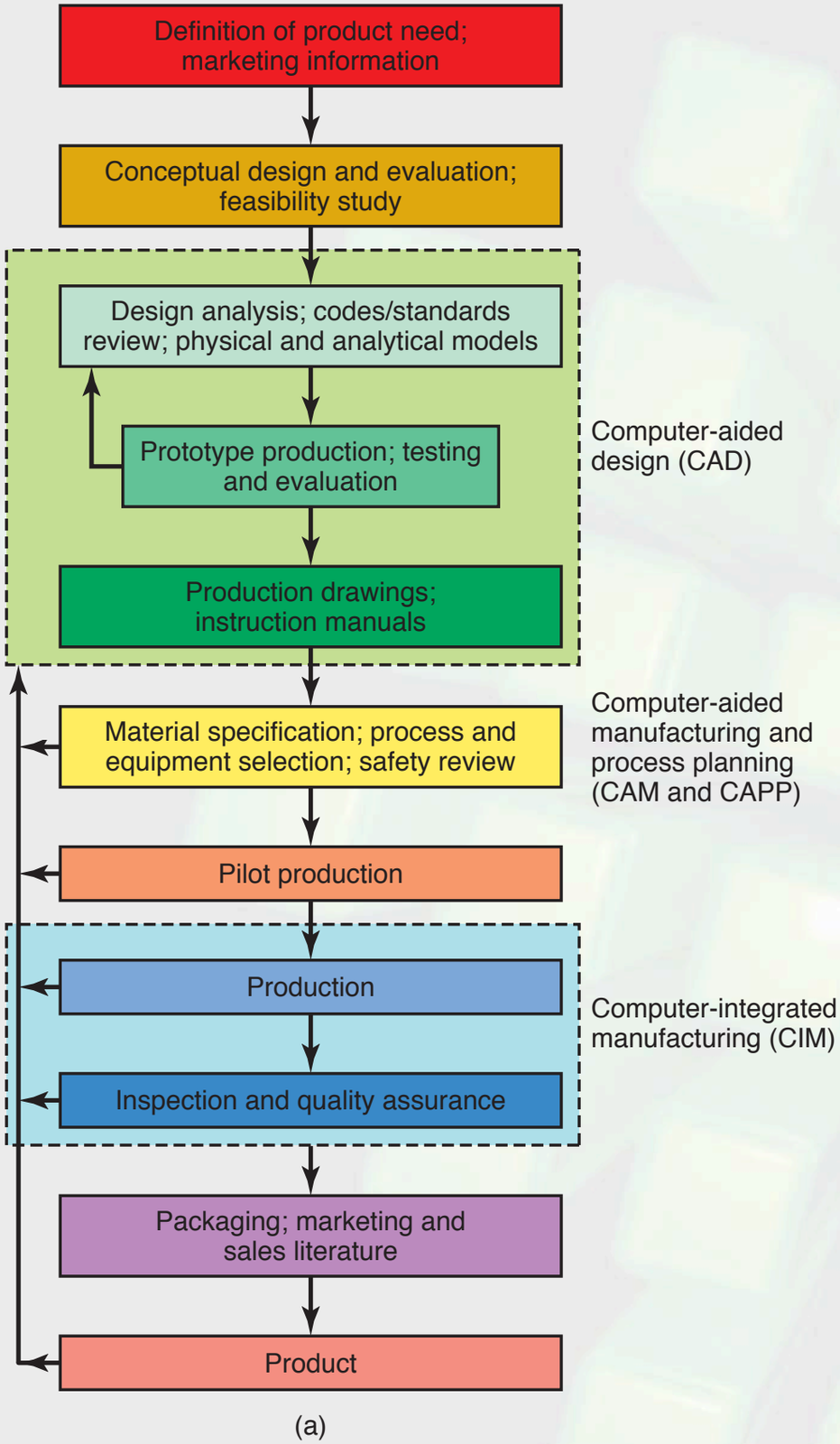
Development Process



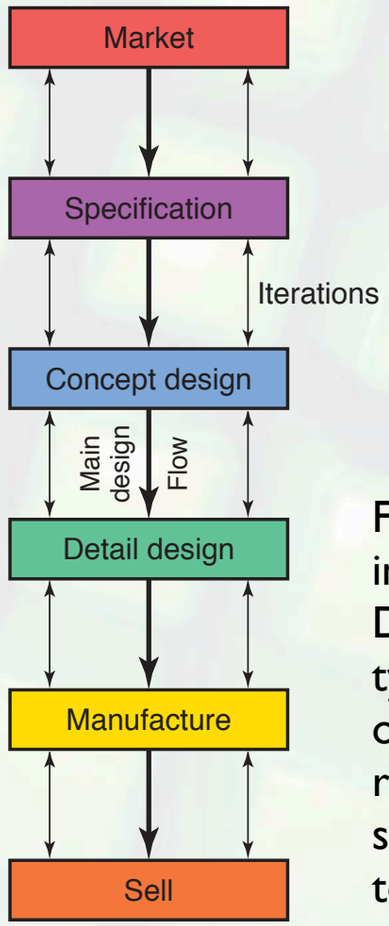
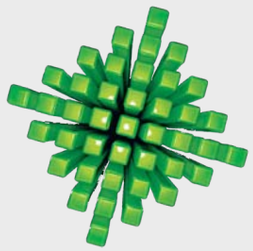


FIGURE 1.3 (a) Chart showing various steps involved in designing and manufacturing a product. Depending on the complexity of the product and the type of materials used, the time span between the original concept and the marketing of a product may range from a few months to many years. (b) Chart showing general product flow, from market analysis to selling the product, and depicting concurrent engineering. *Source:* After S. Pugh.



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Shapes & Manufacturing Process

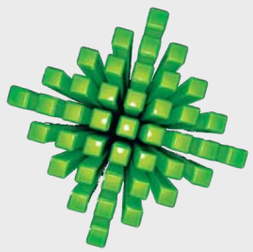
Shape or feature	Production method[a]
Flat surfaces	Rolling, planing, broaching, milling, shaping, grinding
Parts with cavities	End milling, electrical-discharge machining, electrochemical machining, ultrasonic machining, blanking, casting, forging, extrusion, injection molding, metal injection molding
Parts with sharp features	Permanent-mold casting, machining, grinding, fabricating[b], powder metallurgy, coining
Thin hollow shapes	Slush casting, electroforming, fabricating, filament winding, blow molding, sheet forming, spinning
Tubular shapes	Extrusion, drawing, filament winding, roll forming, spinning, centrifugal casting
Tubular parts	Rubber forming, tube hydroforming, explosive forming, spinning, blow molding, sand casting, filament winding
Curvature on thin sheets	Stretch forming, peen forming, fabricating, thermoforming
Openings in thin sheets	Blanking, chemical blanking, photochemical blanking, laser machining
Cross-sections	Drawing, extrusion, shaving, turning, centerless grinding, swaging, roll forming
Square edges	Fine blanking, machining, shaving, belt grinding
Small holes	Laser or electron-beam machining, electrical-discharge machining, electrochemical machining, chemical blanking
Surface textures	Knurling, wire brushing, grinding, belt grinding, shot blasting, etching, laser texturing, injection molding, compression molding
Detailed surface features	Coining, investment casting, permanent-mold casting, machining, injection molding, compression molding
Threaded parts	Thread cutting, thread rolling, thread grinding, injection molding
Very large parts	Casting, forging, fabricating, assembly
Very small parts	Investment casting, etching, powder metallurgy, nanofabrication, LIGA, micromachining

Notes:

[a] Rapid prototyping operations can produce all of these features to some degree.

[b] 'Fabricating' refers to assembly from separately manufactured components.

TABLE 1.2 Shapes and some common methods of production.



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Design for Assembly

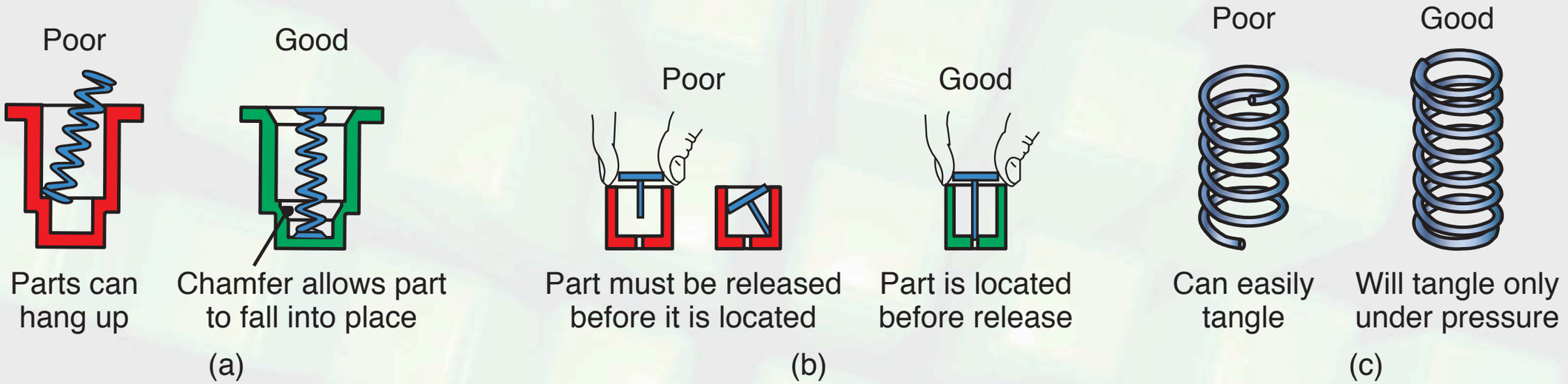
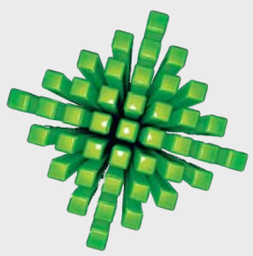


FIGURE 1.4 Redesign of parts to facilitate automated assembly. *Source:* Reprinted from G. Boothroyd and P. Dewhurst, *Product Design for Assembly*, 1989, by courtesy of Marcel Dekker, Inc.



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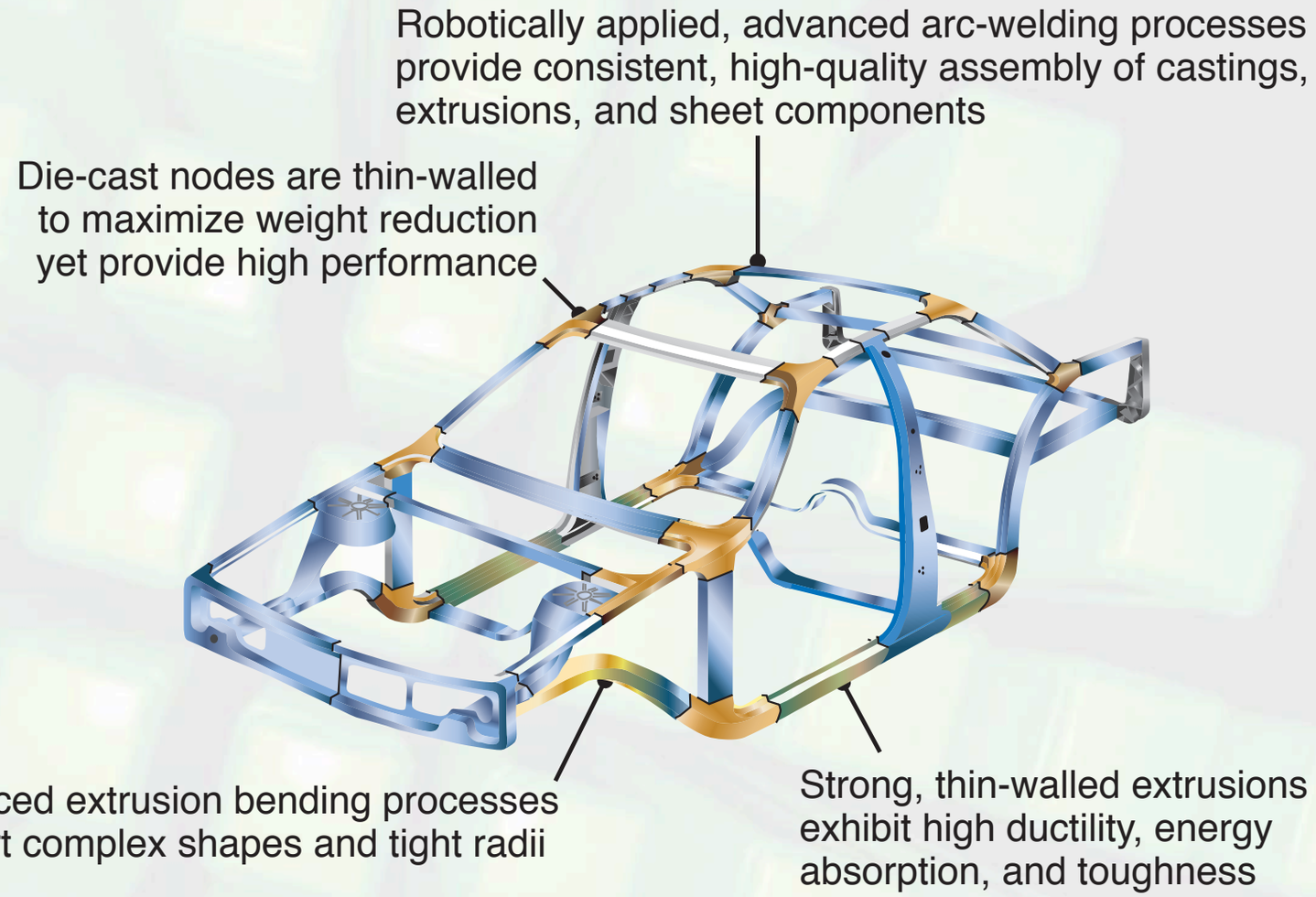
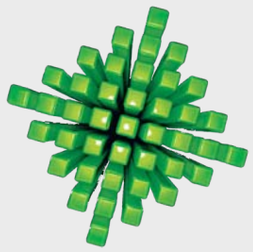
All-Aluminum Automobile



(a) (b)

FIGURE 1.5 (a) The Audi A8 automobile, an example of advanced materials construction; (b) The aluminum body structure, showing various components made by extrusion, sheet forming, and casting processes. *Source:* Courtesy of ALCOA, Inc.



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Methods of Manufacture

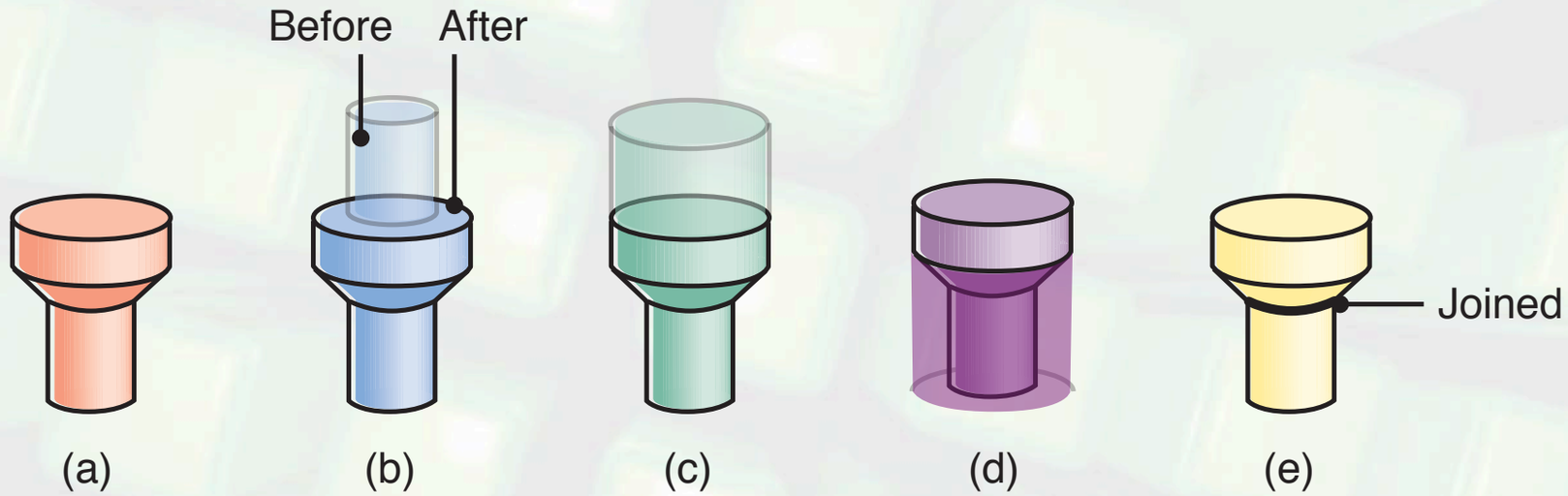

FIGURE 1.6 Various methods of making a simple part: (a) casting or powder metallurgy, (b) forging or upsetting, (c) extrusion, (d) machining, (e) joining two pieces.

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Scales in Manufacturing

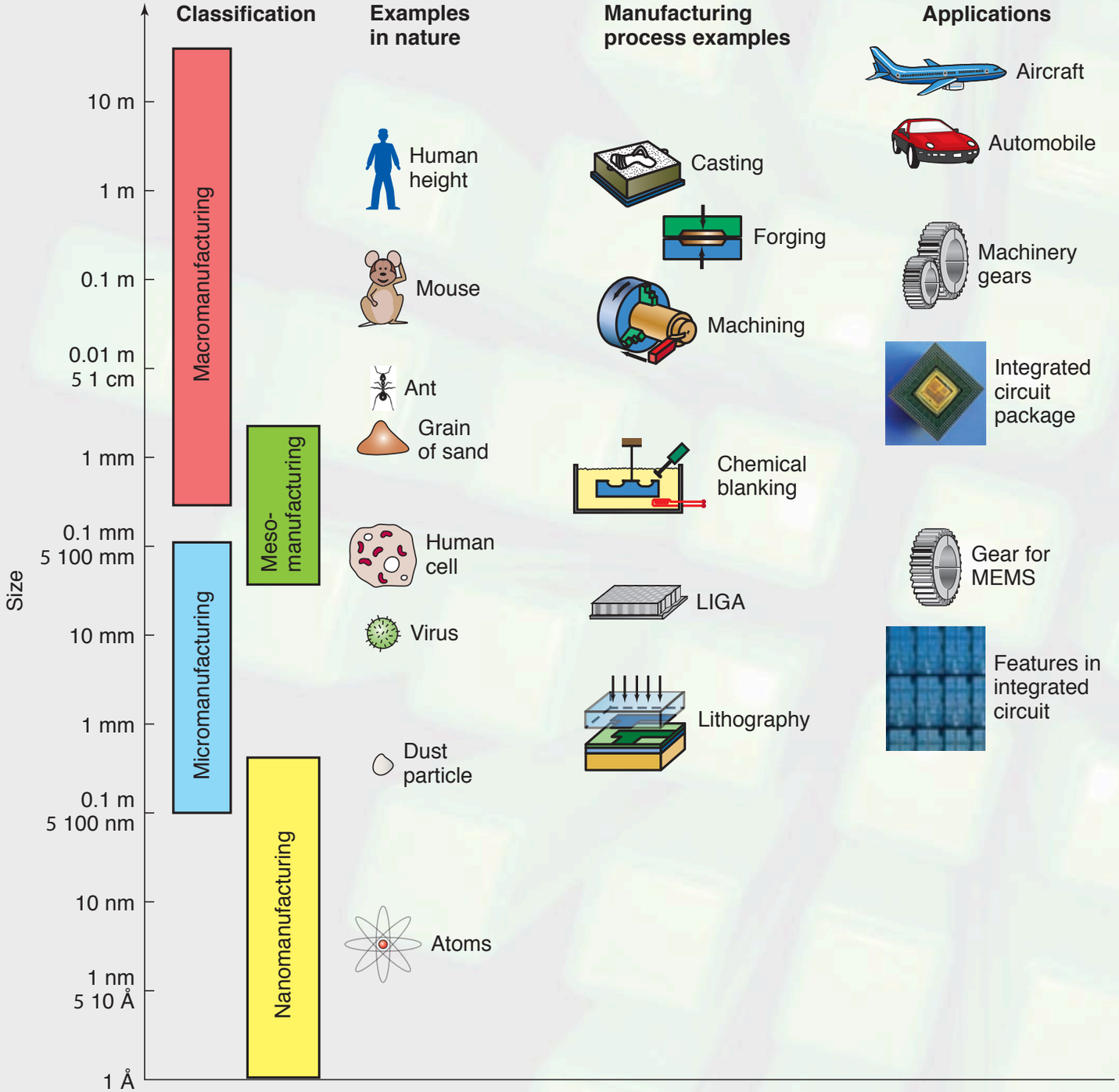
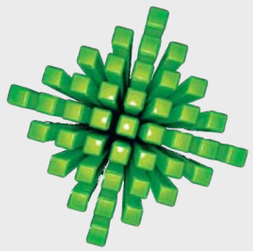


FIGURE 1.7 Illustration of the range of common sizes of parts and the capabilities of manufacturing processes in producing these parts.



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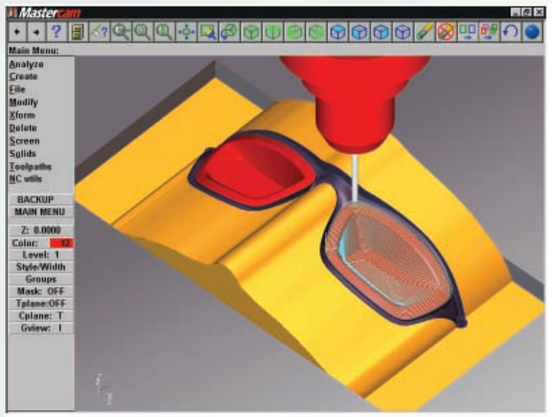
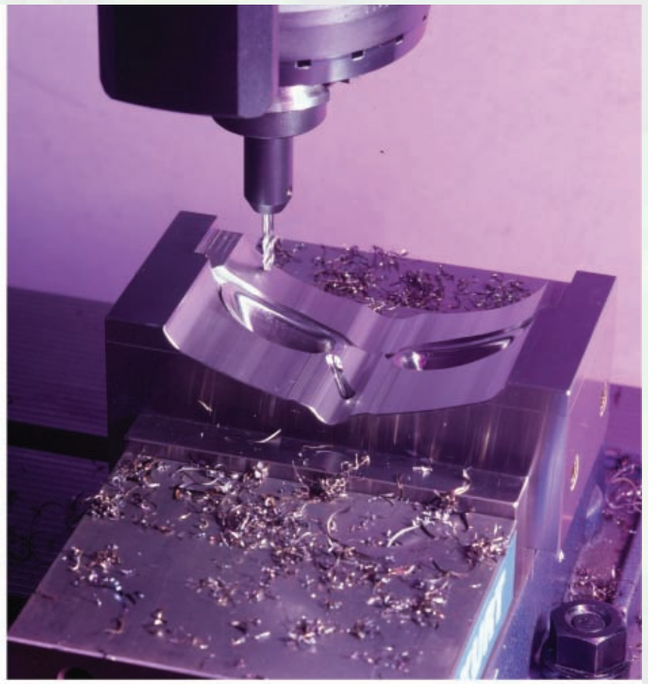
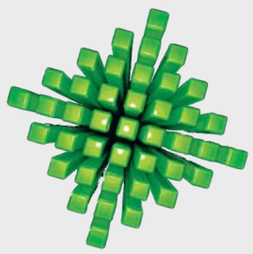
Machining a Mold Cavity





(c)

FIGURE 1.8 Machining a mold cavity for making sunglasses. (a) Computer model of the sunglasses as designed and viewed on the monitor. (b) Machining the die cavity using a computer numerical control milling machine. (c) Final product produced from the mold. *Source:* Courtesy Mastercam / CNC Software, Inc.



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Flexible Manufacturing

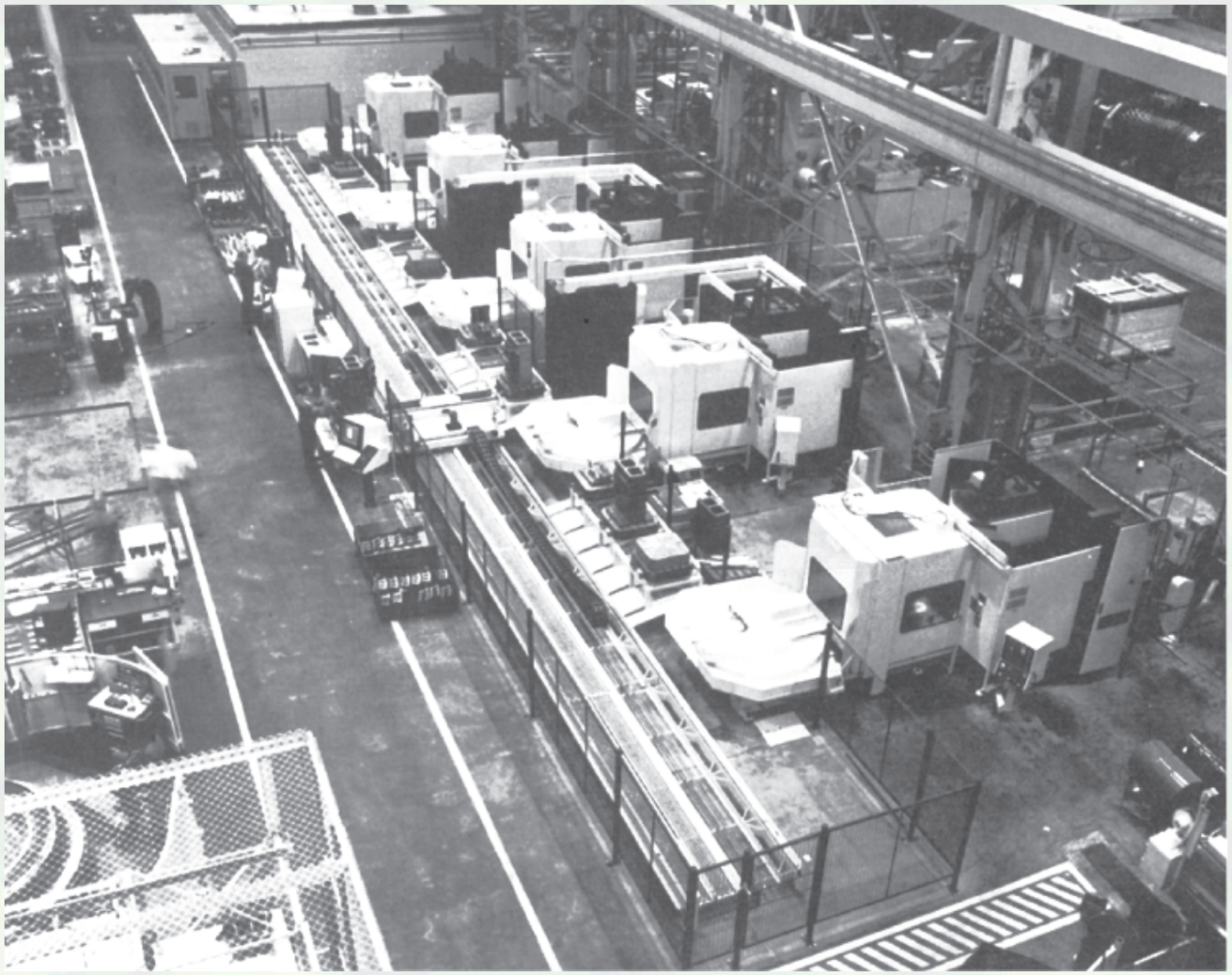

FIGURE 1.9 General view of a flexible manufacturing system, showing several machines (machining centers) and an automated guided vehicle (AGV) moving along the aisle. *Source:* Courtesy of Cincinnati Milacron, Inc.

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Global Labor Rates

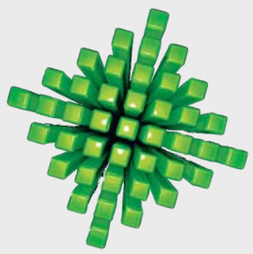
TABLE 1.3

Approximate Relative Hourly Compensation for Production Workers, for 2003. United States = 100. Compensation Costs Vary Depending on Benefits and Allowance.

Denmark	147	Ireland, Italy	85
Norway	144	Spain	67
Germany	136	Israel	53
Belgium, Switzerland	127	New Zealand, Korea	48
Finland, Netherlands	123	Singapore	33
Austria, Sweden	116	Portugal, Taiwan	27
United States	100	Czech Republic	20
France	96	Brazil, Mexico	11
United Kingdom	93	China, India	10
Australia, Canada, Japan	90		
European countries	111		
Asian countries	33		

Source: Courtesy of U.S. Department of Labor, November 2004.

FIGURE 1.5 (a) The Audi A8 automobile, an example of advanced materials construction; (b) The aluminum body structure, showing various components made by extrusion, sheet forming, and casting processes. *Source:* Courtesy of ALCOA, Inc.



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