Systems Thinking to Improve the Public's Health

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Challenges of Biomedical and Public Health

- Why Team Science? Complexity
- What characterizes complexity?
  - Single variable cannot explain an outcome
  - Variables are inter-related and may be non-linear
  - Variables interact with time
  - Factors may be cumulative in some cases
  - Causal factors can contribute to ‘vicious’ or ‘virtuous’ cycles (positive and negative reinforcers)
  - Tipping points are often unknown

Case in point: Illinois and PM

What is “Systems Thinking”

"Systems thinking is a discipline for seeing wholes, recognizing patterns and interrelationships, and learning how to structure those interrelationships in more effective, efficient ways."

Senge, P. & Lannon-Kim, C., 1991

Systems Thinking – A Cacaphony

system dynamics

set, graph, and network theory

small world phenomena

evolution, biology, and ecology

general systems theory

cybernetics

computational simulation

decision and game theory

control theory

silo effects

information theory

emergence

boundary conditions, scaling, power laws, phase transitions, universality, and renormalization

fractal self-similarity

causal feedback

centralized, decentralized, heterarchical, hierarchical, and self-organizing systems

complex adaptive systems

stock–flow structures

autopoiesis

nonlinear systems and chaos

cellular automata

open and closed systems

Some Streams of Systemic Thought
http://www.iigss.net/gPICT.jpg

Courtesy of Bill Trochim

"…the architectural features of molecular interaction networks within a cell are shared to a large degree by other complex systems, such as the Internet, computer chips or society. This unexpected universality suggests that similar laws govern the development and function of most complex networks in nature."

Barabasi and Oltvai, *Nature Reviews Genetics* **5**, 101-113 (2004)

Systems Thinking – Applied

- Business (e.g. creation and maintenance of feedback-based supply chain infrastructures
- Military (e.g. rapid flow of information to/from front-line soldiers)
- Physics (e.g. analysis of complex networks such as the internet or biological systems)
- Agriculture (e.g. cooperative extension system)
- Natural Sciences (e.g. weather forecasting)
- Public Health (e.g. analysis and development of communicable disease surveillance and intervention systems)

What If?

- We could model which interventions will work, and which will succumb to countervailing forces?
- Our research agenda was informed by best practices in the field?
- We had global visibility and collaboration among stakeholders?
- We could build a consistent, evolving evidence base?

Creation of ISIS

- The Initiative on the Study and Implementation of Systems
- An NCI-funded, transdisciplinary initiative to study and implement systems approaches in tobacco control
- A proof of concept for applying systems thinking methods to public health

The First Two Years of ISIS

- Implement ‘Innovation Team’ to identify essential approaches to explore
- Experts in multiple fields to develop case examples, and to work to bridge disciplines
- Identify critical components of a ‘systems thinking’ approach to tobacco control

Common Features of Complex Systems

- Systems methods: Modeling the behavior of complex adaptive systems (understanding how each component links to the next) for strategic decision-making
- Network methods: Development and analysis of linked/collaborative relationships, and harnessing a transorganizational and transdisciplinary environment to improve outcomes
- Knowledge management: Creating an informatics and knowledge infrastructure for storing, sharing and interpreting knowledge and evidence-based practices in the context of networks

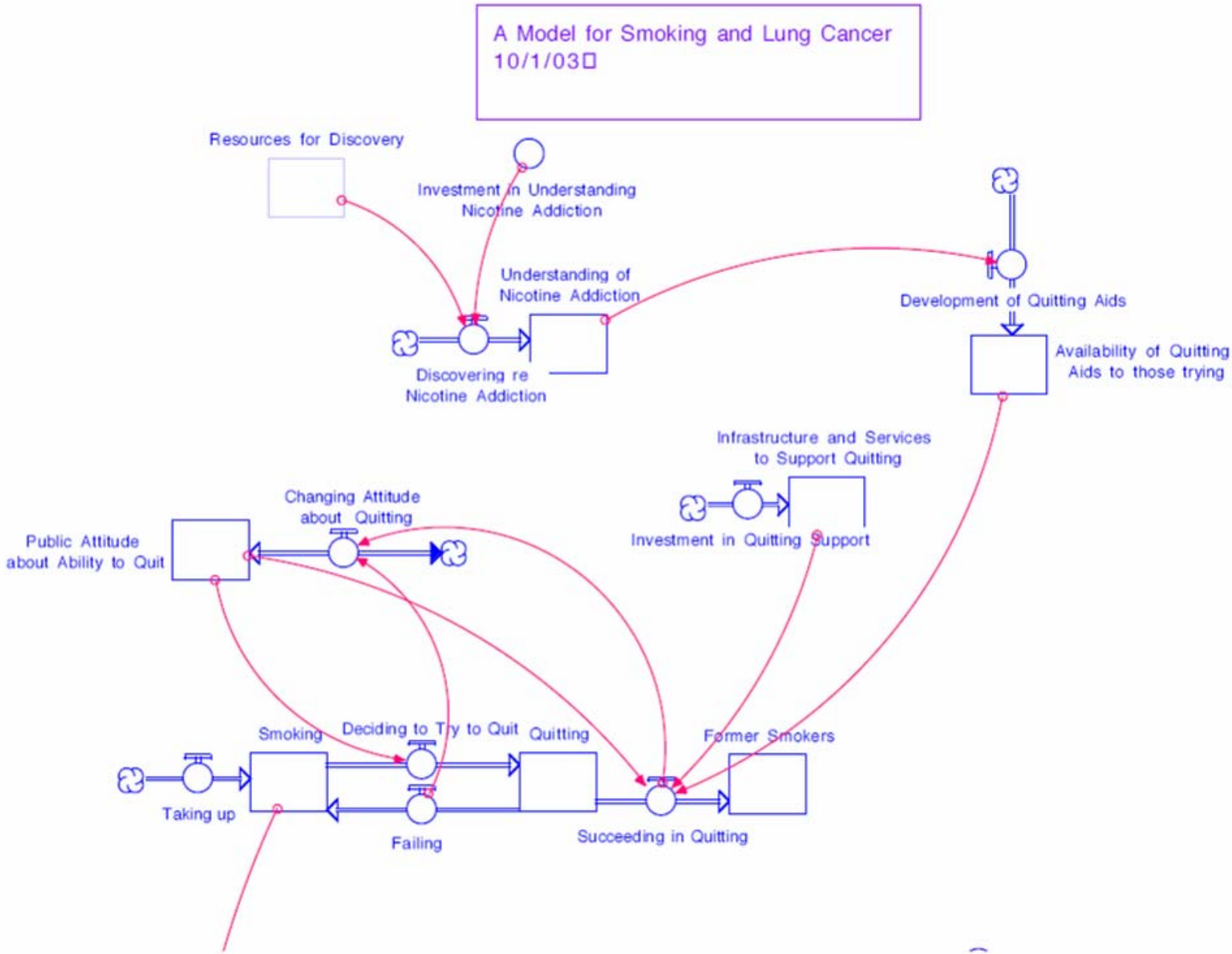
…*and* their integration

- Systems Organizing: Implementing public health programs in the context of a systems approach that optimizes networks and knowledge flow to improve the programs

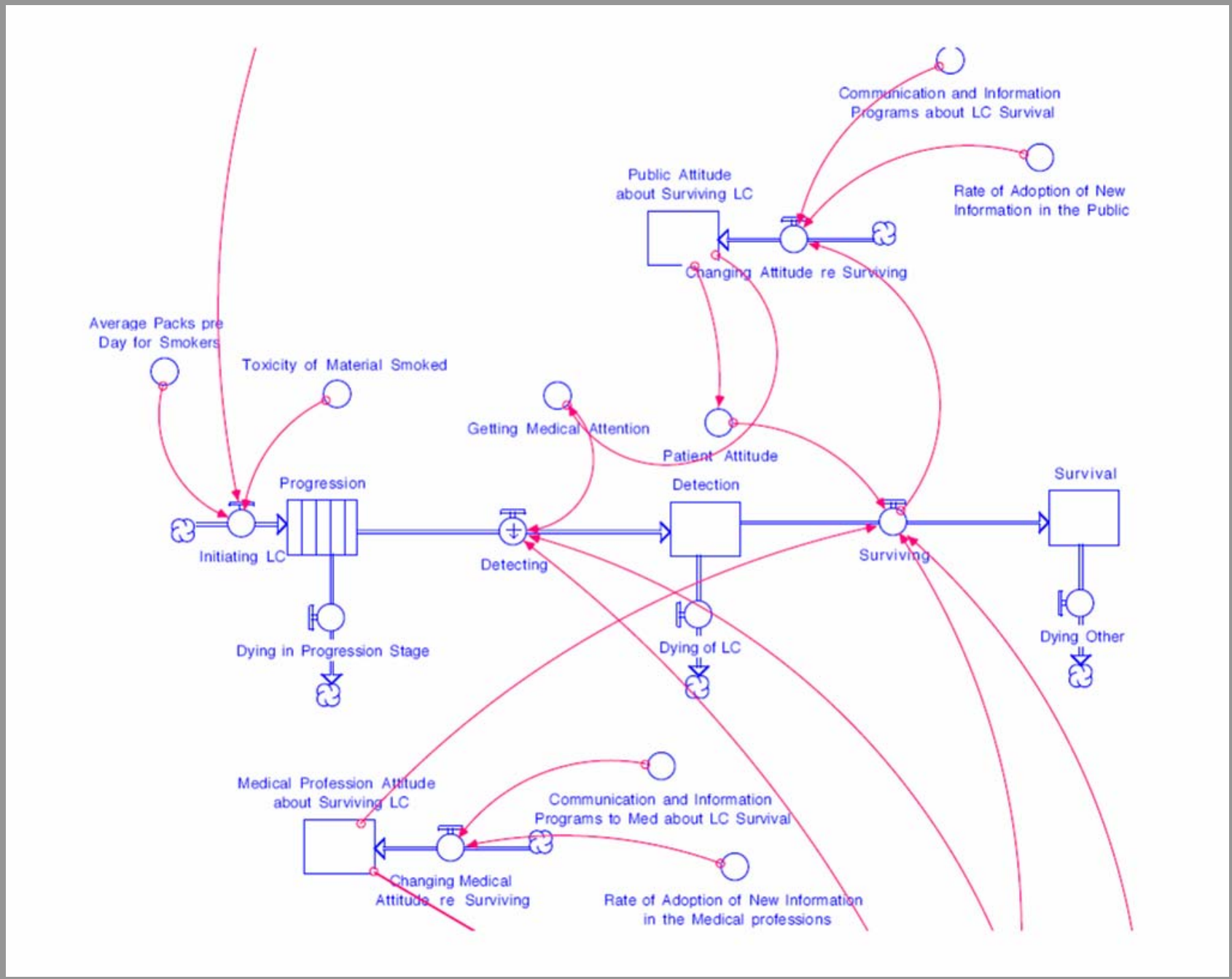
ISIS=Initiative on the Study and Implementation of Systems

Systems Analytic Methods

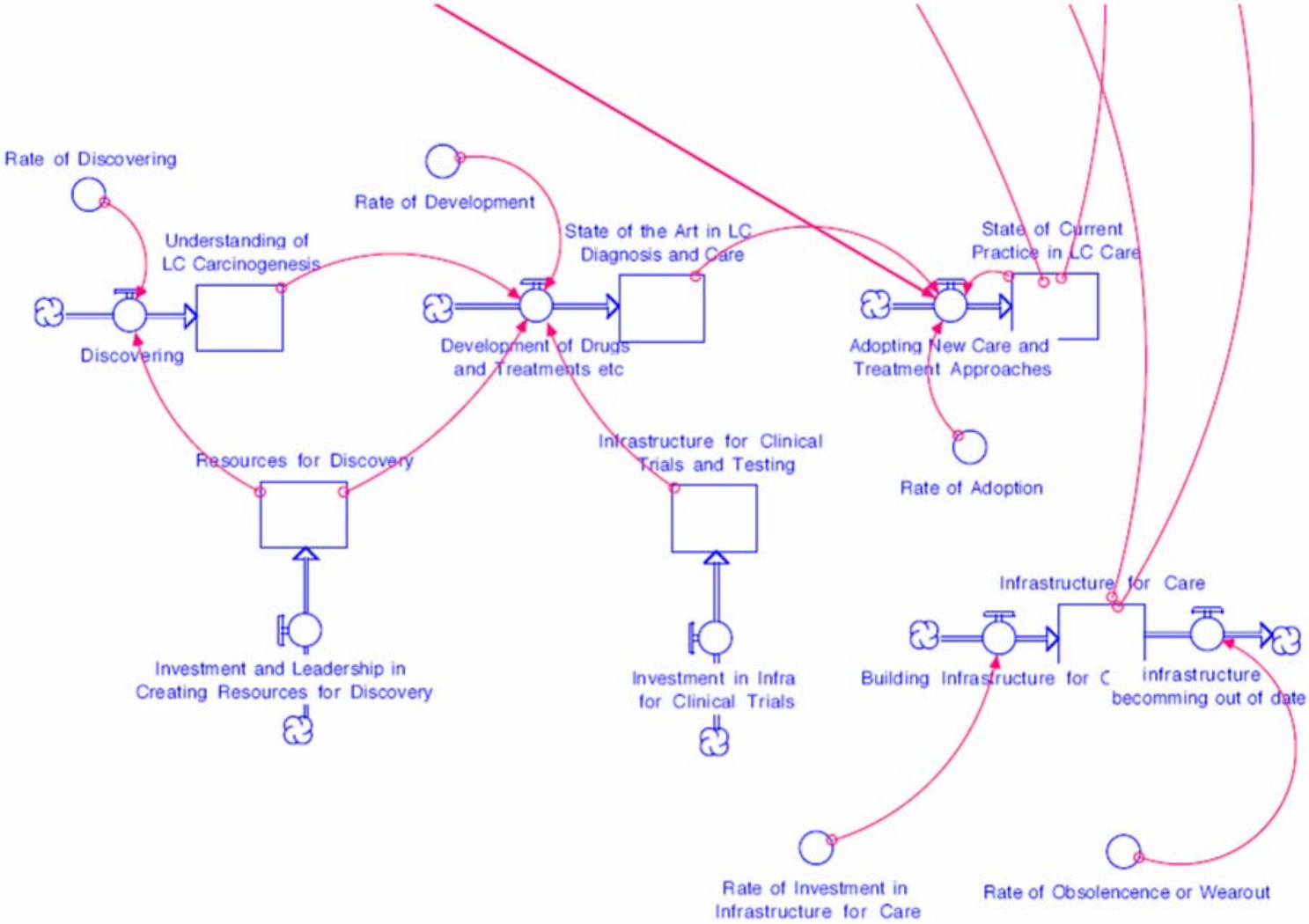
- Soft Systems Methods
- Agent-based Modeling
- Econometric Modeling (eg simultaneous equations modeling)
- Mathematical Modeling and Analysis (eg differential equations)
- System Dynamics


A Model for Smoking and Lung Cancer
10/1/03
Resources for Discovery
Investment in Understanding Nicotine Addiction
Understanding of Nicotine Addiction
Discovering re Nicotine Addiction
Development of Quitting Aids
Availability of Quitting Aids to those trying
Infrastructure and Services to Support Quitting
Investment in Quitting Support
Changing Attitude about Quitting
Public Attitude about Ability to Quit
Smoking
Deciding to Try to Quit
Quitting
Former Smokers
Taking up
Failing
Succeeding in Quitting

Karash, 2003


Communication and Information Programs about LC Survival
Public Attitude about Surviving LC
Rate of Adoption of New Information in the Public
Changing Attitude re Surviving
Average Packs pre Day for Smokers
Toxicity of Material Smoked
Getting Medical Attention
Patient Attitude
Progression
Detection
Survival
Initiating LC
Detecting
Surviving
Dying in Progression Stage
Dying of LC
Dying Other
Medical Profession Attitude about Surviving LC
Communication and Information Programs to Med about LC Survival
Changing Medical Attitude re Surviving
Rate of Adoption of New Information in the Medical professions

Karash, 2003


Rate of Discovering
Rate of Development
Understanding of
LC Carcinogenesis
State of the Art in LC
Diagnosis and Care
State of Current
Practice in LC Care
Discovering
Development of Drugs
and Treatments etc
Adopting New Care and
Treatment Approaches
Resources for Discovery
Infrastructure for Clinical
Trials and Testing
Rate of Adoption
Infrastructure for Care
Investment and Leadership in
Creating Resources for Discovery
Investment in Infra
for Clinical Trials
Building Infrastructure for C
infrastructure
becomming out of date
Rate of Investment in
Infrastructure for Care
Rate of Obsolencence or Wearout

Karash, 2003

Social Network Analysis and Network Development

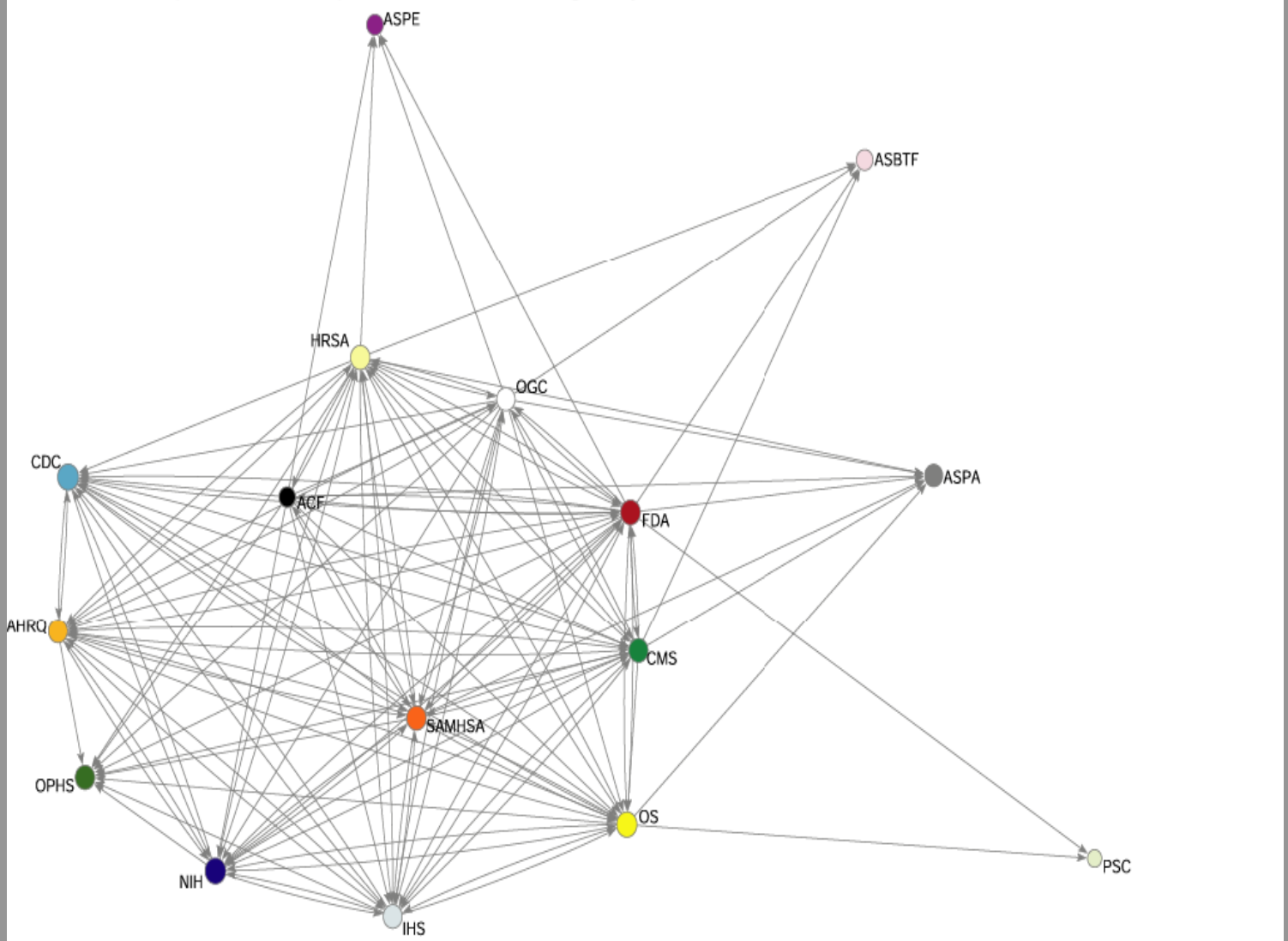
- The shift in focus from the platform to the network
- Focus on ***relationships*** between actors rather than just the attributes of actors
- The shift from viewing actors as independent to viewing them as part of a continuously adapting ecosystem
- Increased emphasis on multi-, trans-, and interdisciplinary science and practice

Cheshire; Cebrowski and Garstka, 1998.
http://www.usni.org/Proceedings/Articles98/PROcebrowski.htm

ISIS Network Efforts

- Development
  - Global Tobacco Research Network
  - Harm Reduction Network
- Analysis
  - Tobacco Harm Reduction Network
  - DHHS Tobacco Network
  - Tobacco Informatics Grid (TOBIG)

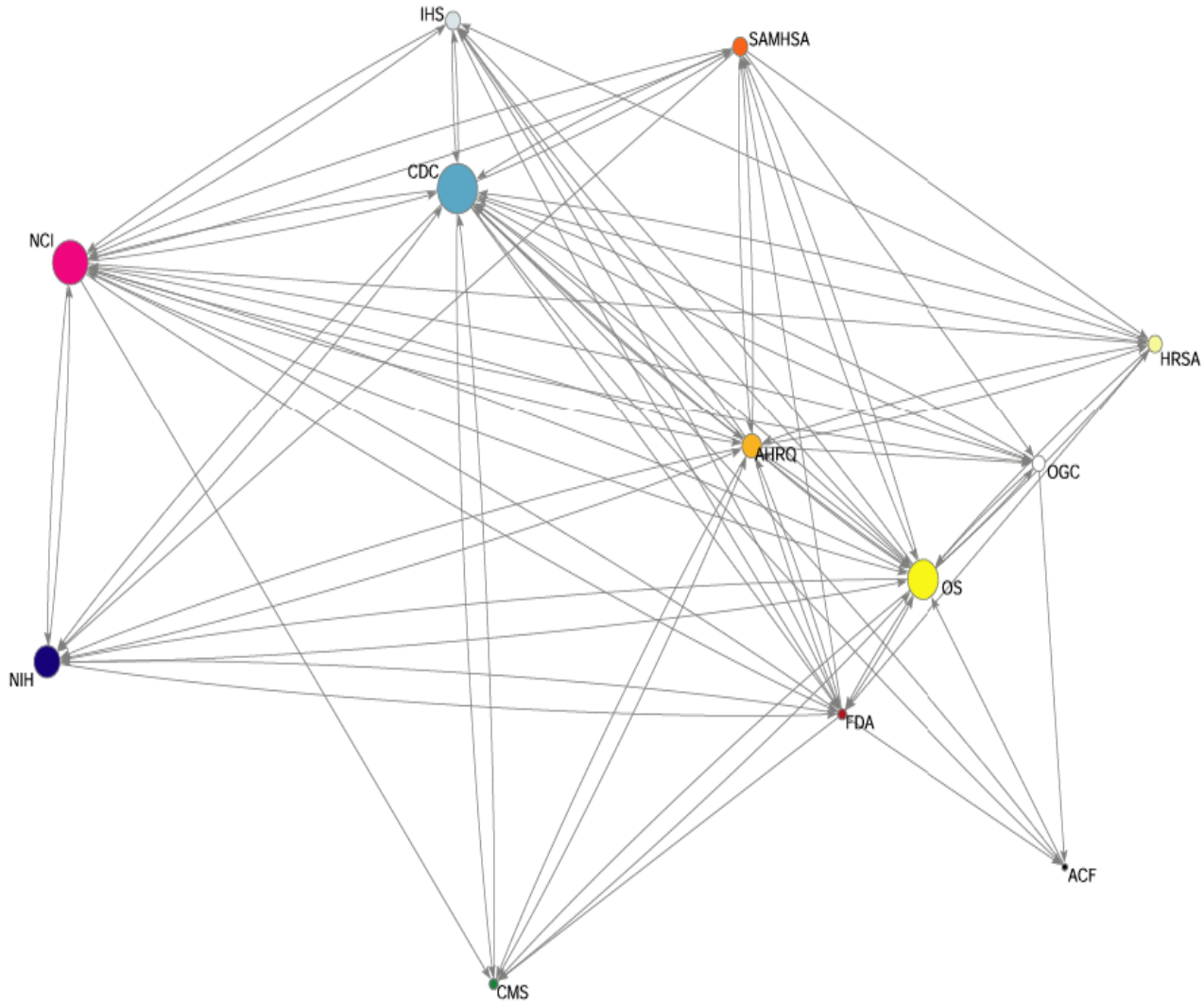
5. Level of perceived importance of each agency to DHHS' tobacco control efforts



- An arrow between two nodes or agencies (A→B) indicates that Agecy A identified Agency B as at least somewhat important to DHHS' efforts in tobacco control
- The size of a node indicates prestige (*e.g.*, a larger node size indicates that more agencies identified the agency (node) as being at least somewhat important to DHHS' tobacco control efforts)

ASBTF AHRQ HRSA OGC
ASPA CDC IHS OS
ASPE CMS NCI PSC
ACF FDA NIH SAMHSA

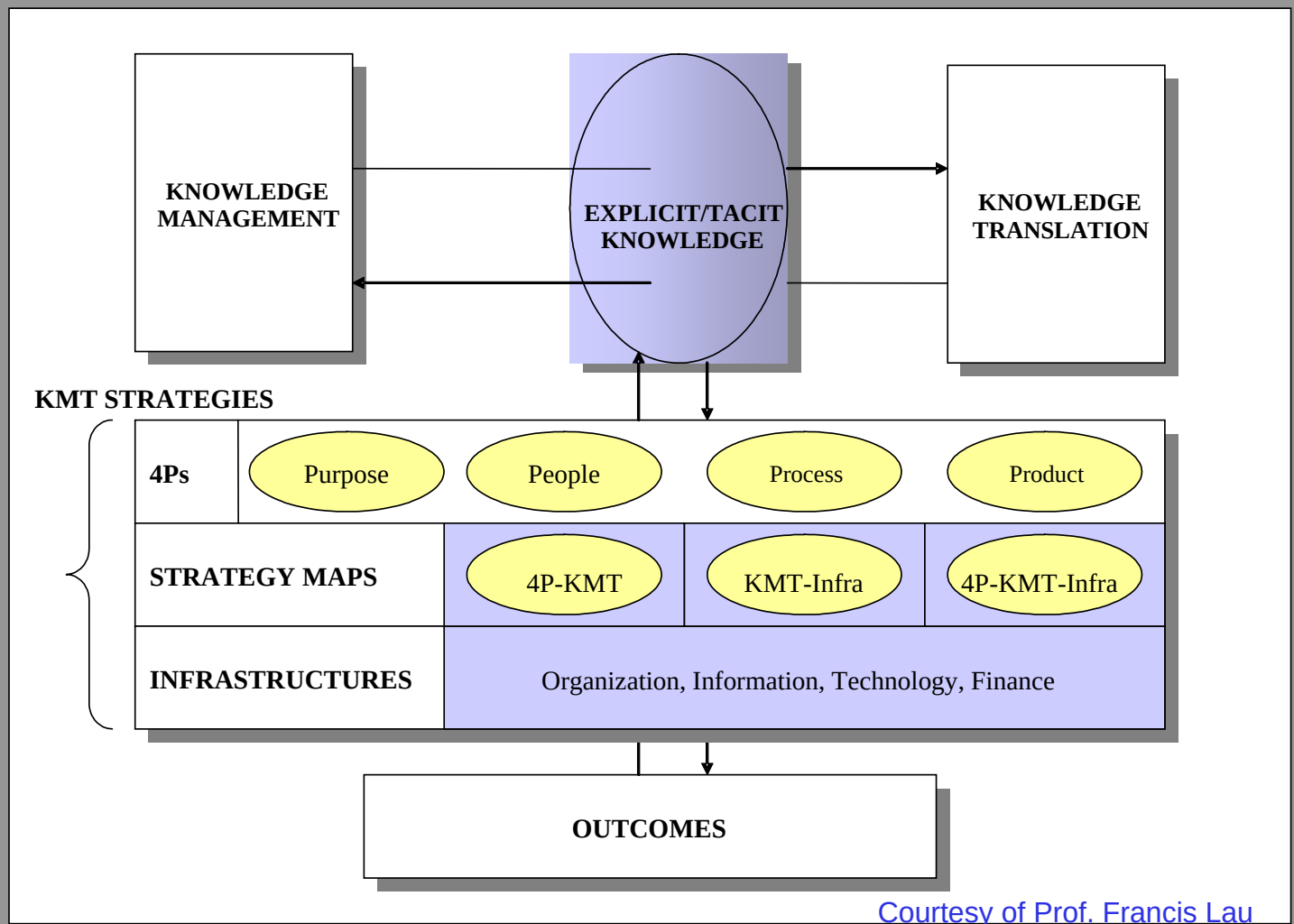
1b. Awareness of individual's work in tobacco control (collapsed to agency level)



- An arrow between two nodes or individuals (A → B) indicates that Individual A was aware of Individual B's work in tobacco control.
- The size of a node indicates prestige (*e.g.*, a larger node size indicates a higher level of awareness for that individual by others)

ACF FDA NIH
AHRQ HRSA OGC
CDC IHS OS
CMS NCI SAMHSA

Knowledge Management and Translation (KMT) Framework for Tobacco Control and Public Health



Courtesy of Prof. Francis Lau

Exemplar ISIS Spin-Off: Tobacco Informatics Grid (TOBIG)

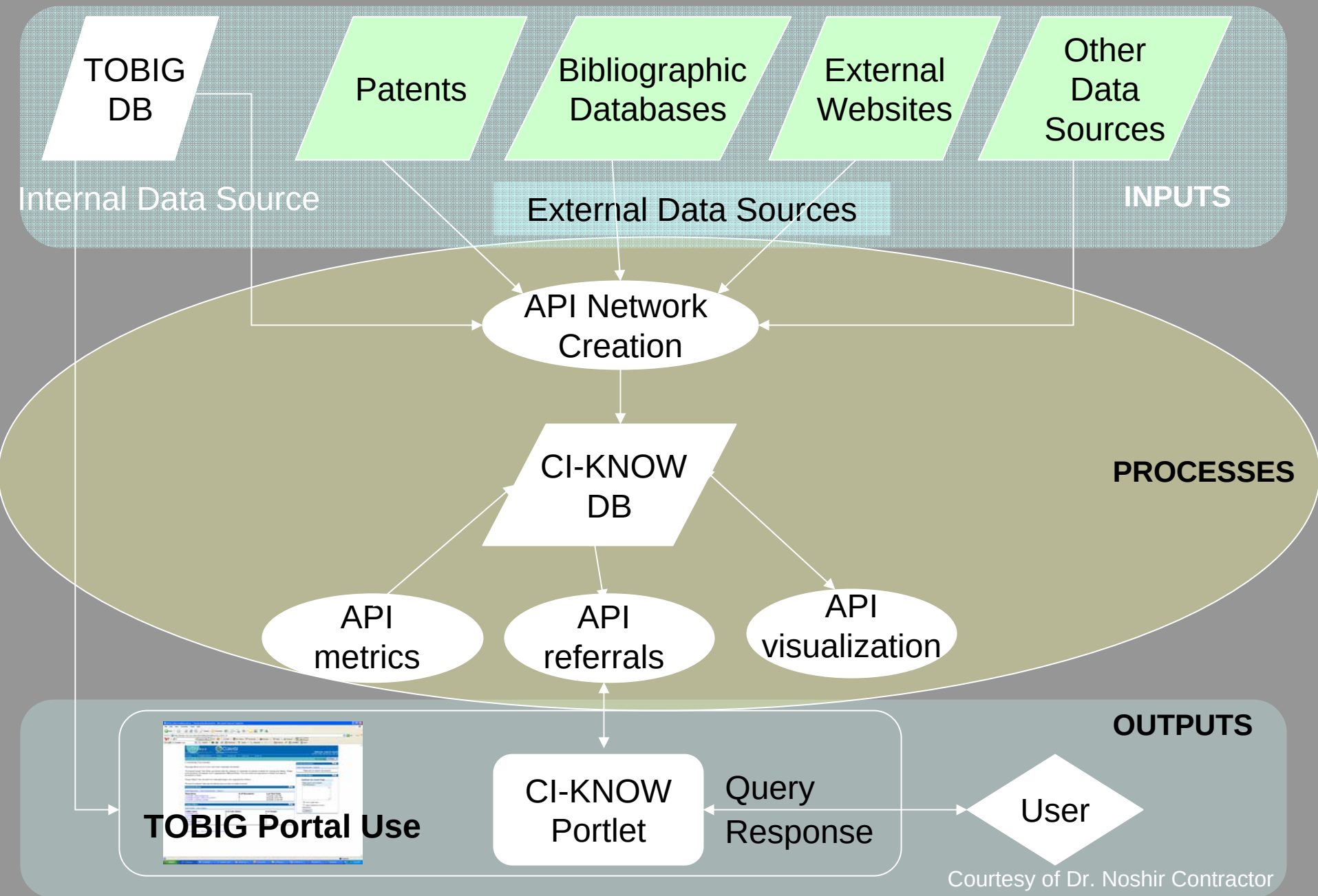
1. A network among public health researchers, practitioners, and social scientists, educators, policy makers, industry, NGOs, the public, and other stakeholders.

2. A cyberinfrastructure consisting of (1) a virtual repository to archive existing and new data and (2) information technology to enable collaboration and data modeling, analysis, and visualization of tobacco related behaviors.

3. The multidisciplinary integration of research, education, analysis, decision-making and management in the area of tobacco control.

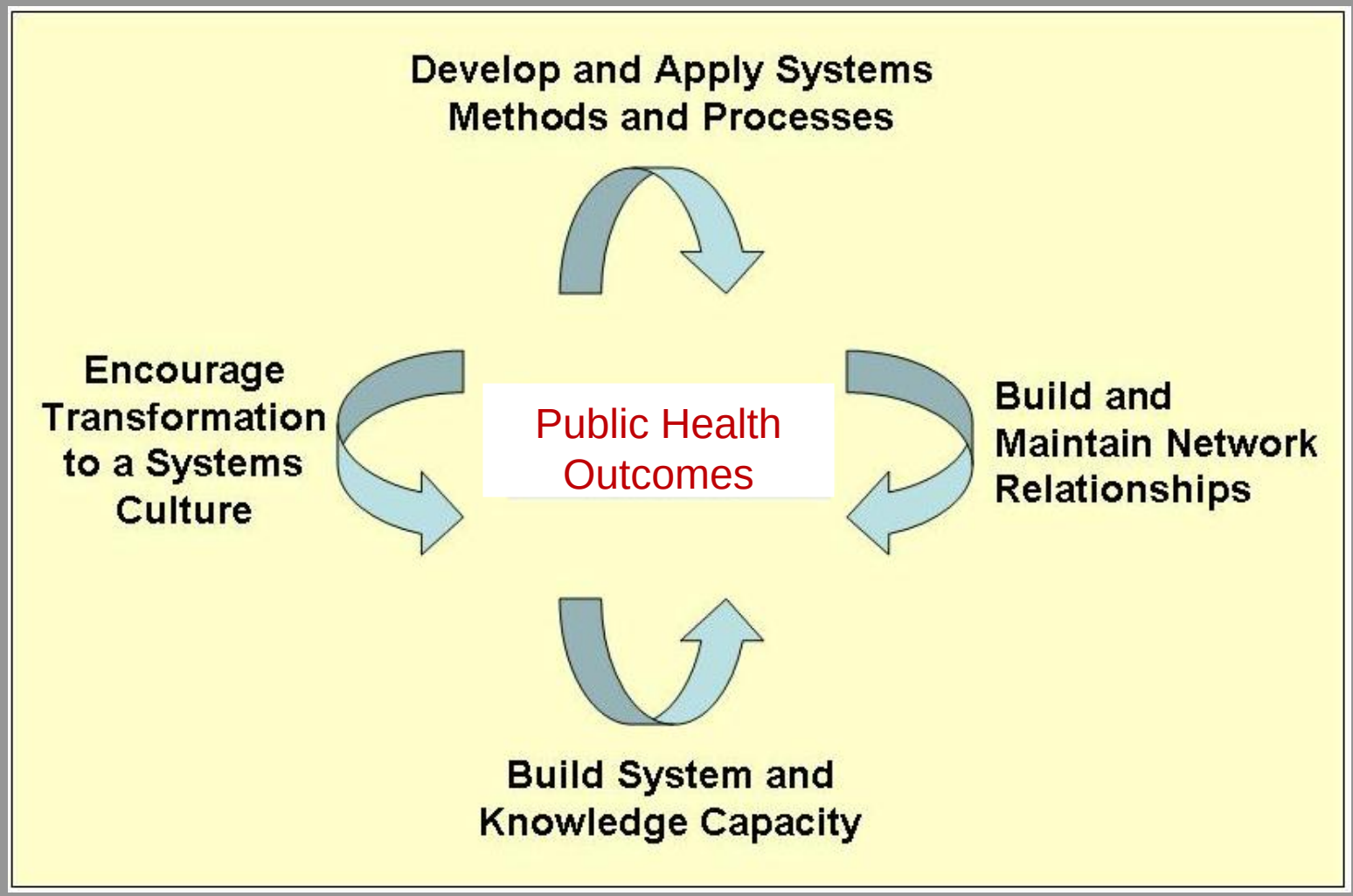
Courtesy of Dr. Noshir Contractor

Overall CI-KNOW Logical Architecture



Courtesy of Dr. Noshir Contractor

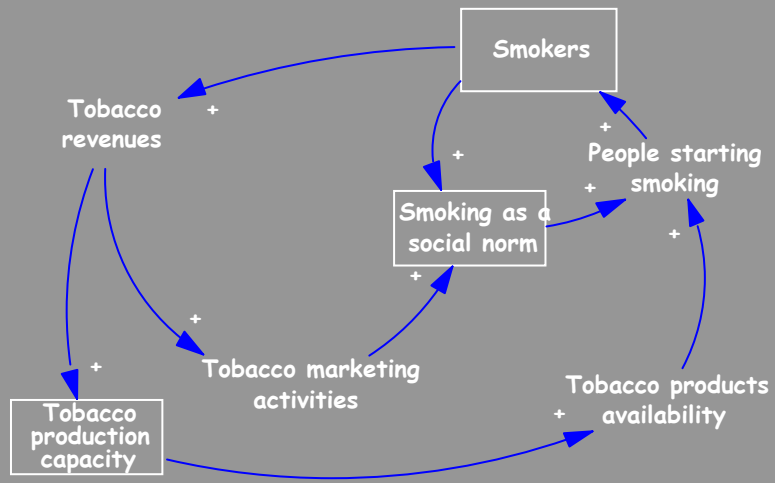
The Goal: An Integrated Systems Thinking Environment



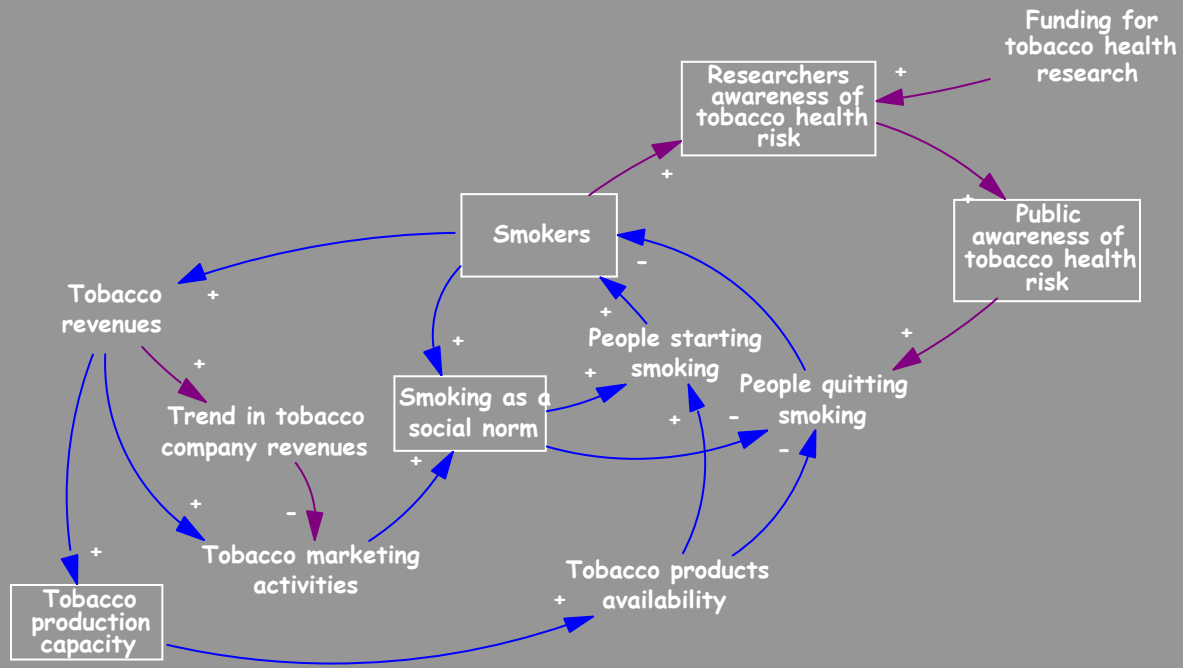
ISIS Recommendations

- **Create networks of excellence for systems thinking in public health**
- **Develop a Web presence for systems methods in tobacco control**
- **Foster development of systems organizing**
- **Link with systems knowledge in other fields**
- **Develop a systems curriculum in academia**
- **Create a leadership program**
- **Organize a national association and a regular national conference on systems thinking in public health**
- **Link with local efforts**

Tobacco Use as a Complex Dynamic 'System'



Source: George Richardson for ISIS



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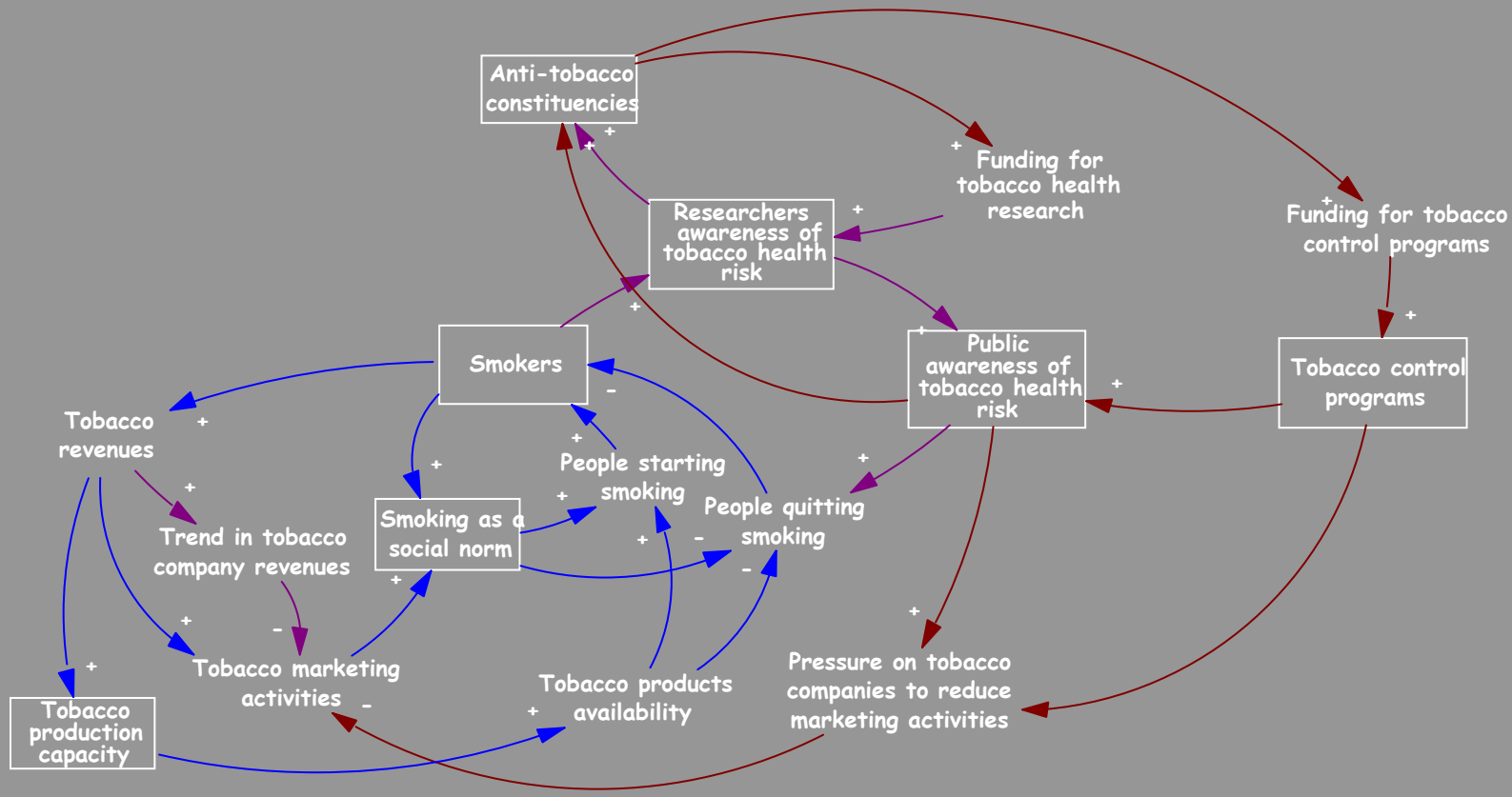

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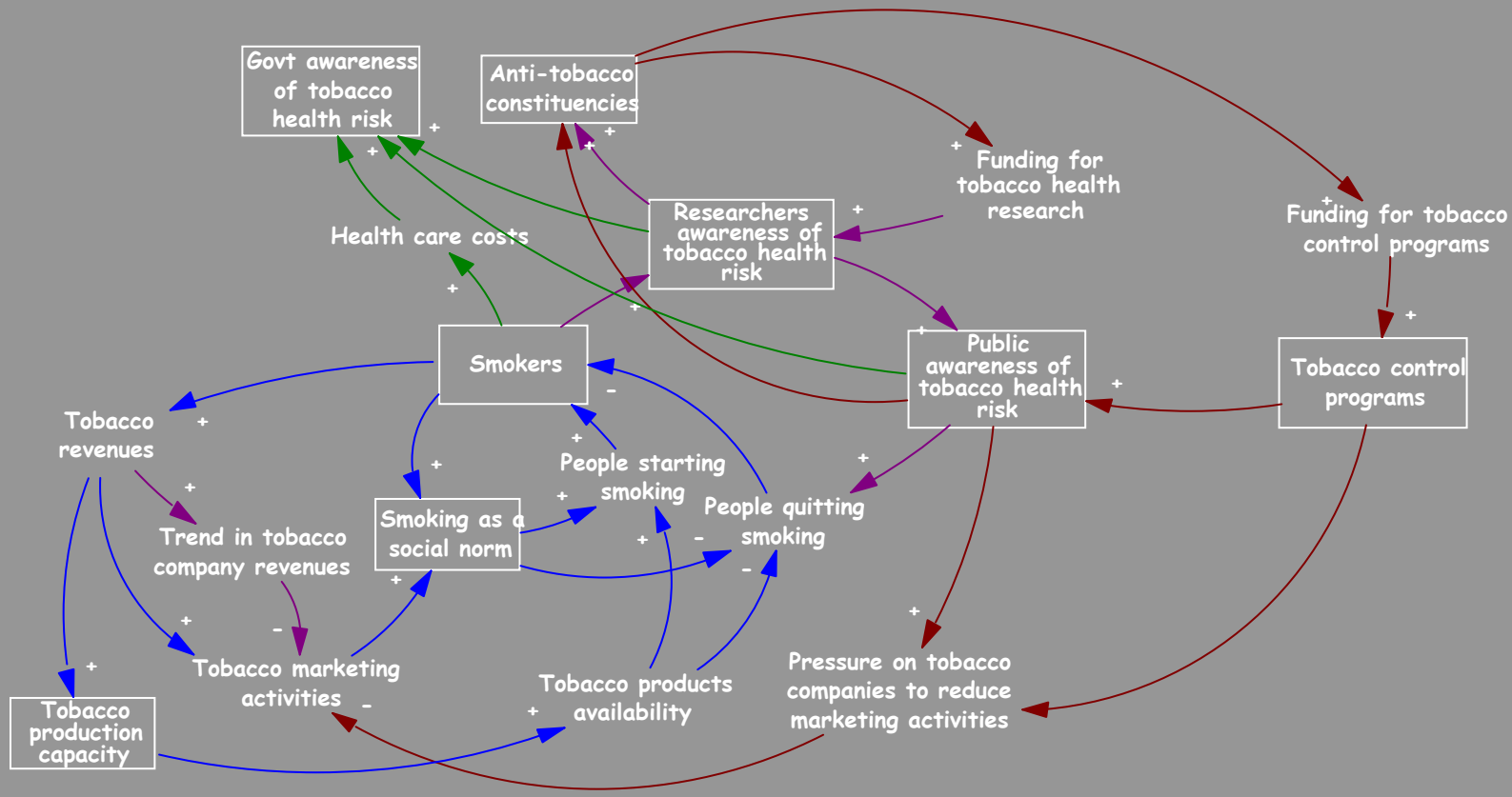

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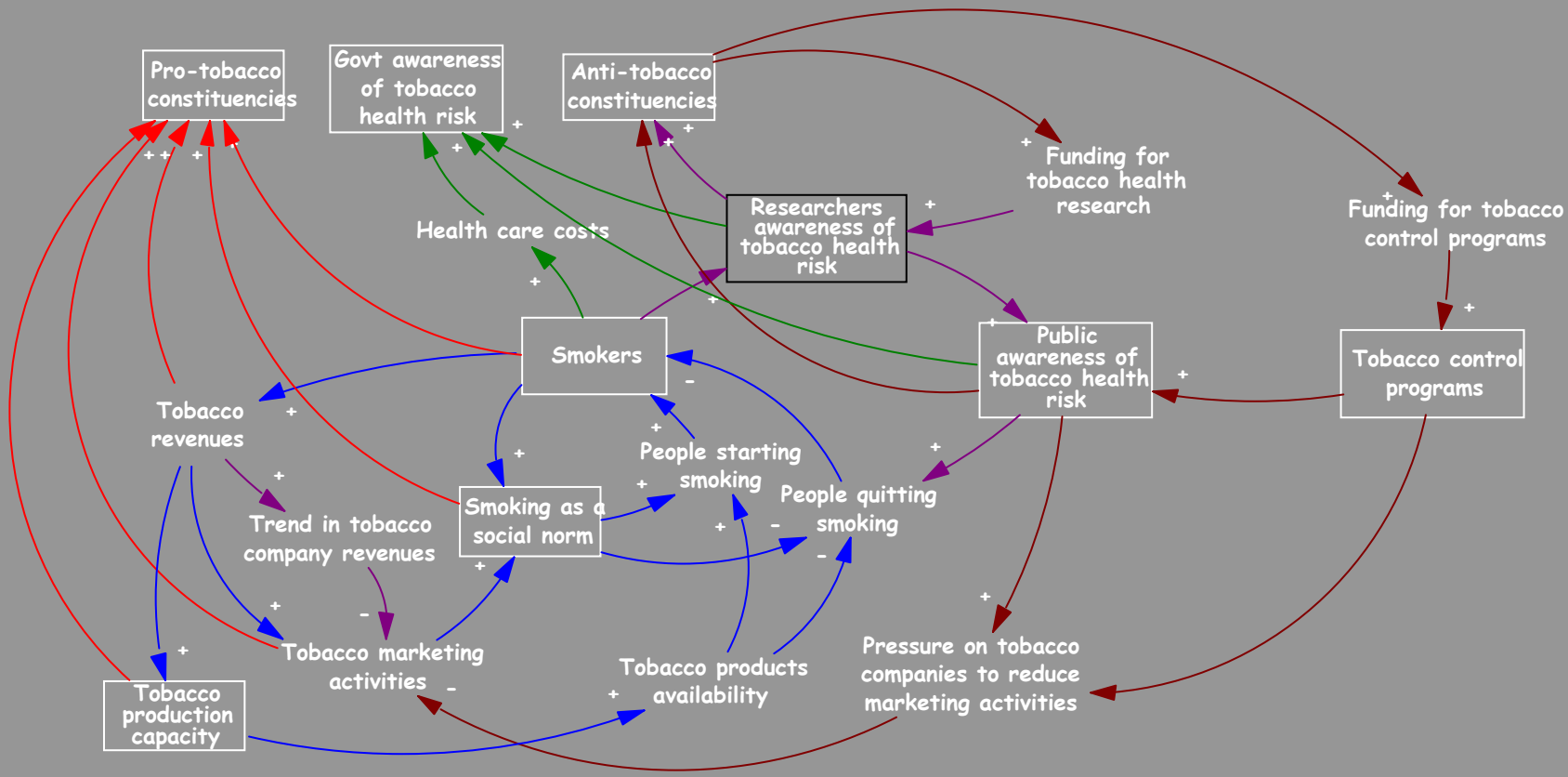

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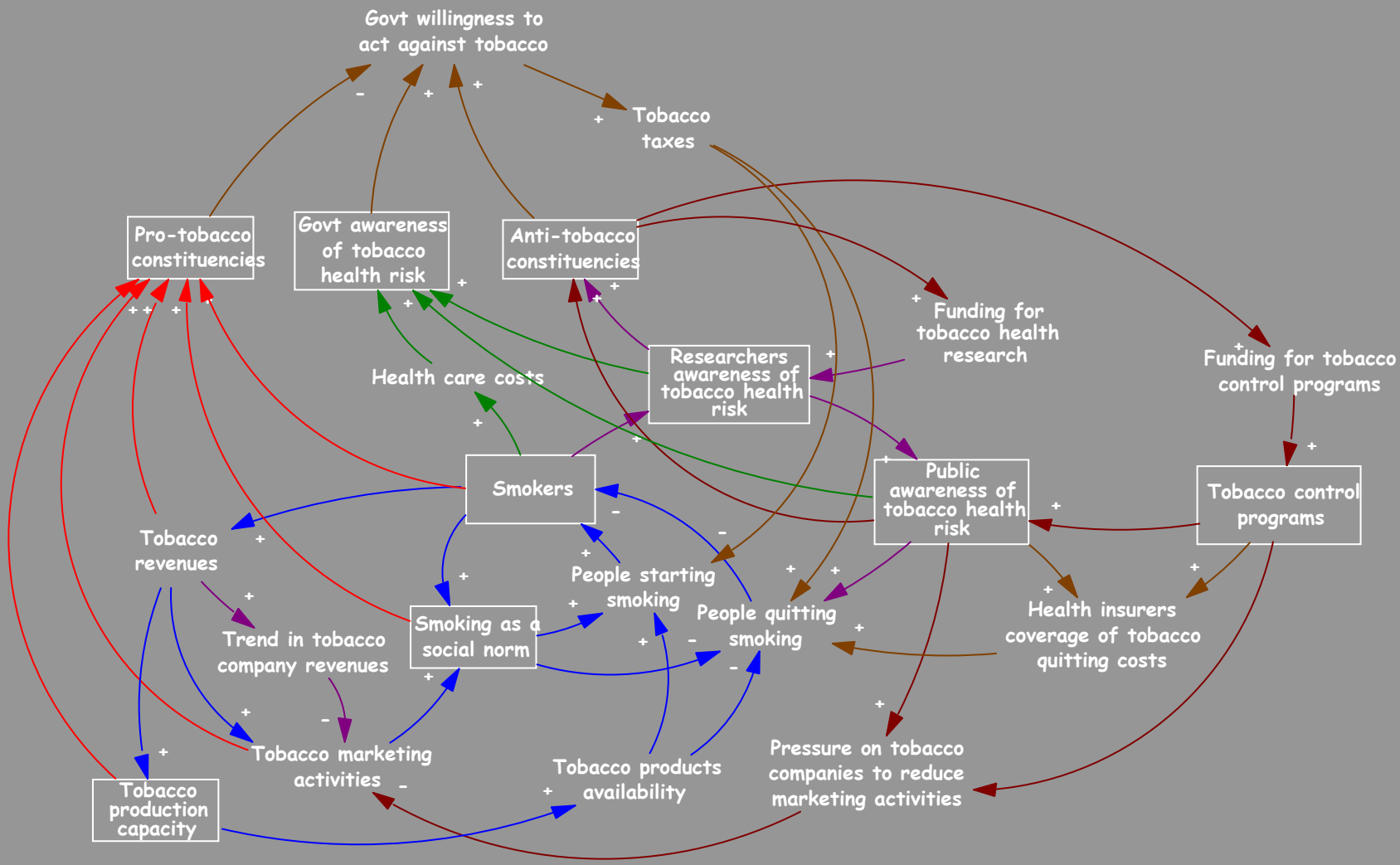

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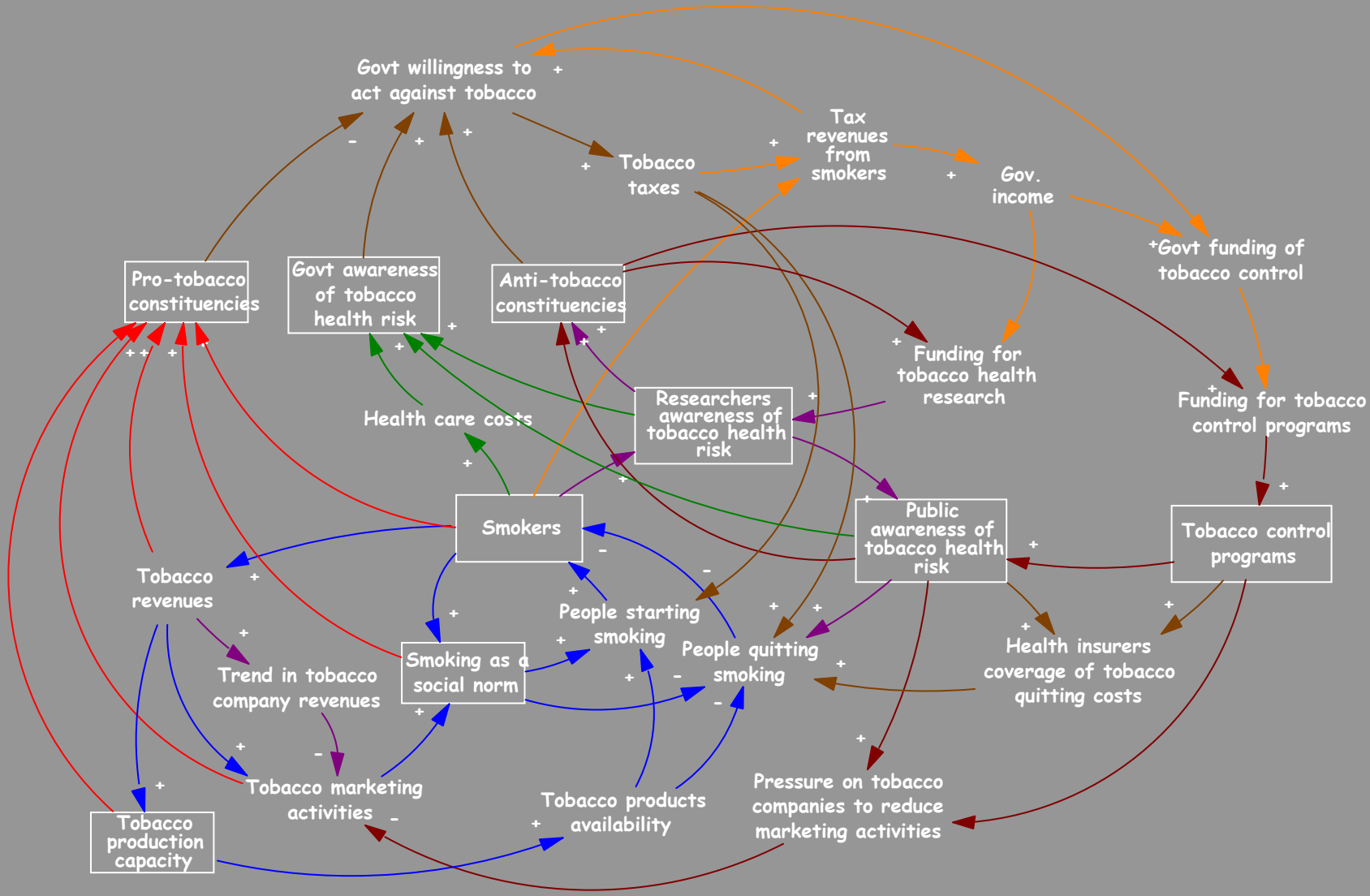

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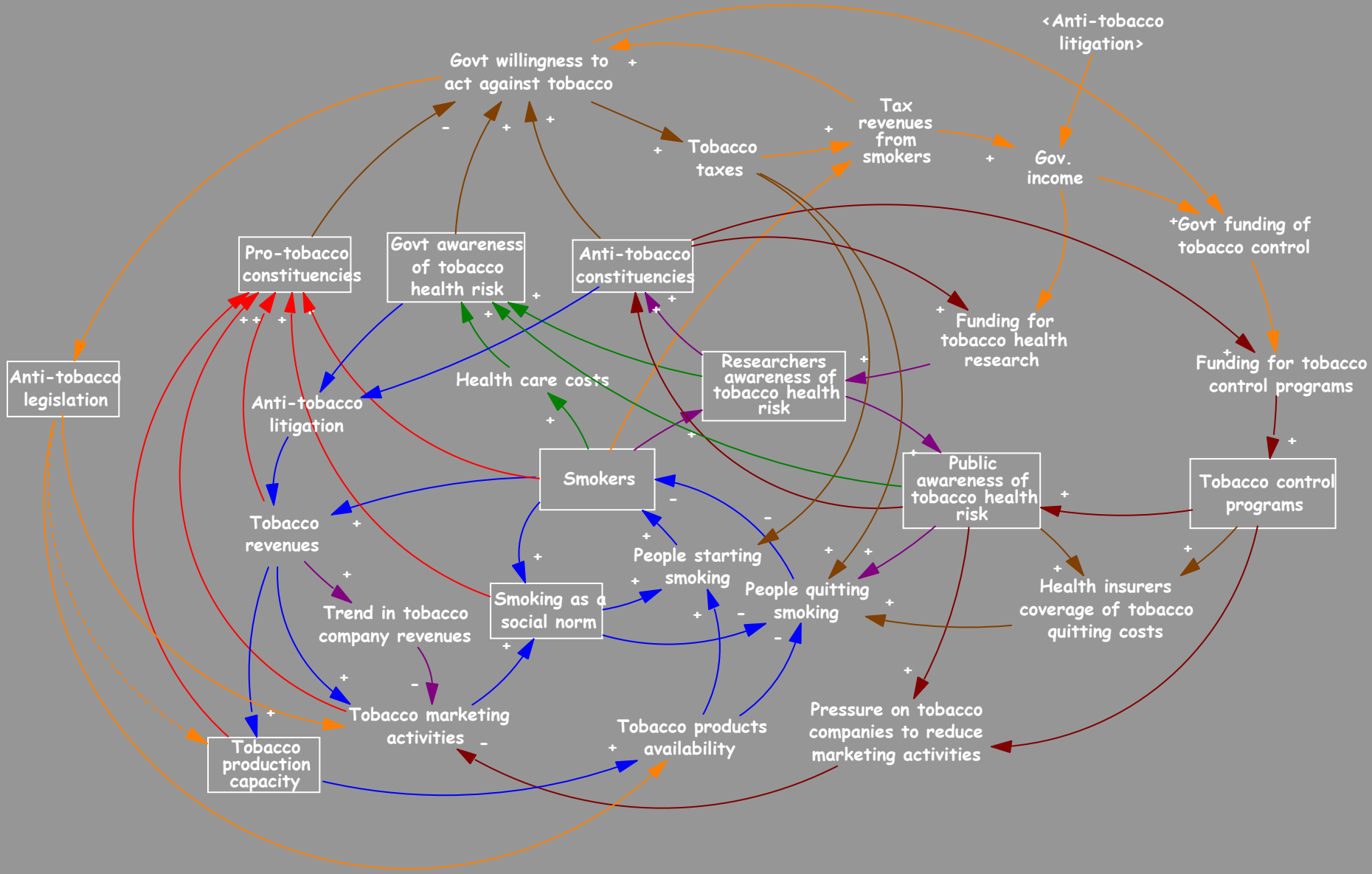

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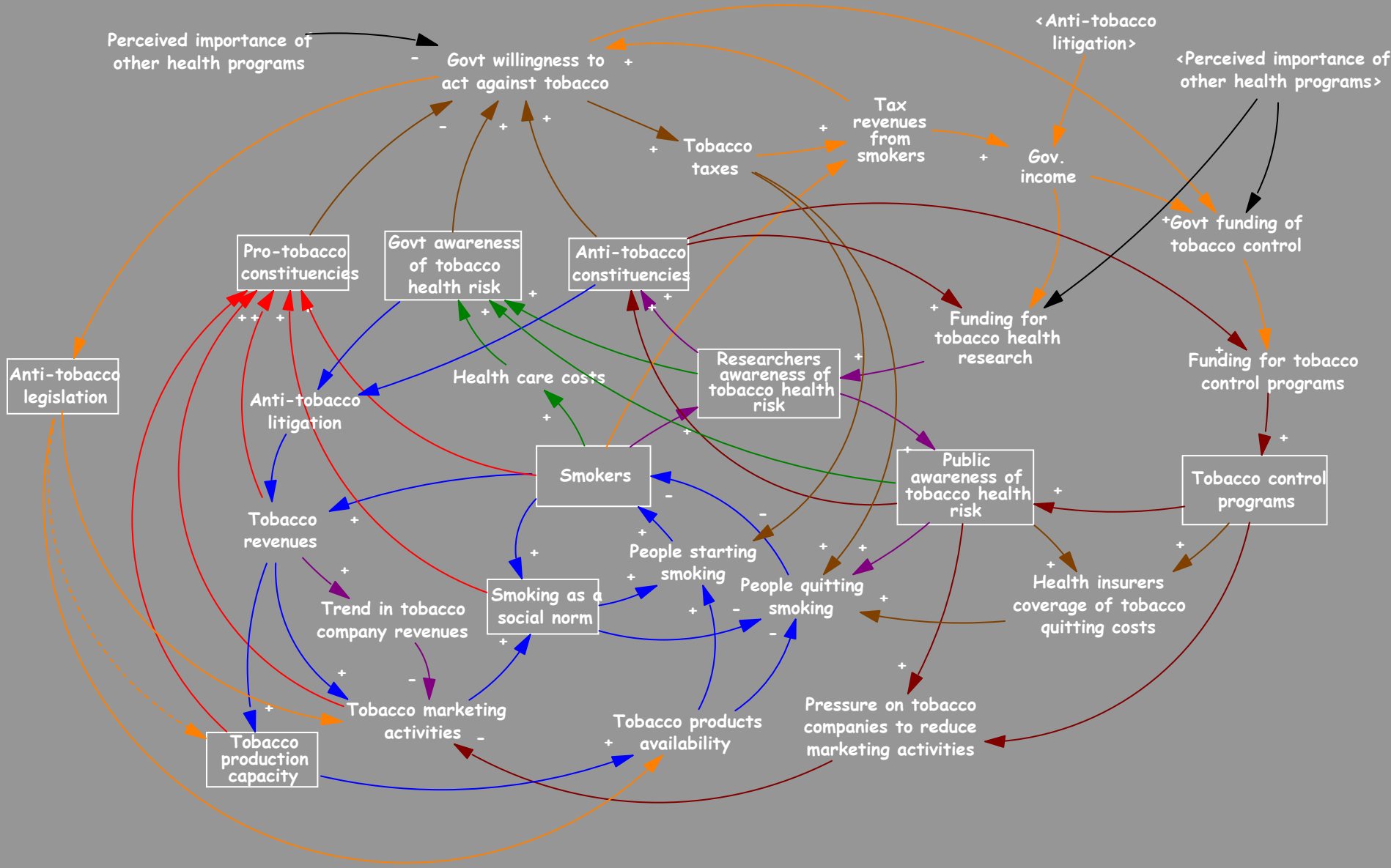

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