Architectural Characteristics

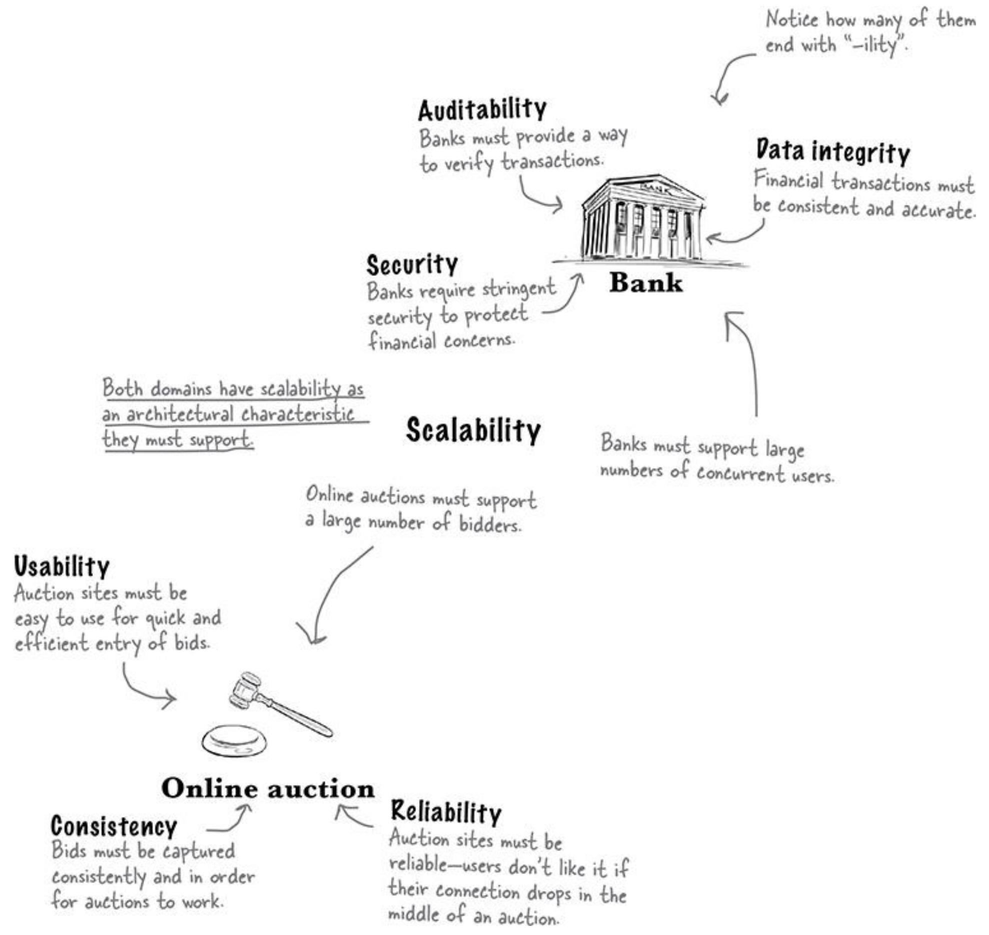
COMP2511, CSE, UNSW

These lecture slides are from the book “*Head First Software Architecture*”,

by Raju Gandhi, Mark Richards, Neal Ford, O'Reilly Media, Inc., March 2024

What Are Architectural Characteristics?

- ❖ Architectural Characteristics define fundamental qualities software architecture must support.
- ❖ They are often not explicitly defined
- ❖ They influence structure, infrastructure, and quality of the system
- ❖ Architectural characteristics guide decisions like architectural style, deployment, and scalability.


Notice how many of them end with "–ility".
Auditability
Banks must provide a way to verify transactions.
Data integrity
Financial transactions must be consistent and accurate.
Security
Banks require stringent security to protect financial concerns.
Bank
Both domains have scalability as an architectural characteristic they must support.
Scalability
Banks must support large numbers of concurrent users.
Online auctions must support a large number of bidders.
Usability
Auction sites must be easy to use for quick and efficient entry of bids.
Online auction
Consistency
Bids must be captured consistently and in order for auctions to work.
Reliability
Auction sites must be reliable—users don't like it if their connection drops in the middle of an auction.

Some of the Popular Architectural Characteristics

- Scalability: Handles growth in traffic or data size
- Availability: Ensures system uptime
- Maintainability: Easy to update, fix, or extend
- Security: Prevents unauthorized access

- Elasticity: Automatically adjusts resources based on load
- Deployability: Enables safe, frequent updates
- Responsiveness: Provides quick feedback to users

- There is no fixed or exhaustive list — they evolve with time and context
- Many required characteristics are not explicitly stated in the requirements
- Proper domain and contextual understanding is essential to identify them
- They are essential to align architecture with real-world needs, for successful development, deployment, and future system resilience

Case Study - Lafter (Sillycon Symposia)

- A fictional tech-comedy conference platform to illustrate architectural thinking.
- Use Case: Participants post jokes/puns, react with "*HaHa*" or "*Giggle*," and engage with speakers.
- Functional Needs:
  - User registration
  - Posting content (jokes/puns)
  - Reaction buttons and speaker tools
  - Language support (international audience)
- Architectural Constraints:
  - ***Scalability***: Must handle traffic bursts during peak conference hours.
  - ***Availability***: Downtime would impact live sessions and user interaction.
  - ***Security***: Accounts and speaker tools require access control.
  - ***Maintainability***: Small team must support system with minimal overhead.

Applying Architectural Thinking to Lafter

- Design Decisions Influenced by Characteristics:
  - Choose **microservices** for independently deployable features (e.g., joke-posting vs. notifications).
  - Use **cloud-based hosting** with autoscaling to manage bursty traffic.
  - Implement **CI/CD pipelines** to ensure rapid, reliable deployments.
  - Enable **internationalisation** to support a multilingual audience.

- Examples of Characteristics Applied:
  - **Elasticity** → Serverless functions for unpredictable joke-post surges
  - **Responsiveness** → Real-time interactions using *WebSockets*
  - **Testability** → Unit-tested microservices enable quick fixes

Architectural Characteristics vs. Logical Components

- Architectural Characteristics: How the system performs under various constraints
- Logical Components: What the software does (domain behavior)
- Both are essential for structural design

Component: User Registration

Characteristic: Scalability
(handles thousands of concurrent signups)

Component: Content Posting

Characteristic: Availability
(system is up when users post jokes)

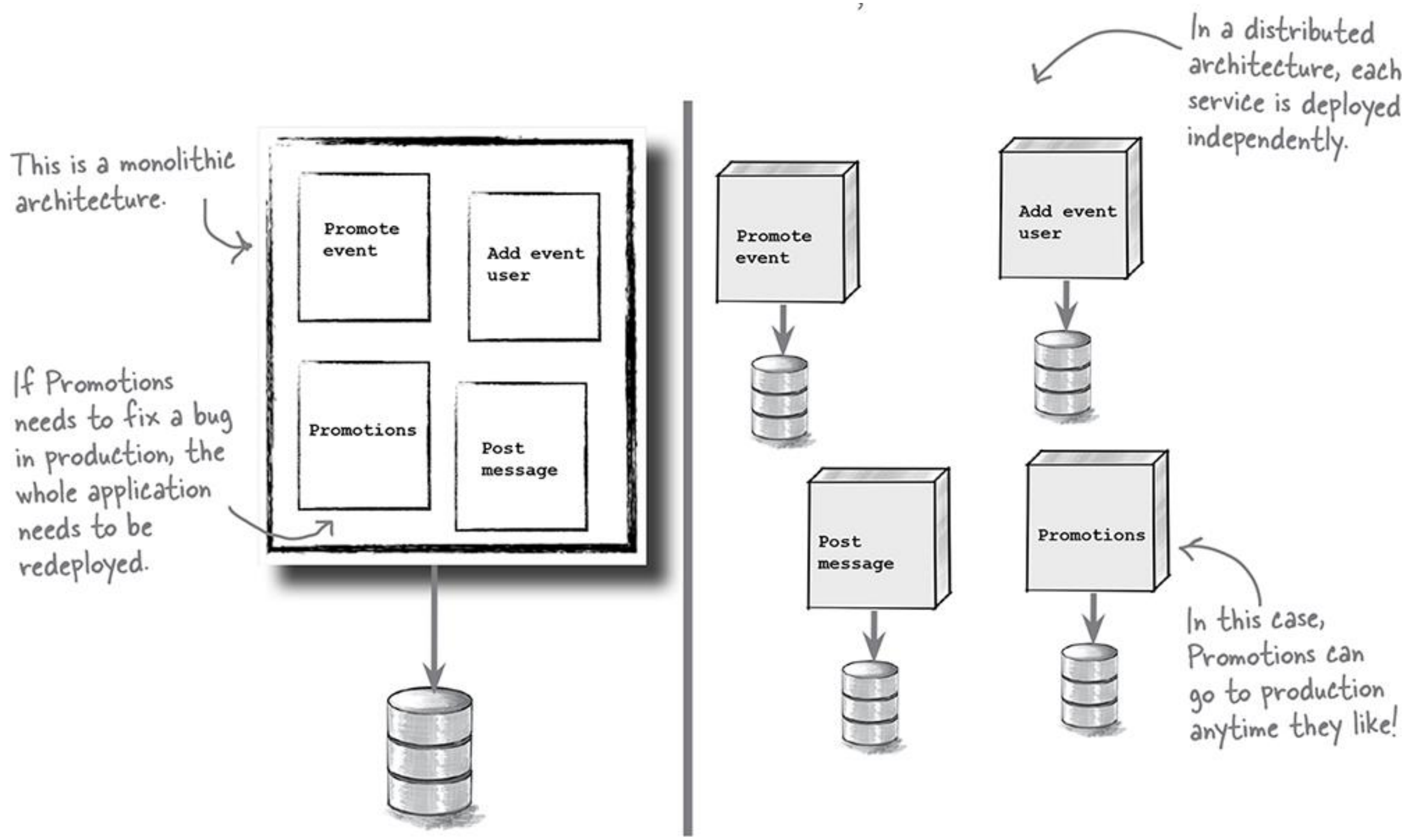
Component: Notifications

Characteristic: Responsiveness
(sends real-time updates with low latency)

Component: Admin Dashboard

Characteristic: Security
(restricts access to authorized users only)

Characteristics Affect Structure


This is a monolithic architecture.
Promote event
Add event user
Promotions
Post message
If Promotions needs to fix a bug in production, the whole application needs to be redeployed.
In a distributed architecture, each service is deployed independently.
Promote event
Add event user
Post message
Promotions
In this case, Promotions can go to production anytime they like!

Characteristics Affect Structure

Architectural Characteristics

- Security: May require encryption layers, role-based access control, audit trails
- Scalability: May need load balancers, stateless services, database sharding
- Availability: May require failover mechanisms, replication, redundant systems
- Responsiveness: Might demand caching, asynchronous processing
- Elasticity: May need autoscaling and container orchestration

Architectural Impact

- Monolithic vs Microservices
- Cloud vs On-Premise deployment
- Etc.

Don’t Overengineer!

- Too many characteristics = complexity
- They are:
  - Synergistic (affect each other, improving *security* may result in low *performance*)
  - Continuously evolving
  - Impossible to standardize (*performance* and *responsiveness* might indicate the same behavior)
- Limit characteristics to prevent overengineering
  - Identifying which characteristics are most critical acts as a filtering mechanism
  - Helps eliminate "*nice-to-have*" features that add unnecessary complexity and cost
  - Stay focused on traits essential for success
  - Limit to around 7 key characteristics, humans best manage 7 ± 2 items!

Implicit vs Explicit Characteristics

- *Explicit*: Stated clearly in the requirements document
  - "The system must support French and Japanese" → Internationalization
  - "Allow only registered users to access admin panel" → Authorization

- *Implicit*: Not stated, but understood or expected (requires domain/context understanding)
  - Users expect their data to be secure even if not mentioned → Security
  - An app must perform well during high traffic without explicit mention → Performance/Scalability
  - A public website is expected to be available 24/7 → High Availability

- Architects must read between the lines to uncover hidden requirements

Explicit
- Packages are stacked outside a door.

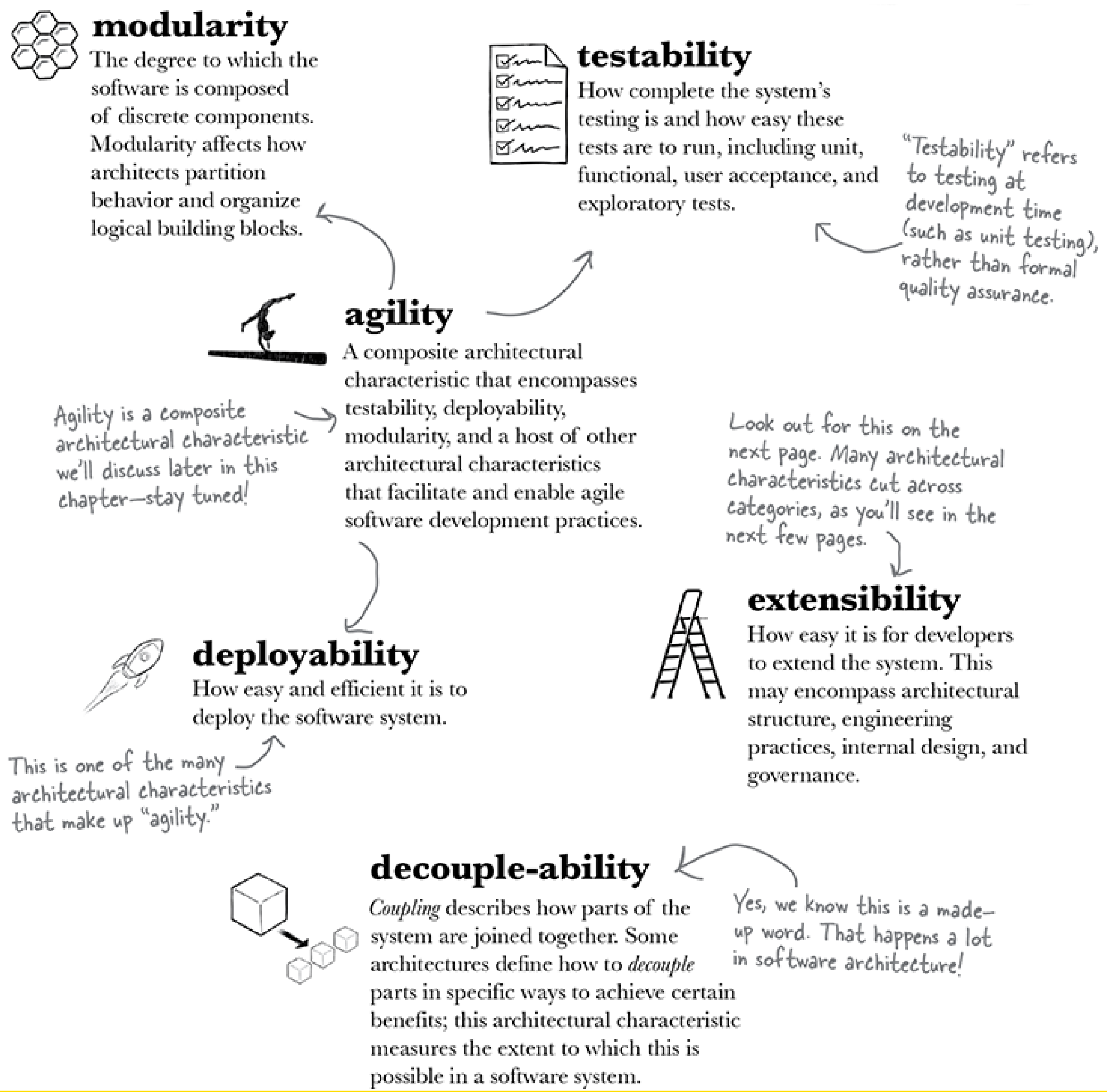
Implicit
- No one is home.
- This family orders a bunch of stuff online.
- Is this family on vacation?

Types of Characteristics

- Process Characteristics: Deployability, Maintainability
- Structural Characteristics: Modularity, Coupling
- Operational Characteristics: Scalability, Availability
- Cross-cutting Characteristics: Accessibility, Security

Process Characteristics

- Represent the intersection between architecture and the software development process
- Reflect how the system is built, tested, deployed, and evolved
- Guide decisions related to engineering practices, automation, and team workflows



modularity
The degree to which the software is composed of discrete components. Modularity affects how architects partition behavior and organize logical building blocks.

testability
How complete the system's testing is and how easy these tests are to run, including unit, functional, user acceptance, and exploratory tests.

"Testability" refers to testing at development time (such as unit testing), rather than formal quality assurance.

agility
A composite architectural characteristic that encompasses testability, deployability, modularity, and a host of other architectural characteristics that facilitate and enable agile software development practices.

Agility is a composite architectural characteristic we'll discuss later in this chapter—stay tuned!

Look out for this on the next page. Many architectural characteristics cut across categories, as you'll see in the next few pages.

deployability
How easy and efficient it is to deploy the software system.

This is one of the many architectural characteristics that make up "agility."

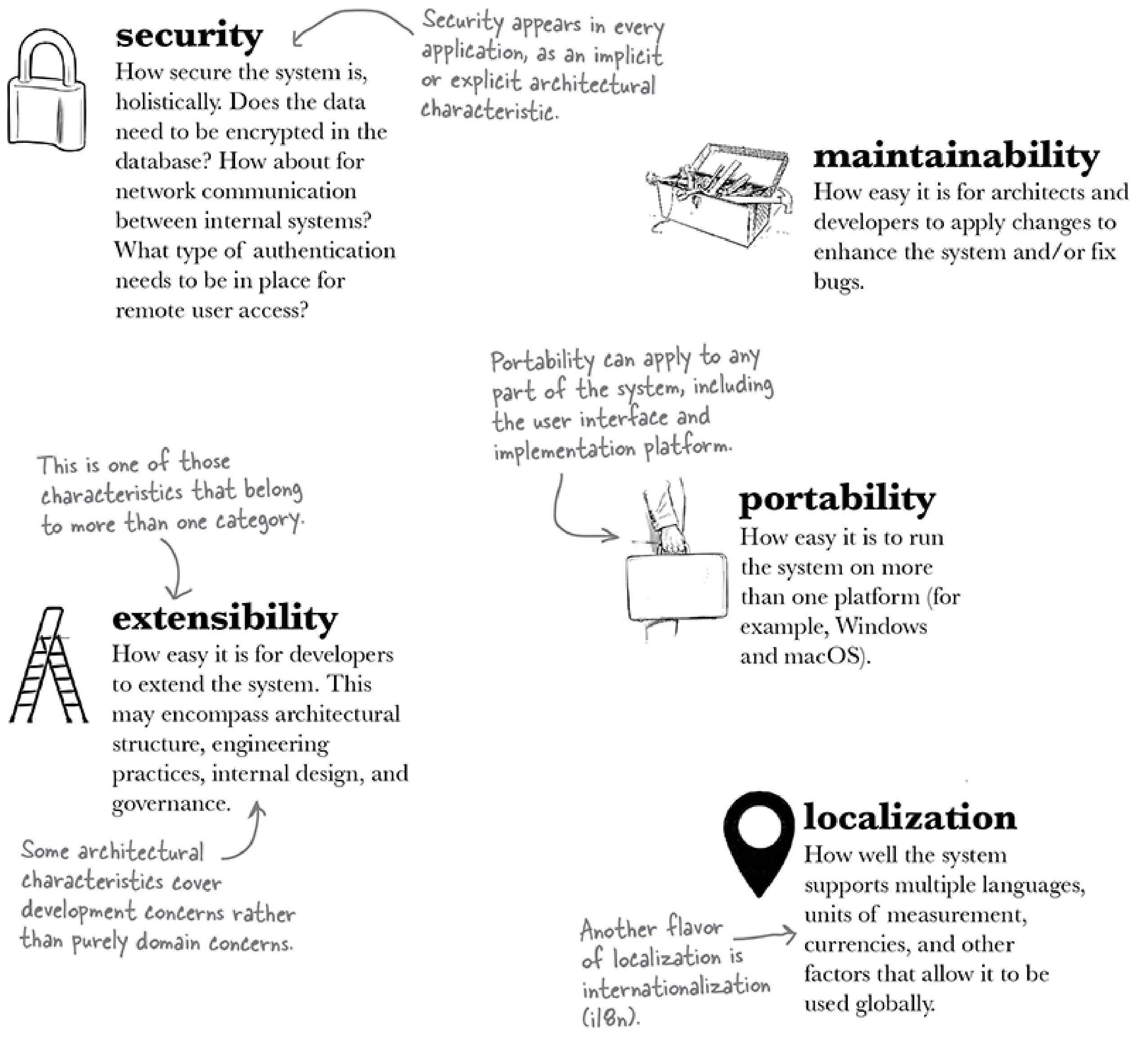
extensibility
How easy it is for developers to extend the system. This may encompass architectural structure, engineering practices, internal design, and governance.

decouple-ability
Coupling describes how parts of the system are joined together. Some architectures define how to *decouple* parts in specific ways to achieve certain benefits; this architectural characteristic measures the extent to which this is possible in a software system.

Yes, we know this is a made-up word. That happens a lot in software architecture!

Structural Characteristics

- ❖ Concerned with the internal structure and composition of the system
- ❖ Influence how components are coupled, interact, and evolve independently
- ❖ Impact design qualities like modularity, cohesion, and adaptability



security
How secure the system is, holistically. Does the data need to be encrypted in the database? How about for network communication between internal systems? What type of authentication needs to be in place for remote user access?

Security appears in every application, as an implicit or explicit architectural characteristic.

maintainability
How easy it is for architects and developers to apply changes to enhance the system and/or fix bugs.

Portability can apply to any part of the system, including the user interface and implementation platform.

portability
How easy it is to run the system on more than one platform (for example, Windows and macOS).

This is one of those characteristics that belong to more than one category.

extensibility
How easy it is for developers to extend the system. This may encompass architectural structure, engineering practices, internal design, and governance.

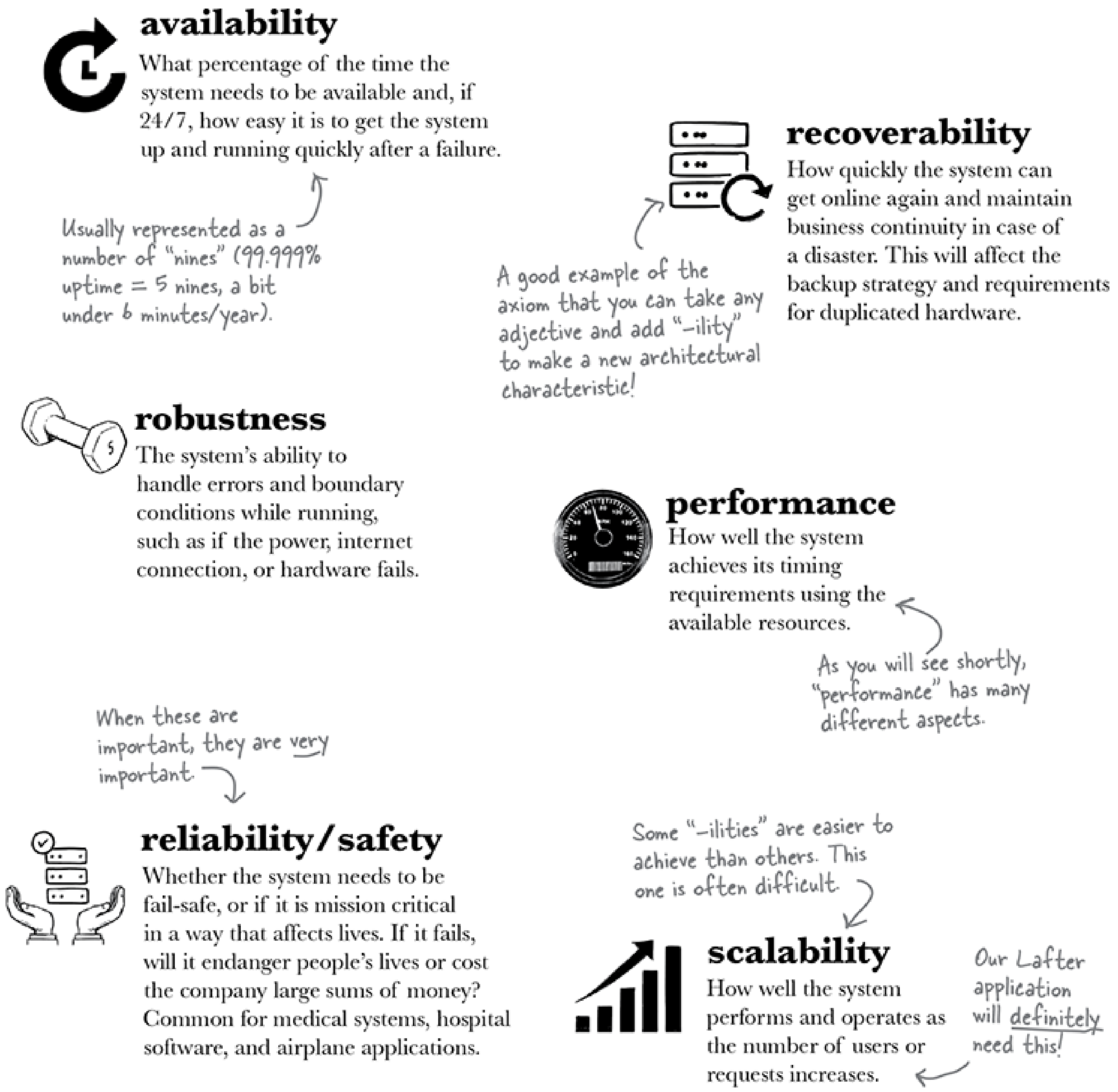
Some architectural characteristics cover development concerns rather than purely domain concerns.

localization
How well the system supports multiple languages, units of measurement, currencies, and other factors that allow it to be used globally.

Another flavor of localization is internationalization (i18n).

Operational Characteristics

- Represent how architectural decisions shape and support system behavior at runtime
- Define what the operations team can monitor, control, or adapt while the system is running
- Directly influence system reliability, performance, and fault tolerance



availability
What percentage of the time the system needs to be available and, if 24/7, how easy it is to get the system up and running quickly after a failure.

Usually represented as a number of "nines" (99.999% uptime = 5 nines, a bit under 6 minutes/year).

recoverability
How quickly the system can get online again and maintain business continuity in case of a disaster. This will affect the backup strategy and requirements for duplicated hardware.

A good example of the axiom that you can take any adjective and add "-ility" to make a new architectural characteristic!

robustness
The system's ability to handle errors and boundary conditions while running, such as if the power, internet connection, or hardware fails.

performance
How well the system achieves its timing requirements using the available resources.

As you will see shortly, "performance" has many different aspects.

When these are important, they are very important.

reliability/safety
Whether the system needs to be fail-safe, or if it is mission critical in a way that affects lives. If it fails, will it endanger people's lives or cost the company large sums of money? Common for medical systems, hospital software, and airplane applications.

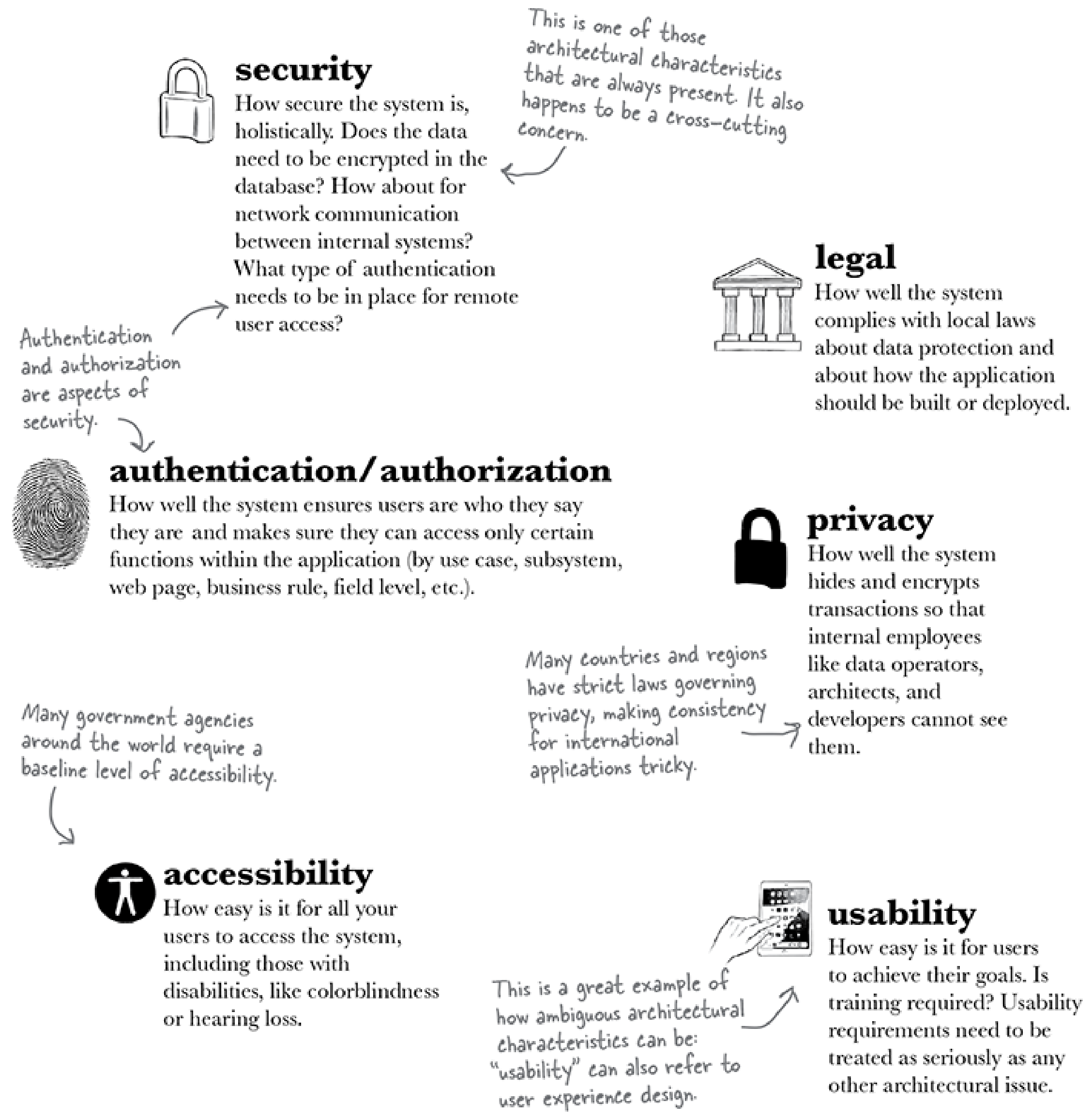
Some "-ilities" are easier to achieve than others. This one is often difficult.

scalability
How well the system performs and operates as the number of users or requests increases.

Our Lafter application will definitely need this!

Cross-Cutting Characteristics

- ❖ Span multiple parts of the system and affect other characteristics
- ❖ Often enforced through design, tooling, and governance



security
How secure the system is, holistically. Does the data need to be encrypted in the database? How about for network communication between internal systems? What type of authentication needs to be in place for remote user access?

This is one of those architectural characteristics that are always present. It also happens to be a cross-cutting concern.

Authentication and authorization are aspects of security.

legal
How well the system complies with local laws about data protection and about how the application should be built or deployed.

authentication/authorization
How well the system ensures users are who they say they are and makes sure they can access only certain functions within the application (by use case, subsystem, web page, business rule, field level, etc.).

privacy
How well the system hides and encrypts transactions so that internal employees like data operators, architects, and developers cannot see them.

Many countries and regions have strict laws governing privacy, making consistency for international applications tricky.

Many government agencies around the world require a baseline level of accessibility.

accessibility
How easy is it for all your users to access the system, including those with disabilities, like colorblindness or hearing loss.

This is a great example of how ambiguous architectural characteristics can be: "usability" can also refer to user experience design.

usability
How easy is it for users to achieve their goals. Is training required? Usability requirements need to be treated as seriously as any other architectural issue.

Composite Characteristics

- Formed from multiple simpler traits
- These high-level characteristics reflect complex system qualities that require multiple dimensions to evaluate.
- Examples:
  - Reliability = Availability + Consistency + Data Integrity
  - Resilience = Robustness + Fault Tolerance + Recoverability
- Must break down into measurable parts

Sources of Characteristics

- Problem Domain (Feature-Driven): Driven by product goals, system features, and expected usage patterns.
  - A real-time multiplayer game must be highly responsive and scalable due to concurrent users → Responsiveness, Scalability
  - An e-commerce site must support flash sales and high traffic → Elasticity, Performance, Availability

- Environmental Awareness (Organizational Constraints): Driven by company's culture, budget, and capabilities
  - A startup must deliver features fast → favors Deployability, Agility
  - A globally distributed team → needs Testability, Modularity for asynchronous collaboration
  - Legacy-heavy organizations → may prioritize Integrability with existing systems

Sources of Characteristics

- ❖ Holistic Domain Knowledge (Industry and Compliance Expectations): Driven by regulatory standards, industry best practices, and user trust factors.
  - A banking app must comply with regulations → Security, Auditability, Availability
  - A healthcare platform must protect patient data → Confidentiality, Data Integrity, Compliance
  - Government services need to meet accessibility and privacy laws → Accessibility, Security, Maintainability

- ❖ Why It Matters:
  - Ignoring a source can lead to critical failures later
  - Architects must triangulate across all three to identify the most important characteristics

Translating Business Goals into Architecture

- ❖ A core responsibility of the architect is to translate high-level business goals into concrete architectural characteristics and decisions.

Examples:

- ❖ Business: “The system must always work.”
  - → High Availability, Fault Tolerance, Robustness
- ❖ Business: “Customers shouldn’t wait.”
  - → Responsiveness, Performance, Latency Budgeting
- ❖ Business: “We need to move fast and innovate.”
  - → Deployability, Modularity, Testability
- ❖ Business: “We need to meet compliance and regulation.”
  - → Security, Auditability, Traceability, Accessibility

Trade-offs Between Architectural Characteristics (1)

- ❖ Architectural characteristics frequently compete or conflict
- ❖ Enhancing one trait can reduce or compromise another

Examples:

- o Security vs. Performance [More security controls (e.g., encryption, validation) add processing overhead]
- o Scalability vs. Simplicity [Scalable systems often introduce distributed complexity (e.g., microservices, load balancers)]
- o Availability vs. Maintainability [High availability may require complex failover and redundancy, complicating upgrades and maintenance]

Key Insight:

- o Trade-offs are not flaws, but conscious architectural decisions
- o There are no universally right answers—"*It depends*."

Trade-offs Between Architectural Characteristics (2)

More Examples:

- Deployability vs. Robustness: Rapid deployments can reduce test cycles and stability
- Responsiveness vs. Data Consistency: Fast user interactions might rely on eventually consistent models
- Flexibility vs. Performance: Designing for plugin support or configuration often introduces performance bottlenecks

Best Practices:

- Engage stakeholders early to understand what matters most
- Prioritise characteristics based on system goals, user needs, and domain constraints
- Trade-offs reflect organizational priorities and constraints
- Use Architectural Decision Records (ADRs) to document trade-offs and rationale

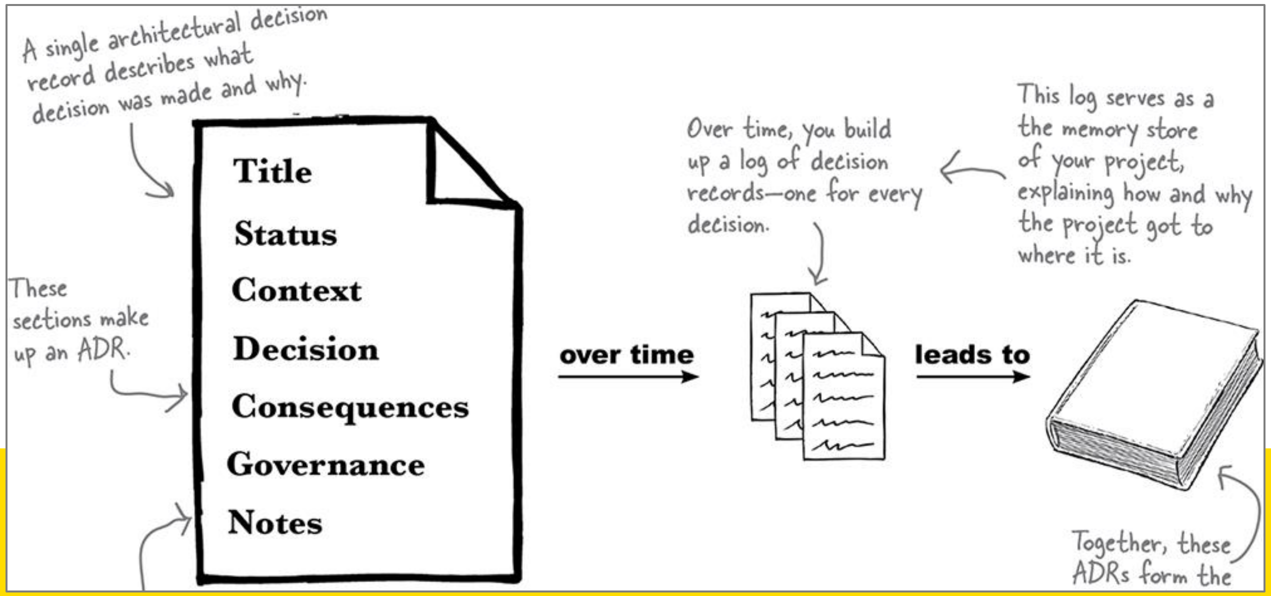
Architectural Decision Records (ADRs)

- "Why is more important than how."
- Architectural decisions must be justified
- Future team members need to understand the rationale
- Without context, good decisions may seem arbitrary or incorrect
- Architectural Decision Records (ADRs) capture the what, why, and impact
- An ADR has seven sections: Title, Status, Context, Decision, Consequences, Governance, and finally Notes.
- Important aspects of an architectural decision are documented, including the decision itself.

ADR

Benefits of Using ADRs

- Serves as a memory log for decisions
- Helps new team members understand context
- Improves consistency and governance
- Supports continuous evolution and learning



A single architectural decision record describes what decision was made and why.
Title
Status
Context
Decision
Consequences
Governance
Notes
These sections make up an ADR.
over time
Over time, you build up a log of decision records—one for every decision.
leads to
This log serves as a the memory store of your project, explaining how and why the project got to where it is.
Together, these ADRs form the

- Title: 012: Use of queues for asynchronous messaging
- Status: Accepted
- Context: Notification & analytics systems need real-time data
- Decision: Queues offer secure, tailored messaging
- Consequences: Higher coupling, infrastructure provisioning needed
- …
- …

Example ADR

Summary

- Architecture is about making conscious trade-offs
- Every decision comes with upsides and downsides
- Capture both the decision and the reason behind it
- Embrace change—architecture evolves with the system

- Architecture isn't about right answers—it's about right reasoning