



# Introduction to Agent-Based Modelling

*Lecture 10.1*

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## Example 1: Pandemics (2020)

The image displays a world map highlighting confirmed COVID-19 cases across continents. A legend at the top right indicates four levels of concern: 'Confirmed cases' (yellow), 'Travel, but be careful' (light orange), 'At-risk groups avoid travel' (medium orange), and 'Avoid all non-essential travel' (dark red). Data labels on the map include: CANADA (22), U.S. (88), MEXICO (5), ICELAND (3), UK (36), GERMANY (100+), FRANCE (100+), ITALY (1,600+), ALGERIA (3), NIGERIA (1), ISRAEL (10), EGYPT (2), RUS (not explicitly labeled but implied by context), CHINA (80,000+), S. KOREA (4,800+), JAPAN (900+), and INDIA (5).

**ACTIVE CASES**  
41,203  
Currently Infected Patients  
33,828 (80%) in Mild Condition  
7,375 (18%) Serious or Critical

**CLOSED CASES**  
48,576  
Cases which had an outcome:  
45,507 (94%) Recovered / Discharged  
3,069 (6%) Deaths

**Total Cases**  
Linear  
Logarithmic

**Total Deaths**  
Linear  
Logarithmic

**Sky News**  
Coronavirus: Risk in EU from outbreak rises from moderate to high  
15 minutes ago

**CNN**  
Trump announces new coronavirus screening procedures for travelers to US  
Yesterday

**BBC News**  
Coronavirus cases grow outside China as deaths top 3,000  
4 hours ago

**BBC News**  
New coronavirus cases jump sharply in Europe, with Italy worst hit  
Yesterday

**한국 언론사 MBC**

Australia (29) and New Zealand (1) are also labeled on the map.



## Example 1: Pandemics (2021)

**Global Cases**  
**111,351,190**

Cases by Country/Region/Sovereignty

- 28,133,699** US
- 10,991,651** India
- 10,168,174** Brazil
- 4,127,574** United Kingdom
- 4,117,992** Russia
- 3,597,540** France

**ACTIVE CASES**  
**22,150,424**  
Currently Infected Patients

**CLOSED CASES**  
**89,809,298**  
Cases which had an outcome:

- 87,327,118** (97%) Recovered / Discharged
- 2,477,855** (3%) Deaths

**Daily New Cases**  
Cases per Day  
Data as of 8:00 GMT+0

**Daily Deaths**  
Deaths per Day  
Data as of 8:00 GMT+0

**Global Deaths**  
**2,466,154**

**Das Neuste zur Coronakrise - Polizei löste am Wochenende illegale Partys und Versammlungen auf**  
Bremische Radio und Fernsehen (BRF) - Vor 27 Minuten

**89.4 %**

**Coronavirus: Was wir zu den neuen Varianten wissen**  
Neue Zürcher Zeitung - Vor 5 Tagen

**Global Deaths**  
498,879 deaths  
US  
246,504 deaths  
Brazil  
180,107 deaths  
Mexico  
156,302 deaths  
India  
120,810 deaths  
United Kingdom  
95,711 deaths  
Italy  
83,546 deaths  
France  
81,924 deaths  
Russia  
67,948 deaths  
Germany

**The Guardian**  
Coronavirus live news: US death toll nears 500,000; England roadmap out of lockdown revealed  
10 minutes ago

**Sky News**  
COVID-19: UK reports another 215 coronavirus deaths as number of people jabbed hits 17.5 million  
12 hours ago

**Covid a Brescia: la provincia oltre la soglia della fascia rossa, boom di contagi**  
Cronaca della Seta - 8 ore fa

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## Example 1: Pandemics (late 2021)

COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)

Last Updated at (M/D/YYYY)  
21/11/2021, 19:22

Total Cases		Total Deaths		Total Vaccine Doses Administered	
<b>257,447,558</b>		<b>5,149,871</b>		<b>7,389,629,480</b>	
Cases   Deaths by Country/Region/Sovereignty		28-Day Cases		28-Day Deaths	
		<b>13,373,835</b>		<b>201,029</b>	

**United Kingdom**  
28-Day: **1,081,769** | 4,430  
Totals: **9,897,197** | 144,369

**Russia**  
28-Day: **1,056,640** | 32,474  
Totals: **9,170,898** | 259,107

**Germany**  
28-Day: **908,273** | 13,963  
Totals: **5,382,587** | 99,082

**Turkey**  
28-Day: **725,364** | 5,930  
Totals: **4,552,347** | 74,847

**Ukraine**  
28-Day: **605,059** | 18,250  
Totals: **3,492,203** | 86,260

**Poland**  
28-Day: **358,264** | 4,347  
Totals: **3,945,388** | 80,822

**Netherlands**  
28-Day: **346,463** | 650  
Totals: **2,483,042** | 19,411

**India**  
28-Day: **334,945** | 11,393  
Totals: **34,510,413** | 465,662

**Brazil**  
28-Day: **288,591** | 7,130  
Totals: **22,012,150** | 612,587

**France**  
28-Day: **276,071** | 1,141

**Total Cases**  
**257,447,558**

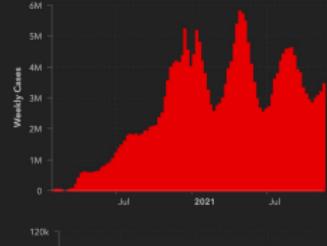
**Total Deaths**  
**5,149,871**

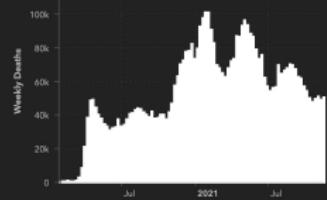
**Total Vaccine Doses Administered**  
**7,389,629,480**

**28-Day Cases**  
**13,373,835**

**28-Day Deaths**  
**201,029**

**28-Day Vaccine Doses Administered**  
**783,832,148**

**Weekly Cases**  


**Weekly Deaths**  


**Daily Doses Administered**  


**Map of Global COVID-19 Cases**  
The map shows the distribution of COVID-19 cases across the world. Red dots indicate the location and density of cases. Major clusters are visible in North America, South America, Europe, and Asia.

**Covid: Huge protests across Europe over new restrictions**  
BBC News - 41 minutes ago

**Mehr Covid-19-Patienten auf Intensivstationen: Alle Berliner Kliniken verschieben planbare**  
Mehr Covid-19-Patienten auf Intensivstationen: Alle Berliner Kliniken verschieben planbare

**Demonstration in Zürich – Rund 8000 Menschen protestierten gegen die Corona-Massnahmen**  
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## New concepts became familiar to us

Reproduktionszahl R - Wie soll wird der R-Wert nachträglich angepasst. Frau Stadler?  
Schweizer Radio und Fernsehen (SRF) - Vor 9 Tagen - Meinung

Germany's R rate goes above one, despite 10 weeks in lockdown  
Euronews - 9 hours ago

R number drops to lowest level in the UK since records began  
In Your Area - 3 days ago

Corona-Zahlen, Spitäler, R-Wert: Ist die Lockerung realistisch?  
Neue Zürcher Zeitung - Vor 3 Tagen

Il numero di cui parlano tutti  
Il Post - 4 mag 2020

Covid-19: le taux de reproduction ( $R_0$ ) se stabilise à 0,84  
Finances News Hebdo - il y a 20 jours

*The basic reproduction rate  $R_0$ , which is an inherent property of the contagion process*



## New concepts became familiar to us

Sweden eyes tighter Covid measures as third wave looms  
Financial Times - 5 days ago



¿Era inevitable una segunda ola de la Covid? ¿Y la tercera?  
www.infosalus.com - Hace 19 días



Coronavirus: seconda ondata, numeri da paura  
La Prealpina - 25 giorni



EU vaccine policy partly responsible for third wave - health minister  
The First News - 2 days ago

Covid: in Toscana la seconda ondata ha fatto il triplo di morti  
LA NAZIONE - 21 giorni fa



Poland discovers South African COVID-19 variant as third wave looms  
Reuters - 3 days ago



*The fact that epidemics can be described as a waves, each one consisting of an accelerated growth of contagions, a peak, to later slow down*



## New concepts became familiar to us

Das Neuste zur Coronakrise - Polizei löste am Wochenende illegale Partys und Versammlungen auf  
Schweizer Radio und Fernsehen (SRF) · Vor 27 Minuten



Contagi e varianti spaventano: ipotesi lockdown come a Natale  
Il Sole 24 ORE · 2 giorni fa



COVID-19: Government scientists want to keep social distancing measures in place for foreseeable future  
Sky News · 7 days ago



Libanon: Proteste gegen Lockdown und Armut eskalieren | NZZ  
Neue Zürcher Zeitung · 27. Jan.



FFP2-Masken für Kinder oder OP-Maske: Welche Maske sollten Schulkinder jetzt tragen?  
familie.de · Vor 3 Tagen



Masque FFP2 : quelle efficacité ? Où en acheter ? Qui peut le porter ?  
L'Interneute.com · Il y a 11 jours · Article d'opinion



*The fact that interventions (top-down or at the individual level) can be implemented to curb the spreading dynamics*



## New concepts became familiar to us

<p>Variant anglais : où en est la situation dans le pays ? LCI - Il y a 17 heures</p>	<p>Coronavirus: Was wir zu den neuen Varianten wissen Neue Zürcher Zeitung - Vor 5 Tagen</p>
<p>Covid-19 - Wie gefährlich sind die neuen Mutationen des Coronavirus? Deutschlandfunk - Vor 6 Stunden</p>	<p>New Covid variant with potentially worrying mutations found in UK The Guardian - 6 days ago</p>
<p>Britische Corona-Mutation: Symptome sind anders – Experten warnen nzz24.de - Vor 24 Minuten</p>	<p>"A Napoli variante Covid con mutazioni critiche" Adnkronos - 5 giorni fa</p> <ul style="list-style-type: none"><li>Covid, fallimento del presidente virologi: "A Napoli variante nuova con mutazioni critiche"</li></ul>

*The fact that viruses mutate, and thus immune response may be insufficient*



## In summary

1. There is a system composed of many elements : Humans
2. There is a microscopic interaction mechanism : Contagion
3. There a set of global properties : The number of infected people, deaths, recovered



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1. There is a system composed of many elements : Humans
2. There is a microscopic interaction mechanism : Contagion
3. There a set of global properties : The number of infected people, deaths, recovered
4. It is possible to apply interventions
  - at the level of the microscopic mechanism: *masks, social distancing*
  - as a top-down approach: *lockdown, travel restrictions, vaccination*



## The essence of Agent-Based Modelling

*In systems with many interacting agents, understand the link between microscopic mechanisms and global properties.*



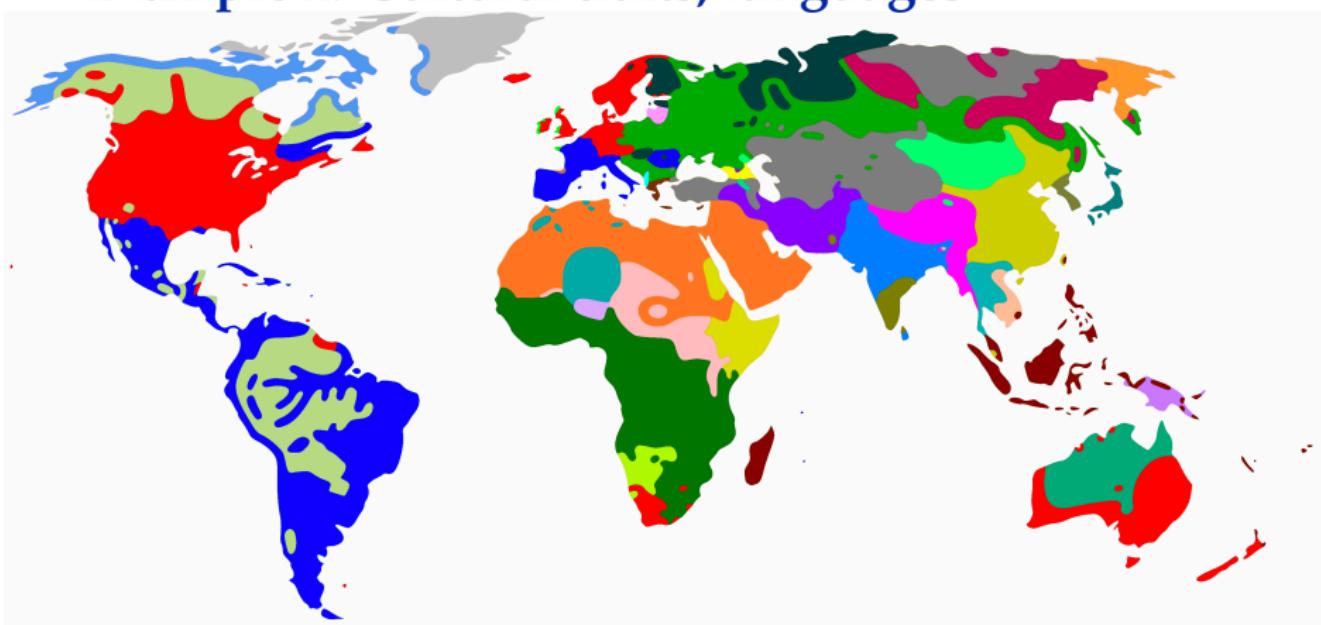
## The essence of Agent-Based Modelling

*In systems with many interacting agents, understand the link between microscopic mechanisms and global properties.*

- + Do so through minimalistic computational models
- + Possibly apply interventions



## Example 2: Cultural traits, languages





## In summary

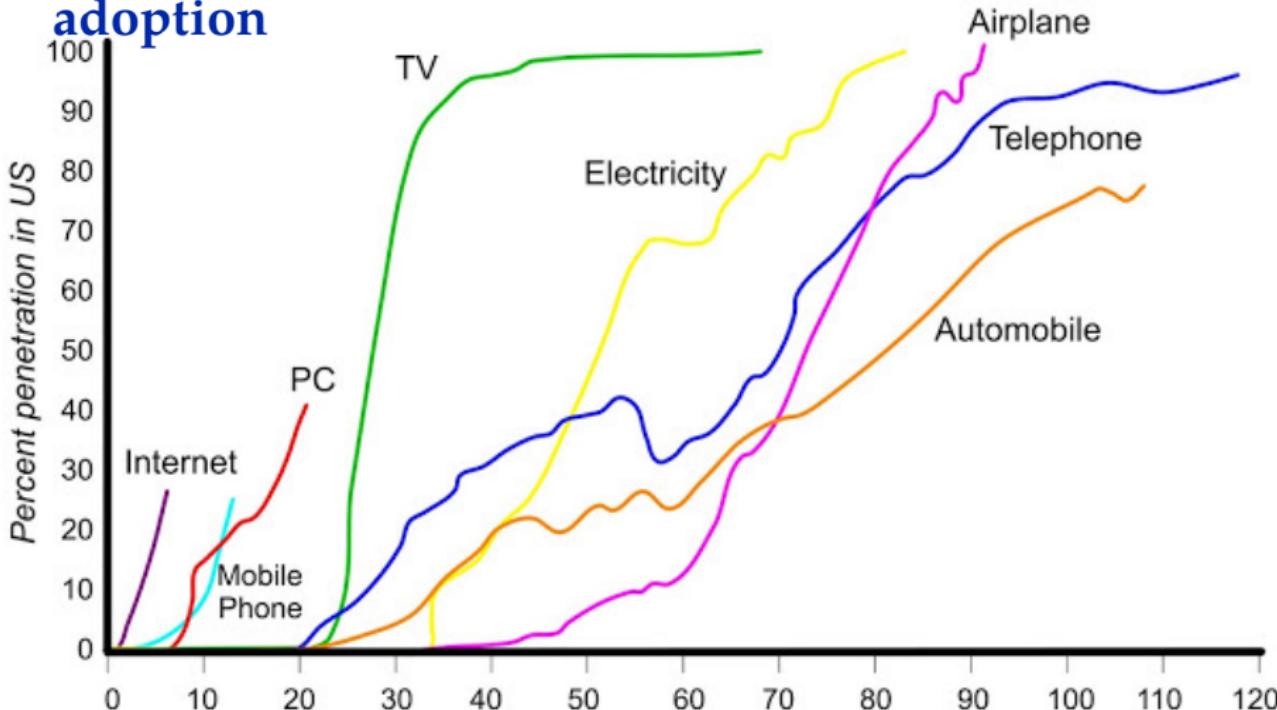
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2. There is a microscopic interaction mechanism : learning, speaking
3. There a set of global properties : Large extensions where languages are prevalent



## In summary

1. There is a system composed of many elements : Humans
2. There is a microscopic interaction mechanism : learning, speaking
3. There a set of global properties : Large extensions where languages are prevalent
4. It is possible to apply interventions
  - as a top-down approach: *imposition of languages in specific areas*

## Example 3: Opinion formation / Product adoption





## But there is more

1. There is a system composed of many elements : Humans
2. There is a microscopic interaction mechanism : imitation
3. There a set of global properties : Total sales, awareness



## But there is more

1. There is a system composed of many elements : Humans
2. There is a microscopic interaction mechanism : imitation
3. There a set of global properties : Total sales, awareness
4. It is possible to apply interventions
  - at the level of the microscopic mechanism: *influencer, opinion leaders*
  - as a top-down approach: *advertisement*



## In summary

*The mathematical mechanisms that describe product adoption/diffusion of opinions are the same as those used in epidemics*



## In summary

*The mathematical mechanisms that describe product adoption/diffusion of opinions are the same as those used in epidemics*

- + Interdisciplinary insights are useful
- + The approaches presented have multiple applications



*Many large-scale phenomena  
have their roots in  
micro-behaviour*



*The mechanisms that explain  
the phenomena are the same*



# Definitions



## What is an agent?

*An agent is an autonomous computational individual or object with particular properties and actions*



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*An agent is an autonomous computational individual or object with particular properties and actions*

- + Individuals (social diffusion / traders / contagion )
- + Computers or computing devices ( information / contagion )
- + Firms / organisations ( knowledge / production / sale)
- + Countries ( production / import-export )



## What is an agent?

*An agent is an autonomous computational individual or object with particular properties and actions*

- + Individuals (social diffusion / traders / contagion )
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*Key observations about agents*

- Do not act in isolation, but naturally **interact** with others

Agents can ...



*A complex socio-economic system is one composed by many interacting constituents. Its global properties are not the simple aggregation of individual behaviour, but a richer emergent one*



*“The action of the whole is  
more than the sum of its  
parts” (Holland)*



*Bottom-up: On complex  
systems, order can emerge  
without any design or  
designer action.*



*A model is an abstract,  
limited, idealised, description  
of reality that still captures a  
specific phenomenon*



*Social and economic systems  
have a multitude of factors.  
Including them all in a model  
is unattainable*



*ABM are not intended to reproduce society, economy as a whole, but to shed light on mechanisms behind specific observed phenomena*



## What are ABMs? Why ABMs?

### ABMs are

- + constructed out of individual objects and simple rules for their behaviour
- + easier to understand than purely mathematical representations of the same phenomenon

### ABMs ...

- + facilitate experimentation (can be run repeatedly)
- + are simplifications of reality They provide us with analogies.
- + describe past patterns of behaviour
- + explain mechanism that lead to observed patterns



## Components of a model: Agents

### *State variables*

Each agent is characterised by a set of variables which identify their state

- + **Binary**
  - Whether it adopted a product or not
  - In favour or against a legislation
- + **Categorical**
  - Status with regard to an illness
- + **Real**
  - Knowledge level
  - Investment



## Components of a model: Interactions

### *Network*

Agents do not act in isolation, but are affected by (or affect) the behaviour of peers

- + *All-to-all*
- + *Local neighbours*
- + *Social network*



## Subject of study: (ii) The role of a mechanism

### Dynamics

Agents change their state(s) because of the interaction with others or information from the environment. These are **microscopic rules**, or mechanisms under study

- + *Imitation*
- + *Herding*
- + *Diffusion*
- + *Homophily*



## Control Parameters

*The rules that specify the mechanism, the agents, etcetera are endowed with numerical parameters that can be adjusted to understand their effect on emergent properties*



## Order Parameters

*During the simulation, we measure large-scale properties of the system. They quantify the emergent state of the system*



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