The aim of science is not to open the door to infinite wisdom, but to set a limit to infinite error.

_Bertolt Brecht (Leben des Galelei (Life of Galileo))_
4 transistors
5 resistors


Nvidia H100
Multiinstance GPU
900 GB/s Nvlink

7.7 × 10^7 transistors
Semiconductors are the foundation of the information edifice of the modern society

Communications (cell phones, all the financial transactions, ...): semiconductors based.
Computing (transactions, financial bookkeeping, Aadhar, UPI, education, ...): semiconductors based.
Sensing and decision making (data gathering, inferencing, ...): semiconductors based.
Defense (monitoring, reactions, controls, operations, ...): semiconductors based.
Even cars are increasingly semiconductors and computing on wheels

Like agriculture!
the Stanford marshmallow experiment of delayed gratification
Development and growth is a flow.

A flow across the entire chain in all its dimensions.

People, ideas, development, products, ... in time
1% 40% of wealth
10% 63% of wealth
40% of the wealth created in the country from 2012 to 2021 went to top 1%.
3% went to bottom 50%

64% of GST from bottom 50%

Degree education (millions)

~30% to college

1--2 generations; 25 years
Maternal-mortality death rate per 100,000 live births by select country, 2020 estimates

- India: 102.7 per 100k
- Brazil: 72.1
- China: 23
- U.S.: 21.1
- Russia: 13.7
- Canada: 11
- U.K.: 9.8
- Finland: 8.3
- France: 7.9
- Italy: 4.6
- Sweden: 4.5
- Germany: 4.4
- Japan: 4.3
- Netherlands: 4.3
- Spain: 3.4
- Australia: 2.9
- Norway: 1.7

Source: World Health Organization
Low/middle income trap
Fast and slow, short and long, scattering and friction, work and heat.

Lower income and middle income trap

**UK:** Manufacturing gone, class and feudal and financial chicanery
**Italy:** Tourism and gastronationalism is half of GDP
**Greece:** Tourism and right-left ancient debates
**Türkiye:** Tourism and secular-religious cultural fights
When a community finds itself deprived of its sense of identity, because of whatever historical shock or fracture with its past, it invents traditions to act as founding myths.

_Eric Hobswam_
### Different years 2021, 2022

<table>
<thead>
<tr>
<th></th>
<th>Türkiye</th>
<th>South Korea</th>
<th>China</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual GDP $M</td>
<td>817,508</td>
<td>1,797,810</td>
<td>17,744,640</td>
<td>3,176,296</td>
</tr>
<tr>
<td>GDP/capita</td>
<td>9,654</td>
<td>34,744</td>
<td>12,564</td>
<td>2,257</td>
</tr>
<tr>
<td>Debt/GDP %</td>
<td>41.8</td>
<td>51.33</td>
<td>68.06</td>
<td>89.18</td>
</tr>
<tr>
<td>Debt/Capita</td>
<td>4,036</td>
<td>17,968</td>
<td>7,164</td>
<td>1,704</td>
</tr>
<tr>
<td>Deficit/Gdp %</td>
<td>-3.86</td>
<td>-0.02</td>
<td>-9.72</td>
<td>-12.76</td>
</tr>
<tr>
<td>Expenditure $/Capita</td>
<td>3012</td>
<td>9046</td>
<td>3726</td>
<td>588.5</td>
</tr>
<tr>
<td>Export/GDP %</td>
<td>26.15</td>
<td>35.61</td>
<td>18.97</td>
<td>12.46</td>
</tr>
<tr>
<td>Education $/Capita</td>
<td>395</td>
<td>1487</td>
<td>347</td>
<td><strong>56</strong></td>
</tr>
<tr>
<td>Education/Budget %</td>
<td>12.41</td>
<td>24.98</td>
<td>11.45</td>
<td>12.75</td>
</tr>
<tr>
<td>Health $/Capita</td>
<td>291</td>
<td>1214</td>
<td>337.9</td>
<td><strong>19.9</strong></td>
</tr>
<tr>
<td>Health/Budget %</td>
<td>9.69</td>
<td>13.42</td>
<td>9.07</td>
<td>3.38</td>
</tr>
<tr>
<td>Density</td>
<td>108</td>
<td>515</td>
<td>147</td>
<td>428</td>
</tr>
<tr>
<td>Life expectancy</td>
<td>75.85</td>
<td>83.5</td>
<td>78.08</td>
<td>70.15</td>
</tr>
<tr>
<td>Population</td>
<td>84,680,273</td>
<td>51,736,000</td>
<td>1,412,360,000</td>
<td>1,407,563,842</td>
</tr>
</tbody>
</table>

GVA adjusts GDP by the impact of subsidies and taxes (tariffs) on products.
### China to USA

#### US with China: Total Trade in Goods

<table>
<thead>
<tr>
<th>Year</th>
<th>Exports</th>
<th>Imports</th>
<th>Deficit</th>
<th>Surplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source:** U.S. Census Bureau USA Trade Portal February 15, 2022

#### S. Exports to China in Agriculture Products

<table>
<thead>
<tr>
<th>Year</th>
<th>Billion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>$18.9</td>
</tr>
<tr>
<td>2018</td>
<td>$8.7</td>
</tr>
<tr>
<td>2019</td>
<td>$13.4</td>
</tr>
<tr>
<td>2020</td>
<td>$24.8</td>
</tr>
<tr>
<td>2021</td>
<td>$31.6</td>
</tr>
</tbody>
</table>

**Source:** Automated Export System, retrieved on February 22, 2022

### USA to China

#### China Commodity Trade 2021

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total Value All Commodities</th>
<th>US exports to China by Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1%</td>
<td>Agriculture (Chapters 01-24)</td>
<td>$15,065,225,124</td>
</tr>
<tr>
<td>0.1%</td>
<td>Oils, Minerals, Lime, Cement (Chapters 25-27)</td>
<td>11.2%</td>
</tr>
<tr>
<td>10.5%</td>
<td>Chemicals, Plastics, Rubber, Leather (Chapters 28-43)</td>
<td>16.6%</td>
</tr>
<tr>
<td>1.6%</td>
<td>Wood, Cork, Paper, Printed Books (Chapters 44-49)</td>
<td>3.1%</td>
</tr>
<tr>
<td>9.9%</td>
<td>Textiles, Footwear, Headgear (Chapters 50-67)</td>
<td>1.4%</td>
</tr>
<tr>
<td>1.7%</td>
<td>Stone, Glass, Metals, Pearls (Chapters 68-71)</td>
<td>3.0%</td>
</tr>
<tr>
<td>5.7%</td>
<td>Base Metals, Iron, Steel, Tools (Chapters 72-83)</td>
<td>2.6%</td>
</tr>
<tr>
<td>47.7%</td>
<td>Machinery &amp; Mechanical Appliances (Chapters 84-85)</td>
<td>23.9%</td>
</tr>
<tr>
<td>3.4%</td>
<td>Transportation Equipment (Chapters 86-89)</td>
<td>8.8%</td>
</tr>
<tr>
<td>2.9%</td>
<td>Optical, Measuring, Medical, Other Instruments (Chapters 90-92)</td>
<td>7.2%</td>
</tr>
<tr>
<td>0.1%</td>
<td>Arms &amp; Ammunition (Chapter 93)</td>
<td>0.0%</td>
</tr>
<tr>
<td>13.5%</td>
<td>Miscellaneous Manufactured Items (Chapters 94-96)</td>
<td>0.2%</td>
</tr>
<tr>
<td>0.0%</td>
<td>Art, Collectors' Pieces, Antiques (Chapter 97)</td>
<td>0.1%</td>
</tr>
<tr>
<td>1.9%</td>
<td>Special Items (Chapter 98)</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

**Source:** U.S. Census Bureau USA Trade Portal February 15, 2022
American export controls

https://www.bis.doc.gov/index.php/regulations/export-administration-regulations-ear

Semiconductors: TSMC

Founded 1987, $75B/yr (2022), 65000 employees. Foundry (Intel is $62B/yr)
Morris Chang (from TI (founded 1951, made the 1st integrated circuit (Kilby)), $21B/yr Analog/Digital)

13 foundries.
1/3 of all of world’s silicon chips
All of iPhones, Macs, ...

USA: CHIPS Act is roughly $280B

China:
1 B internet users
$6.6T digital economy

https://companiesmarketcap.com/tsmc/revenue/
Dirigisme (Fr. diriger)
Technology, value and control

Large cloud providers: Amazon, Google, Microsoft, Alibaba Cloud.

Dominant desktop OS providers: Microsoft, Apple and various Linux.

Dominant mobile OS providers: Google and Apple.

Chip companies: Samsung, TSMC, Intel, GlobalFoundaries.

Design companies: Nvidia, Broadcom, Qualcomm.

Social networks: Meta, Whatsapp, Snap, TikTok, WeChat.

Car companies: Tesla, Hyundai, Toyota, VW, Mercedes, BMW.

Airplanes: Boeing, Airbus, Comac C919.
### World change from post WWII order

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9,831,510 km²</td>
<td>331,894,000 people</td>
</tr>
<tr>
<td></td>
<td>9,562,910 km²</td>
<td>1,412,360,000 people</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>GDP: $23,315,081B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GDP: $17,734,063B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Company</th>
<th>Revenue (B)</th>
<th>Users</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon</td>
<td>$514B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>$388B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Google</td>
<td>$283B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tesla</td>
<td>$82B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meta/FB</td>
<td>$117B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Twitter</td>
<td>$4.4B/yr</td>
<td>328M users</td>
<td>7.7 x 10^{10}trx</td>
</tr>
<tr>
<td>Nvidia</td>
<td>$27B/yr</td>
<td>H100</td>
<td>7 nm</td>
</tr>
<tr>
<td>Alibaba</td>
<td>$135B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huawei</td>
<td>$110B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baidu</td>
<td>$20B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BYD</td>
<td>$52B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ByteDance(TTok)</td>
<td>$58B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tencent(WeChat)</td>
<td>$81B/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sina(Weibo)</td>
<td>$2.1B/yr</td>
<td>340M users</td>
<td>7.7 x 10^{10}</td>
</tr>
<tr>
<td>Biren Tech</td>
<td>$100B/yr</td>
<td></td>
<td>7 nm</td>
</tr>
</tbody>
</table>

Amazon, Google, Facebook, Snapchat, Pintrest: $380 billion in advertising revenue in 2022.
China spectrum

![China spectrum chart]

www.statista.com
Total shareholder return for S&P 500 sectors, 03/09-12/21, % annualised

Semiconductors-dominated and based information structure

https://www.ft.com/content/939e819e-8381-4fee-8639-439847a196b3
Semiconductor companies market revenue worldwide from 2009 to 2022 (in billion U.S. dollars)

TSMC: $75B
NVidia’s competition: Biren Technology

Founded Shenzen: 2019
Fabless design
AI and high performance computing
Chips from TSMC

7 nm, $7.7 \times 10^{10}$
(Nvidia’s H100 is at 4 nm node)
300 MB on-chip sram
2048 TOPS INT 8
1024 TFLOPS BF 16
512 TFLOPS TF 32
256 TFLOPS FP 32
64GB HBM2E
8BLinkTM
2.3TB/sexternall/Obandwidth

550 W

© Sandip Tiwari 2023
ARM

230B cumulative ARM-based chips in 2022
80B per year currently
(most going to China, and China’s ARM has as strong a control of ARM has Softbank)
Is now pervasive from cloud to edge, with cpus in the middle.)
Macs, iPhones, Chrome, ...

Neoverse V2: cloud, hyperscale, HPC; AMBA
CHI, UCIe and CXL, ...

https://20stech.com/files/arm-pr-image-210211.jpg
Arm Limited royalty unit shipments as reported by licensees worldwide from 2016 to 2022, by quarter (in billions)

Source
SoftBank Group
© Statista 2023

Additional Information:
Worldwide, 2016 to 2022
By the end of the decade, open RISC-V will be the dominant instruction set architecture. 1/3rd of chip projects (ASIC, FPGA, ...) now employ at least some RISC-V. Europe is all in RISC-V. (Unix-like open software culture change in design)
**Borderless architecture: RISC-V**

2022: 10B chips, with 5B from China (1/6th of ARM volume)

Chinese academy of sciences on 6mo. cycles of upgrading

Starfive (Dubhe, out-of-order cpu, hypervisor,
SiFive (P650 CPU core, ...)

Alibaba (XuanTie custom-built processors based on RISC-V instruction, and is porting Android 10 to RISC-V ISA.)
Ali Pingtou: Xuantie C908 (one of the most energy efficient processor in industry) multi-core, mutli-cluster, 9 state dual issue; Etian 710 for clouds, Hanguang 800 for AI,

Baidu
Huawei
Not many give credit to George Fernandes who threw IBM out in 1977 (along with Coca Cola) for exercising exclusive control.

It was due to this policy/event that India’s software and computing was born.

GF knew the lessons of the Stanford marshmallow experiment.
**Education**

The strength of the western culture comes from a close relationship between the way in which questions are posed and then acted on. In practical actions, all cultures are just as experienced. It is ability to change the questions asked into questions of principle and thus to arrive at new points of view that bring order and insight into the kaleidoscope of experience. This makes it accessible to human thought. It is this link between the posing of questions of principle and practical action which makes education so powerful and the task for us.

*The Humboldt educational model: The university is the environment where students turn to being autonomous individuals and world citizens.*

Critical thinking and analysis
Problem solving
Self management
Working with people
Technology use and development
Core literacy
700 optical fibers on the ground with two ground-to-satellite links to achieve quantum key distribution over a total distance of 4,600 kilometers.


Institutions of eminence? (2018)

Jio Institute
0 students, 52 acres

Today (2023):
2 graduate programs
120 students
6 faculty

Buildings alone do not make an institute.

Creative students and faculty, hard work, world recognition of the work, local impact, serving humanity does.
A self-sustaining semiconductors value chain

Fabrication across the value chain, less at low end, most at high end (4 nm! and continuing smaller)

Process materials (wafers, ultrahigh purity gases, plumbing, clean-room systems, ...)

Process tools (depositions, etching, patterning including EUV, in-process and post-process characterization)

Demanding of broader capabilities, and distributed, low to high cost, higher employment.

Industry

Lead in design, focus on RISCV

High-end hardware (networking, optical systems, cloud systems, AI/ML systems, ...)

Create own open-source underlying operating systems (AI, ML, smartphone, laptop, simulation and chip design, ...)

Create new ideas across design, hardware, to be at the top

Well within India’s capabilities, traditions, low cost, and of large student interest.

Education

Sustainment of entire value chain through mid-tier education.

India, as a giant independent nation near the center of the world can sustain a large industry just as China can.

Higher end. With world-leading research. Demanding, non-compromising high expectations.
We as faculty like to work with problems that stay within our control.

These are inevitably highly constrained and we all have our own ways.

The world has changed.

A large fraction of the most interesting problems are now complex. Integrative.

We have tools to deal with complexity. AI/ML, 500 years of learning, hardware, new ways, ...

We must embrace complexity to avoid trap.

This implies less friction, painless processes, appropriate organization, .... Success, change and well being will be the reward.
To the waverer

....
Whom do we still count on?
Are we just left over, thrown out
Of the living stream? Shall we remain behind
Understanding no one and understood by none?
Have we got to be lucky?
This you ask.

Expect no answer other than your own.

Bertolt Brecht (1935)