“Computational Power and AI“

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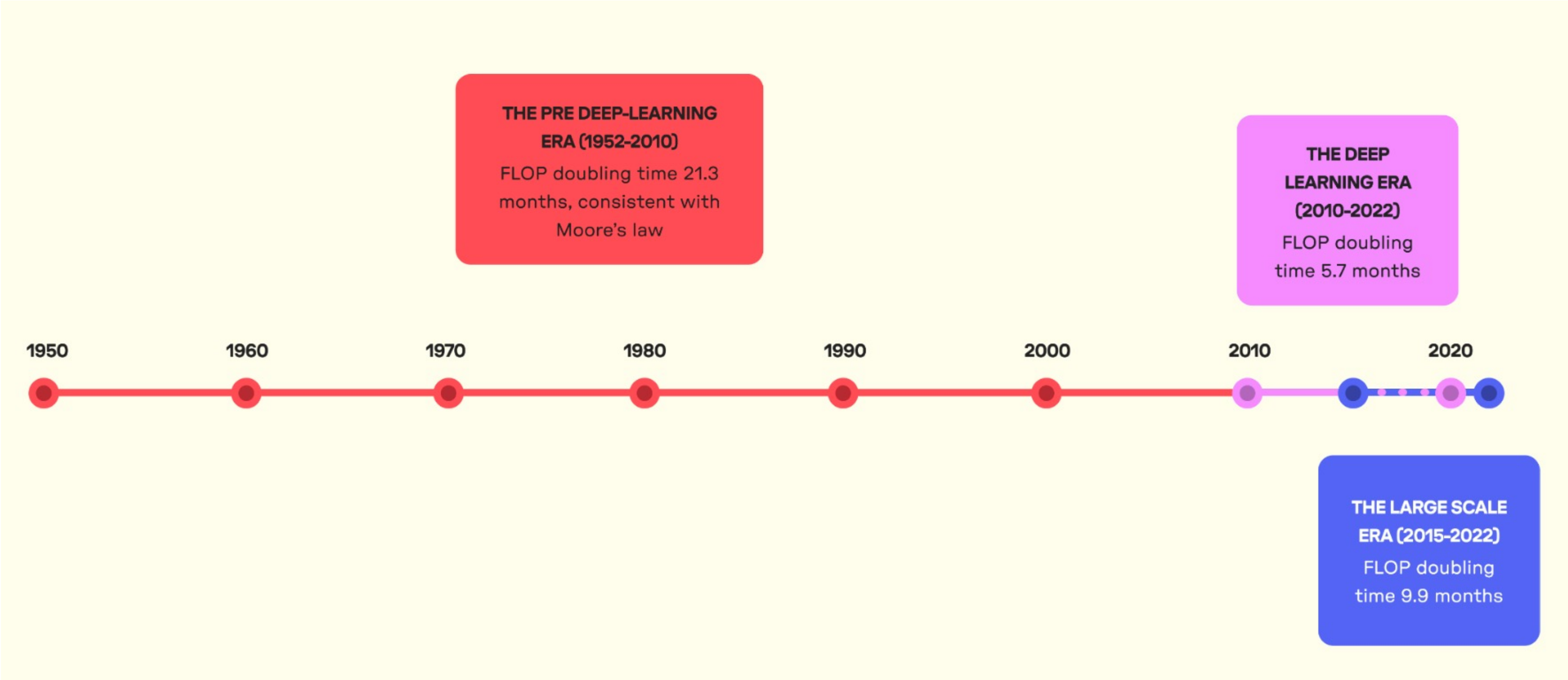
https://ainowinstitute.org/wp-content/uploads/2023/09/AI-Now_Computational-Power-an-AI.pdf

Approach to AI to date:

Researchers in AI have largely concluded that increasing scale is key to accuracy and performance in training deep learning models.

This has driven an exponentially growing demand for compute power, leading to concerns that the current pace of growth is unsustainable

Compute Demand Growth



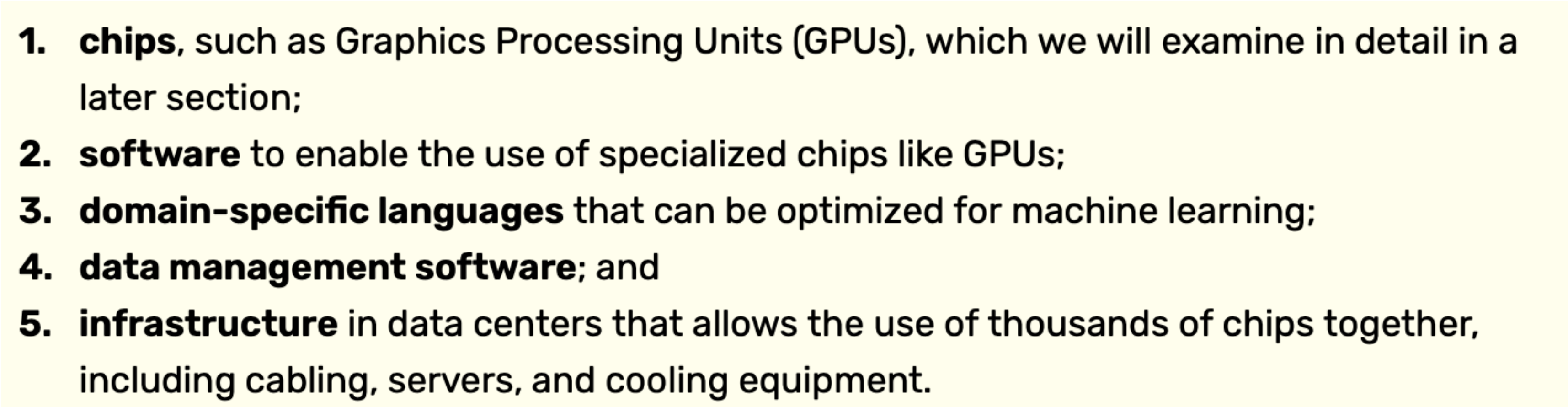
THE PRE DEEP-LEARNING ERA (1952-2010)
FLOP doubling time 21.3 months, consistent with Moore's law

THE DEEP LEARNING ERA (2010-2022)
FLOP doubling time 5.7 months

THE LARGE SCALE ERA (2015-2022)
FLOP doubling time 9.9 months

Pre Deep Learning Era: Compute for AI Models Doubled ~ 21 Months
Deep Learning Era (~2010): Doubled ~5.7 Months
Since 2015: Large-Scale Models Doubled ~9.9 Months
Regular-Scale Models Doubled ~5.7 Months

Defining Compute



1. **chips**, such as Graphics Processing Units (GPUs), which we will examine in detail in a later section;
2. **software** to enable the use of specialized chips like GPUs;
3. **domain-specific languages** that can be optimized for machine learning;
4. **data management software**; and
5. **infrastructure** in data centers that allows the use of thousands of chips together, including cabling, servers, and cooling equipment.

Core Thesis of the Article

- Compute is not just a technical input, it is a **structuring force** for:
  - Market power
  - Research direction
  - Environmental impact
  - Governance and policy
- Current approach to AI infrastructure self perpetuating, not sustainable long term.
- New Policies may be required to prevent hurtful monopolies

AI Dominance

- Compute is a predominant factor driving the industry today. Industry spends more than 80% of total capital spent on compute resources.
- Incentivizes cloud infrastructure providers to act in ways that protect their dominant position in the market
- Encourages lock-in into their cloud ecosystems.
- Reinforces the control of firms that already dominate the tech industry.

The rich get richer……

Effects of Demands

- Demand for Limited Supply of Chips Extremely high
  - Orgs set up to provide GPU rental services
  - Purchases of GPUs by nation-states seeking competitive advantage
- Puts a few in Dominant Positions:
  - Cloud infrastructure firms (AWS, Google Cloud, MSAzure)
  - Chips: NVIDIA
  - Chip Fab: TSMC
- And unsustainable environmental issues
  - TSMC accounts for 4.8% of Taiwan's national energy consumption, more than the entire capital city of Taipei

Self Perpetuating Cycles

- ***Accepted Scaling Assumption***
- Bigger models + more compute => better results
- Industry consensus shaped investment
- Reinforces large-scale, centralized approaches

Self Perpetuating Cycles

- Compute infrastructure evolved to support growth of large language models
  - Hardware Lottery: a research idea wins because it is the most suited to the available hardware and software.
- => self perpetuating cycle:

LLMs => bigger models => increased infrastructure => bigger models ….

Cost of straying from mainstream hardware compatability will increase

Self Perpetuating Cycles

- Software Infrastructure Considerations
  - Corporate Allegiance to the status quo
    - Businesses invest and rely on stable software infrastructure
      - Resistance to retraining software developers
      - Resistance to "reving" up legacy code
      - Resistance to purchasing new Software Infrstr
- Software lock-in reinforces hardware dominance
  - GPU as ML ISA
  - CUDA defines algorithm design
    - Resists Growth of Alternative Algorithmic Approaches
    - Corporations resist switching to alternative hardware base.

Open Source Initiatives.....

- PyTorch opensource initiative under Linux foundation funded by Meta

- ONNX (Open Neural Network Exchange) opensource format for AI models to enable interoperability between frameworks (such as PyTorch and TensorFlow).

And the cycle continues

- More Demand causing shortage of GPUs
- Start-ups enter AI race by making contractual arrangements with Big Tech firms.
  - Grows dominance of existing firms
  - Google touted 70% of generative AI startups use Google cloud facilities.
- Big Tech Firms
  - Need for more compute shaping future product decisions.

Limits Innovation

- Architectures mapping well to GPUs do not just succeed but proliferate

- Alternatives lose mindshare
  - Modern day equivalent of resisting architectural novelty by relying on performance increases from Moore's Law

Large-Scale AI Models

- How Much Compute and What Does it Cost
- At current growth rate: Compute costs in excess of entire US GDP by 2037
- Training GPT-4 “Probably” More than ~$100 Million

Chips for large-scale AI

- GPUs
  - Dominance in Training
- Field Programmable Gate Arrays (FPGAs)
  - Arguments for:
    - Energy Efficiency
    - Flexibility
  - Arguments Against:
    - Lower Density/Performance
    - Lack of Software Centric Protocol Stack
- ASICs
  - Cost
  - Software Infrastructure
  - Time to Market

Components of Computer Hardware

- Logic
- Memory
- Interconnect

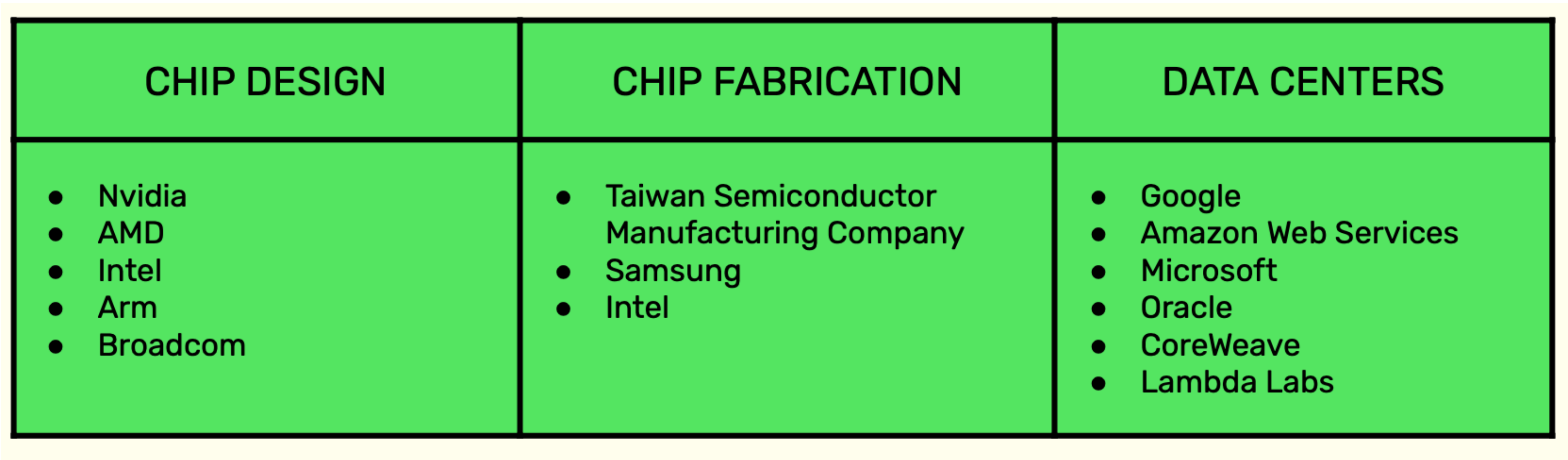
In traditional CPUs, memory tends to account for over half the cost of a server setup. (badly worded in paper). The cost of GPUs has memory seem cheaper ☺

Quantitative Reality: Energy per Operation

- FP16 MAC: ~1–2 pJ
- SRAM access (32b): ~5–10 pJ
- DRAM access (32b): ~100–1000 pJ

Arithmetic is effectively free
Data movement dominates energy

Supply Chain for AI Hardware



CHIP DESIGN	CHIP FABRICATION	DATA CENTERS
● Nvidia ● AMD ● Intel ● Arm ● Broadcom	● Taiwan Semiconductor Manufacturing Company ● Samsung ● Intel	● Google ● Amazon Web Services ● Microsoft ● Oracle ● CoreWeave ● Lambda Labs

Google: TPU used to develop Google Gemini: software/hardware integration impacts entire ecosystem leading to stronger monopolization

Microsoft: Athena => Maia 100 => Maia 200

3 nm node FP8/FP4 cores, 216GB HBM3e at 7 TB/s and 272MB of on-chip SRAM

AWS: Trainium

Market Dominance

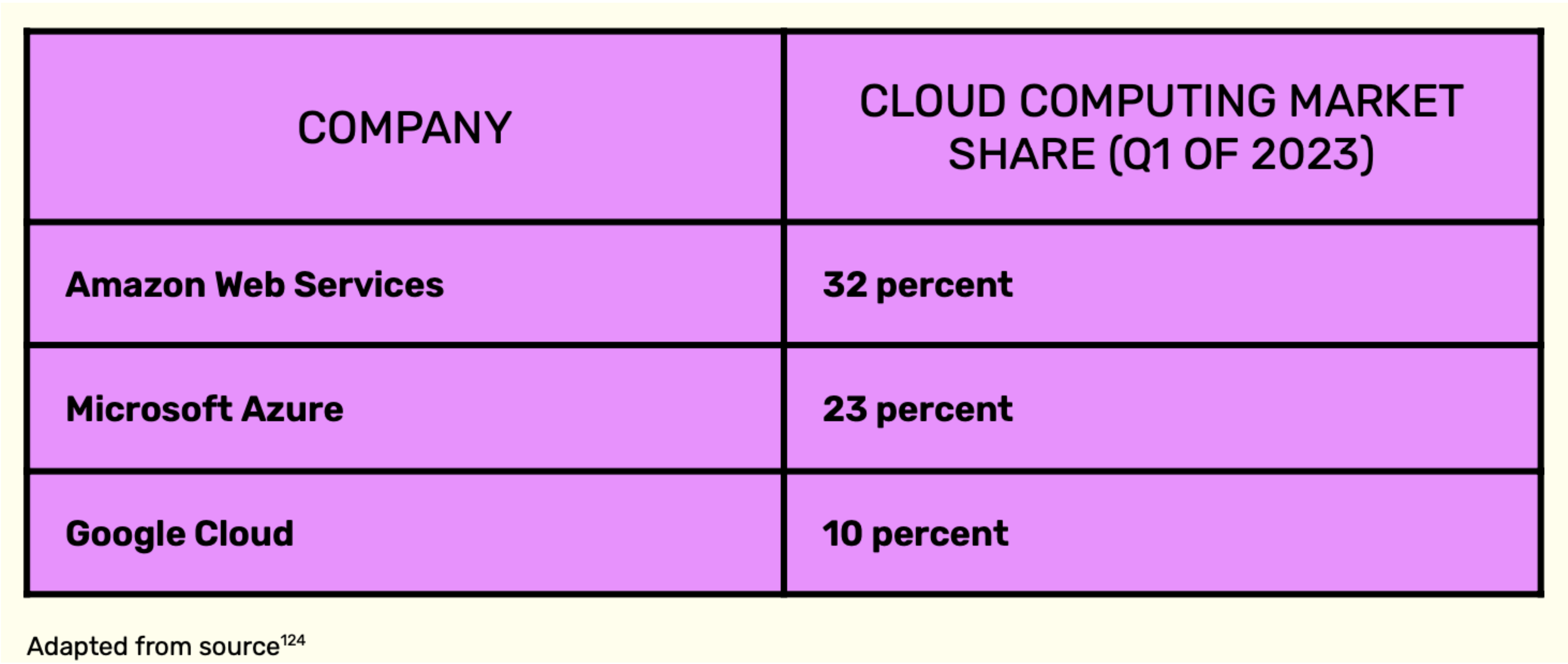
- Data Centers:
  - NVIDIA 92 -98% of Data Center Market
  - AMD 8- 2%
  - Intel < 1%

- Overall GPU Market:
  - NVIDIA 94%
  - AMD ~6%

New Entries

- Cerebras: Wafer Scale Integration
  - Bandwidth 10,000x wrt NVIDIA GPUs
- Rain: Neuromorphic Architecture
- Groq; "Partnership" with NVIDIA
  - Groq hardware + CUDA infrastructure ?

Investments in Self Interest

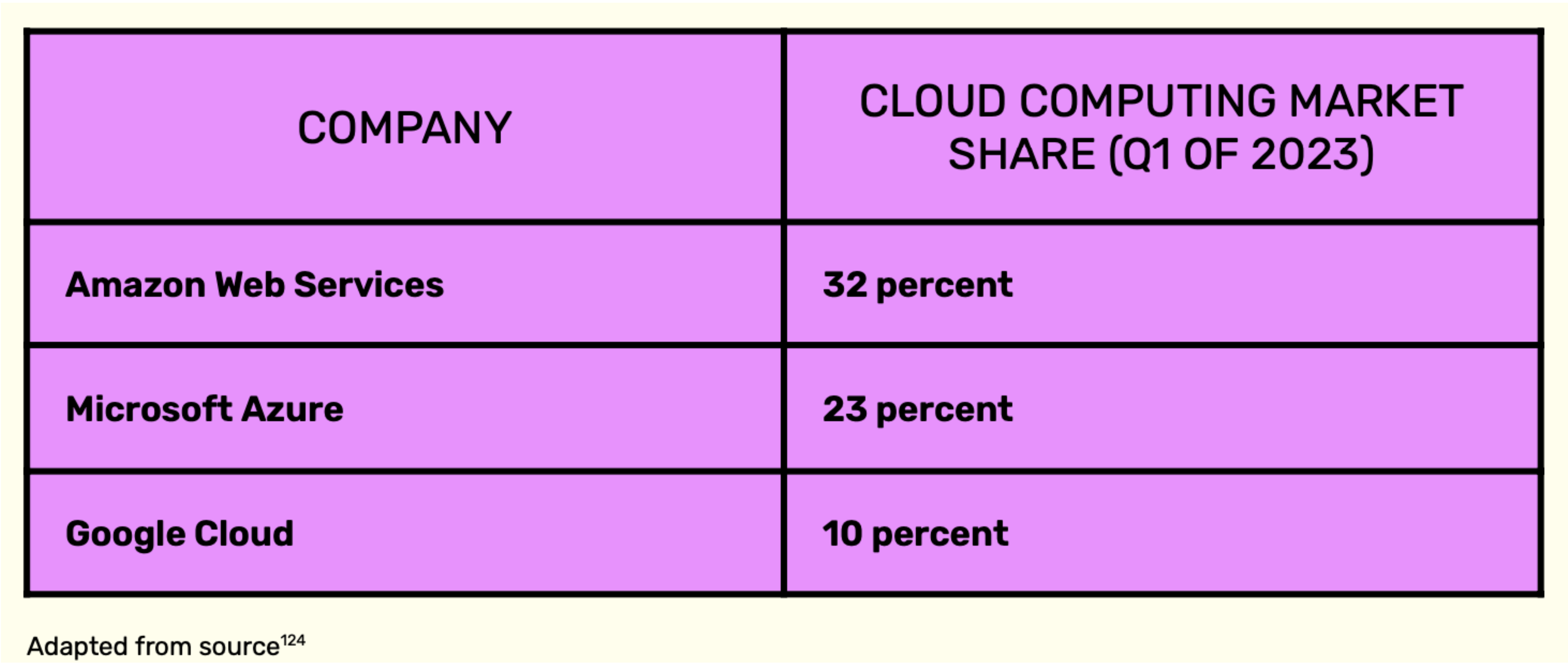


COMPANY	CLOUD COMPUTING MARKET SHARE (Q1 OF 2023)
Amazon Web Services	**32 percent**
Microsoft Azure	**23 percent**
Google Cloud	**10 percent**

Adapted from source[124]

- Microsoft invested in OpenAI, Azure exclusive provider for OpenAI.
- Microsoft AI Supercomputers built for OpenAI

Investments in Self Interest



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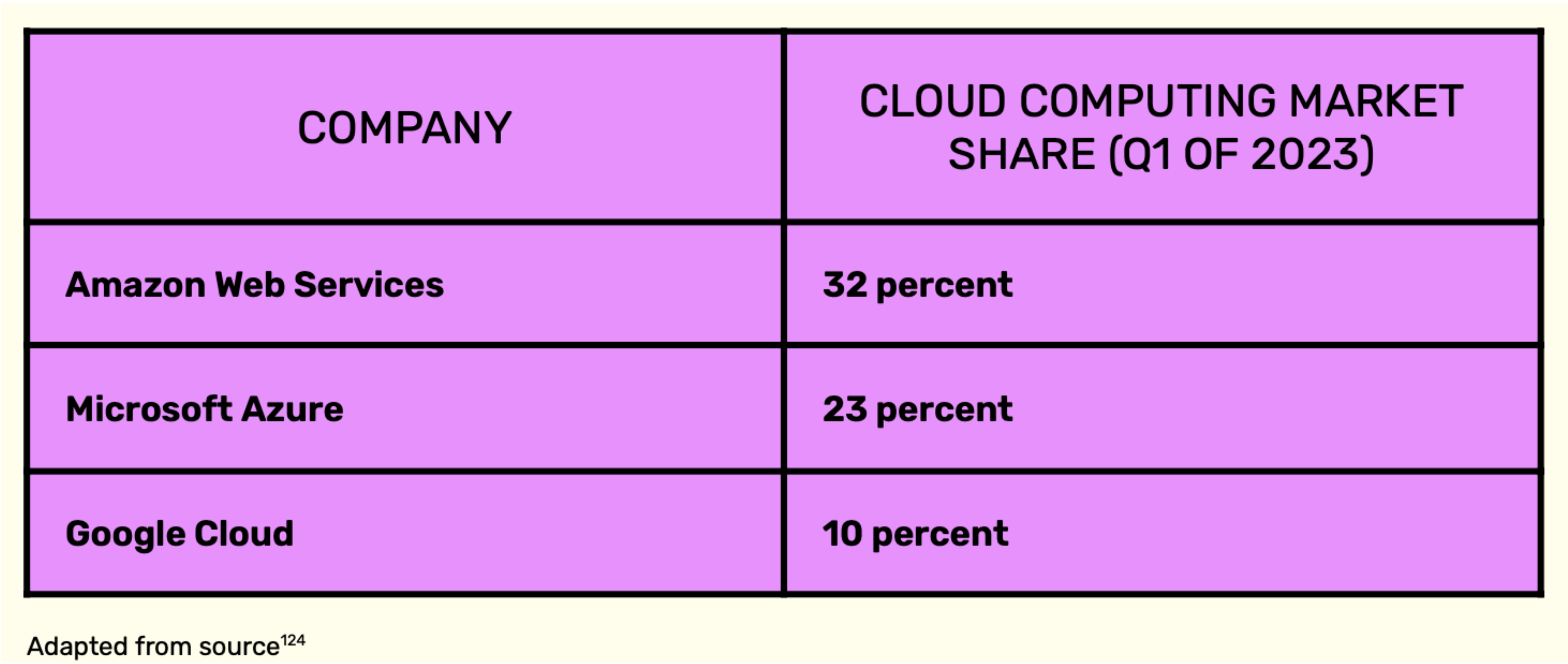
- Google Brain Team and DeepMind fully integrated into Google DeepMind.
- Amazon entered into partnerships with open source model developers and platforms.

Investments in Self Interest



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- Oracle offers compute credit to AI startups
- Cloud companies invest in AI service companies

How to Reduce Compute Costs

- Don't Count on Moore's Law ☺
- New Algorithms: Smaller Models
- Paradigm Shifts and Breakthroughs
  - Memory bottleneck: New Memory Technology could provide significant breakthrough.
  - New Heterogeneous Technologies: Nanotech + CMOS
  - New Architectures: Processor in Memory (PIM), Neuromorphic, Quantum, analog computing architectures

Policy considerations

- Antitrust: Continued Vertical Integration reinforces Hardware Lottery grip:
  - Separate Cloud Provision from Chip Design
  - Separate Hardware from Software, or mandate interoperability
  - Separate AI Model Development from Cloud Infratructure
  - Institute Nondiscrimination or Common Carier Obligations Across Tech Stack
  - Prevent Further Market Concentration
  - Investigate Anticompetitive Conduct
  - Apply Existing Antitrust Principles to AI Compute Markets

Data Minimization

- Data and Compute are separate inputs to AI.
  - Scaling laws limit amount of data that can be efficiently used with a given amount of compute, exclusive data access becomes increasingly important as freely available internet data runs out.
    - Freely available data already used
    - Newly produced data is starting to be protected by more platforms.
      - Reddit, Twitter have implemented protections against free use of data from their platforms.
      - Relative value of internet data declining as it features more AI-generated content.

Data Minimization

- Embrace data-minimization mandates, prohibit collection/processing of sensitive data
- Prohibit secondary use of data collected from consumers for training AI models as violation over consumer control of personal data.

Discussion Questions

- Should compute be regulated as infrastructure?
- How do we promote/fund architectural diversity?