國立臺北大學自然資源與環境管理研究所
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課程進度(04)：工業生態學：生物、物理及社會面向
Industrial Ecology: Biological, Physical, and Social Dimensions

- THE "MASTER EQUATION" OF INDUSTRIAL ECOLOGY
  - The Master Equation (G&A, p.28)

    Environmental Impact = Population×[GDP/person]×[(environmental impact)/(unit of GDP)]

    ⇨ The IPAT Equation: I=Impact; P=Population; A=Affluence, T=Technology
    ⇨ The IPAT Equation and Its Variants (Chertow, 2000)
    ⇨ Application IPAT to assess resource productivity (Wang et al., 2014)
    ⇨ The IPAMDH Equation: I = P×A×M×D×H (Kapur and Graedel, 2004)
      where M is the materials intensity, D the dissipation factor, and H the hazard factor, which depends on the chemical form of the material lost and the susceptibility of the receiving ecosystem.

    Environmental Impact = Population×[GDP/person]×[(units of material)/GDP]×
                        [(units of pollution)/(unit of material)]×[impact/(unit of pollution)]

    ⇨ The Kaya's identity: a mathematical expression for energy-related carbon emission

    $$C = (P)×(GDP/P)×(E/GDP)×(C/E)$$

    where the total energy-related carbon emissions C is expressed as a product of Population P, GDP per capita, energy intensity E/GDP and carbon intensity of energy use C/E.
  - The Tragedy of the Commons (G&A, p.24; http://zh.wikipedia.org/zh-tw/公地悲劇)
    ⇨ The Maximum Sustainable Yield
    ⇨ Free Riders
  - Technology at Work (G&A, p.26)
  - Technological Evolution (Technological Waves) (G&A, p.30)
    ⇨ The Urban System
  - The 'Past Goods' and the 'New Bads' (G&A, p.53)
  - Decoupling of 'Economic Goods' and 'Environmental Bads'
    ⇨ The Environmental Kuznets Curve
  - *Metabolic* "Dissipativeness" of Materials vs. *Anthropic* "Concentration" of Pollutants

- THE RELEVANCE OF BIOLOGICAL ECOLOGY TO TECHNOLOGY
  - The Analogy and a new Definition (G&A, p.63):
    Industrial ecology is the study of technological organisms, their use of resources, their potential environmental impacts, and the ways which their interactions with the natural world could be restructured to enable global sustainability.
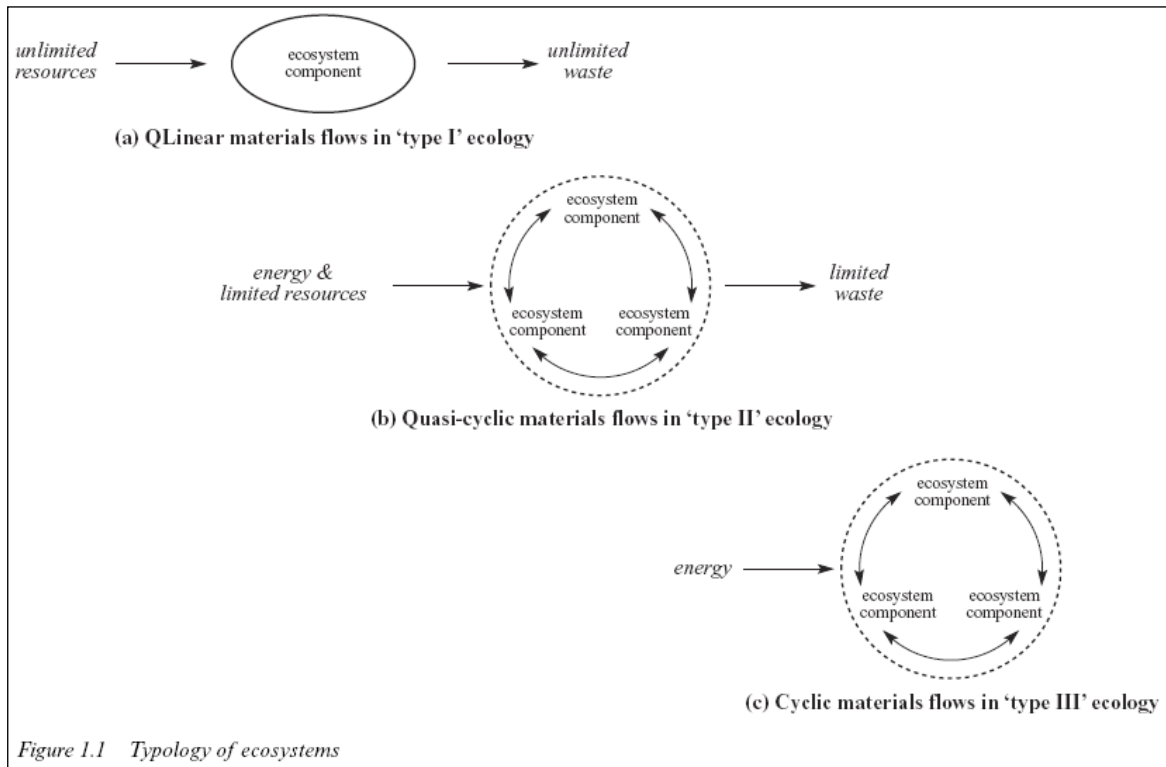 - Biological and Industrial Organisms (G&A, p.64)
  - Biological and Industrial Ecosystems (G&A, p.66)
  - The Industrial Ecosystem (Manahan, 2001, Chap.19)
    ⇨ Material, Energy, and Labor
    ⇨ A successfully operating industrial ecosystem provides several benefits. Such a system *reduces*

pollution. It results in *high energy efficiency* compared to systems of firms that are not linked and it *reduces consumption of virgin materials* because it *maximizes materials recycle*. *Reduction of amounts of wastes* is another advantage of a functional system of industrial ecology. Finally, a key measure of the success of a system of industrial ecology is *increased market value of products* relative to material and energy consumption.

⇨ Five major components of an industrial ecosystem: (1) a primary materials producer, (2) a source or sources of energy, (3) a materials processing and manufacturing sector, (4) a waste processing sector, and (5) a consumer sector.

⇨ Industrial Symbiosis and Industrial Metabolism => Table 19.1

□ Engineering by Biological and Industrial Organisms (G&A, p.63)

□ The Utility of the Ecological Approach

unlimited resources → ecosystem component → unlimited waste

(a) QLinear materials flows in 'type I' ecology

energy & limited resources → ecosystem component ... ecosystem component / ecosystem component → limited waste

(b) Quasi-cyclic materials flows in 'type II' ecology

energy → ecosystem component / ecosystem component ... ecosystem component

(c) Cyclic materials flows in 'type III' ecology

Figure 1.1   Typology of ecosystems

(A Handbook of Industrial Ecology, p.5)

● SOCIETY AND CULTURE; GOVERNMENT, LAWS AND ECONOMICS
  □ Cultural Constructs and Temporal Scales: Paradigm Shift (G&A, p.105)
  □ Social Ecology (G&A, p.108)
  □ Governmental Agencies and NGOs (NPOs)
  □ Industrial Ecology: The *Science of Sustainability*
    ⇨ A nascent and challenging discipline for scientists, engineers and policy makers (Kapur and Graedel, 2004)
  □ Linking Industrial Activity with Environmental and Social Sciences (G&A, p.56)
  □ Environmentalism, Technology and Society: '*3E*'; ESG; 3Ps; 5Ps => 'EPS'
  □ Environmental Ideology (O'Riordan, 1977) *: Eco-centrism vs. Techno-centrism *
  □ Traditional Spheres and the Fifth Sphere
    ⇨ hydrosphere, atmosphere, geosphere, and biosphere: water, air, land, and life
    ⇨ the 'anthroposphere': consisting of the things that humans make, use, and do.
    ⇨ the 'technosphere'? 'infosphere'?