

# L37: Lending Protocols

## Module E: DeFi Ecosystem

Blockchain & Cryptocurrency

December 2025

## [COMIC: Collateralized borrowing]

*Placeholder for comic showing person handing over car keys (collateral) to borrow money, with the lender holding keys until loan is repaid*

### The Setup

- Traditional bank: credit score required
- Years of history, identity verification
- Banks decide who deserves a loan

### The Punchline

- DeFi: your collateral is your credit
- Lock up ETH, borrow stablecoins
- No credit check, no bank approval

*In DeFi, your assets are your credit score – lock them up and borrow instantly*

- Explain how DeFi lending protocols work (Aave, Compound)
- Analyze overcollateralization and its necessity
- Calculate health factors and liquidation thresholds
- Explore interest rate models (utilization-based)
- Compare DeFi lending to traditional finance

**Building on L36:** Lab: Testnet Swap

# The Problem: How do we lend without credit scores?

## The Challenge

How can we create a lending system without banks, credit scores, or identity verification? Traditional finance relies on centralized institutions to assess borrower creditworthiness and enforce repayment through legal systems.

## Why It Matters

- Without credit infrastructure, billions are excluded from lending markets
- Traditional lending requires KYC, credit history, geographic presence, and legal recourse

## What We Need

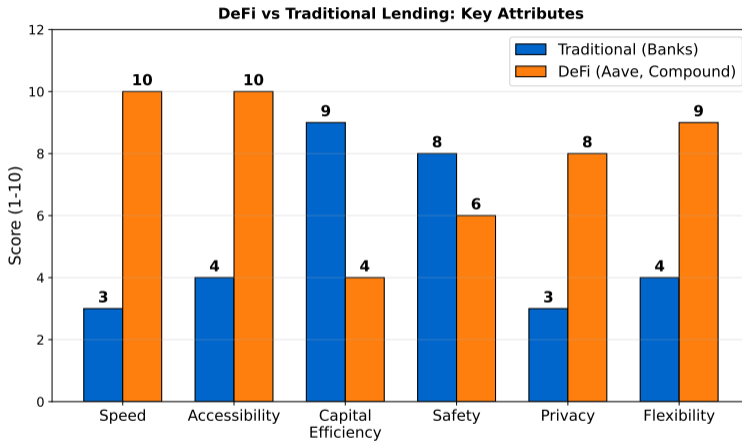
- System that eliminates default risk without identity
- Automated liquidation mechanism that doesn't rely on courts
- Algorithmic interest rates that balance supply and demand

## The Cryptoeconomics Question

*Creating systems with desired properties: How do we align incentives so borrowers never default?*

*Today's lesson: How overcollateralized lending protocols address this challenge*

# How Does DeFi Lending Differ From Banks?



*DeFi trades efficiency for accessibility – overcollateralize, but anyone can participate.*

# What Are the Key Trade-offs?

## Traditional Lending

- Credit checks, KYC required
- Undercollateralized possible
- Long approval process
- Geographic restrictions

## DeFi Lending

- No credit checks
- Overcollateralized only
- Instant approval
- Global access, 24/7

**Key Trade-off:** DeFi accessibility vs. capital efficiency (must lock more than you borrow).

*Compare the approaches shown above*

# How Do You Borrow Without a Bank?

## Core Mechanism:

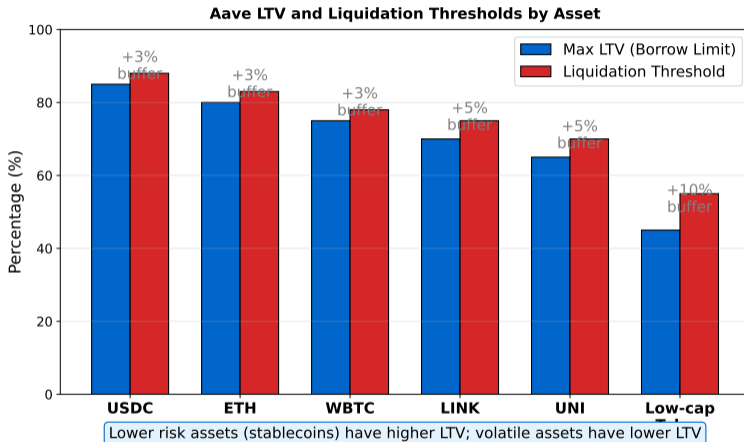
- 1 **Lenders (Suppliers):** Deposit assets, earn interest (APY varies)
- 2 **Borrowers:** Deposit collateral, borrow up to LTV%, pay interest
- 3 **Protocol:** Matches via smart contracts, manages liquidations

## Example: Borrowing on Aave

- Deposit 10 ETH (\$20,000), receive aETH tokens
- ETH has 80% LTV: max borrow = \$16,000
- Borrow \$10,000 USDC (safe margin)
- Pay 5% APY on debt, earn 2% on collateral

*Key point: Core Mechanism*

# How Much Can You Borrow Against Your Collateral?



*LTV replaces credit scores – protocol trusts collateral, not you. If ETH drops, liquidation.*

# What Determines Your Borrowing Limit?

## Definition:

$$\text{LTV} = \frac{\text{Borrowed Value}}{\text{Collateral Value}} \times 100\%$$

## Why Different LTVs?

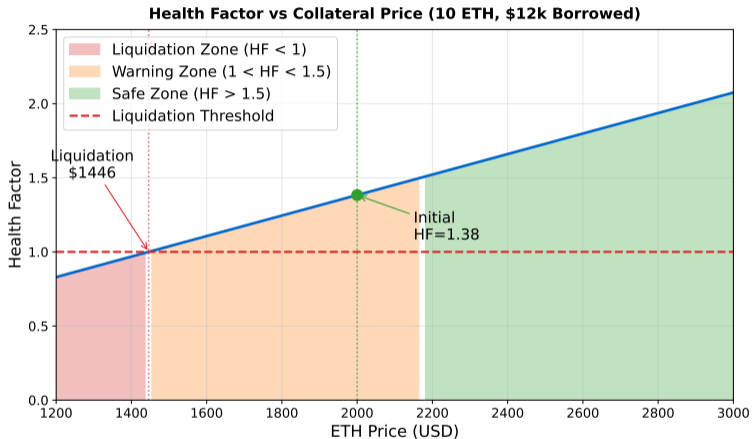
- Volatile assets = lower LTV (more buffer for price swings)
- Stable assets = higher LTV (minimal price risk)

## Example Calculation:

- Collateral: 10 ETH at \$2,000 = \$20,000
- Borrowed: \$12,000 USDC
- LTV:  $\frac{12,000}{20,000} = 60\%$  (safe, under 80% max)

*Key point: Definition*

# How Safe Is Your Loan Position?



*Health factor must stay above 1; monitor closely during volatility*

# How Is Loan Safety Measured?

## Formula (Aave):

$$\text{Health Factor} = \frac{\text{Collateral Value} \times \text{Liquidation Threshold}}{\text{Borrowed Value}}$$

Health factor (loan safety metric: above 1 = safe, below 1 = liquidation):

## Interpretation:

- HF  $\geq$  1.5: Safe (comfortable buffer)
- HF 1.0-1.5: Warning zone
- HF  $\leq$  1: Liquidation occurs

## Example:

- Collateral: \$20,000 (ETH), Borrowed: \$12,000
- Liquidation threshold: 83%
- $\text{HF} = \frac{20,000 \times 0.83}{12,000} = 1.38$  (safe)

Key point: Formula (Aave)

# What Happens When Your Health Factor Drops?

**Liquidation (automatic seizure of collateral when loan becomes unsafe):**  
**When Health Factor  $\leq 1$ :**

- 1 **Liquidator Bot Detects** unhealthy position
- 2 **Liquidator Repays** portion of debt (up to 50%)
- 3 **Liquidator Receives** equivalent collateral + 5-10% bonus
- 4 **Borrower Loses** liquidation penalty

**Example:**

- Debt: \$12,000, Collateral: \$14,460
- Liquidator repays 50% (\$6,000), receives \$6,300 in ETH
- Borrower loses \$300 penalty (5%)

*Liquidation replaces courts – bots seize collateral, ensuring debts are always repaid.*

## Aave-Style Liquidation Logic

```
function check_liquidation(position):  
  health = (collateral_value * liq_threshold)  
           / borrowed_value  
  if health < 1.0:  
    // Position is underwater  
    repay_amount = borrowed_value * 0.5  
    bonus = repay_amount * 0.05 // 5% liquidation bonus  
    seize_collateral(repay_amount + bonus)  
    reduce_debt(repay_amount)  
    emit Liquidation(position, repay_amount)
```

**Key Insight:** The 5% bonus incentivizes liquidator bots to act instantly. Without this profit motive, unhealthy positions would linger and threaten protocol solvency.

*Smart contracts replace courts: automated liquidation ensures debts are always repaid without legal action*

## Recall Our Problem

*How do we lend without credit scores?*

## What We've Learned So Far

- Overcollateralization: deposit \$150 to borrow \$100 – eliminates default risk without credit history
- Health factor tracks loan safety:  $HF_i > 1$  is safe,  $HF_i < 1$  triggers automatic liquidation
- Math replaces credit checks: collateral + liquidation = guaranteed repayment without courts

## Still to Address

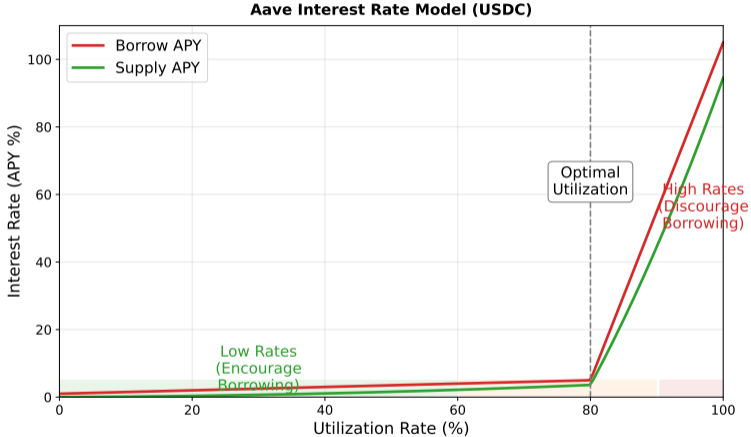
- Interest rate models: how supply/demand automatically sets borrowing costs
- Can DeFi ever offer undercollateralized loans while staying permissionless?

## Think About

- Based on what you've seen, how would *you* solve this problem?
- What trade-offs do you expect?

*Pause and reflect: How does what we've learned so far address "How do we lend without credit scores?"?*

# How Are Interest Rates Determined?



High utilization triggers steep rate increase to prevent liquidity crises

# How Do Interest Rates Adjust Automatically?

## Utilization Rate:

$$U = \frac{\text{Total Borrowed}}{\text{Total Supplied}}$$

## Rate Behavior:

- Low utilization (0-60%): Low rates (encourage borrowing)
- Optimal (80%): Moderate rates (balanced)
- High (>90%): Very high rates (discourage borrowing)

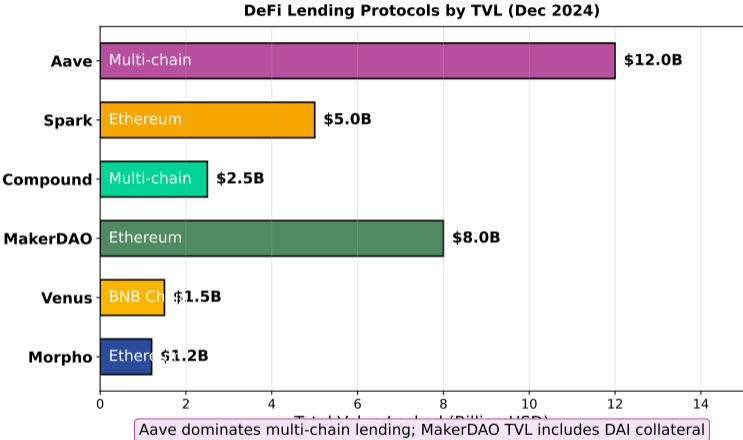
## Supply APY Formula:

$$\text{Supply APY} = \text{Borrow APY} \times U \times (1 - \text{Reserve Factor})$$

**Key Insight:** Supply APY always lower than borrow APY.

*Key point: Utilization Rate*

# Which Protocols Dominate DeFi Lending?



*Aave leads through multi-chain expansion; Compound pioneered the model*

# How Do Aave and Compound Compare?

## Aave

- Flash loans (no collateral)
- Stable/variable rate choice
- Credit delegation
- E-Mode for correlated assets
- \$31B TVL (Dec 2025), 60%+ DeFi lending market share

## Compound

- cTokens (interest-bearing)
- Simpler, fewer features
- Pioneered DeFi lending
- COMP governance token
- \$2.5B TVL

**Historical Note:** Compound launched 2018, Aave 2020. Compound's COMP mining sparked "DeFi Summer" 2020.

*Aave vs Compound: both solve creditless lending, but Aave adds flash loans and stable rates.*

# How Can You Borrow Without Collateral?

**Definition:** Borrow any amount without collateral, repay in same transaction.

## How It Works:

- 1 Borrow \$1M USDC from Aave
- 2 Use for arbitrage, collateral swap, or liquidation
- 3 Repay \$1M + 0.09% fee
- 4 All atomic (succeeds or reverts entirely)

## Use Cases:

- Arbitrage across DEXs
- Collateral swaps without closing position
- Self-liquidation to avoid penalty

**Risk:** Used in many DeFi exploits (oracle manipulation attacks).

*Key point: Definition*

# What Can Go Wrong in DeFi Lending?

## 1. Smart Contract Risk

- Bugs or exploits (Rari Capital, Cream Finance hacks)

## 2. Liquidation Risk

- Volatile markets, network congestion prevents adding collateral

## 3. Oracle Risk

- Price feed manipulation, stale prices

## 4. Liquidity Risk

- High utilization prevents withdrawals

**2022 Lesson:** CeFi lenders (Celsius, BlockFi) collapsed; DeFi protocols survived.

*Key point: 1. Smart Contract Risk*

# Can DeFi Ever Lend Without Overcollateralization?

**Current Limitation:** Overcollateralization is capital inefficient.

## Emerging Solutions:

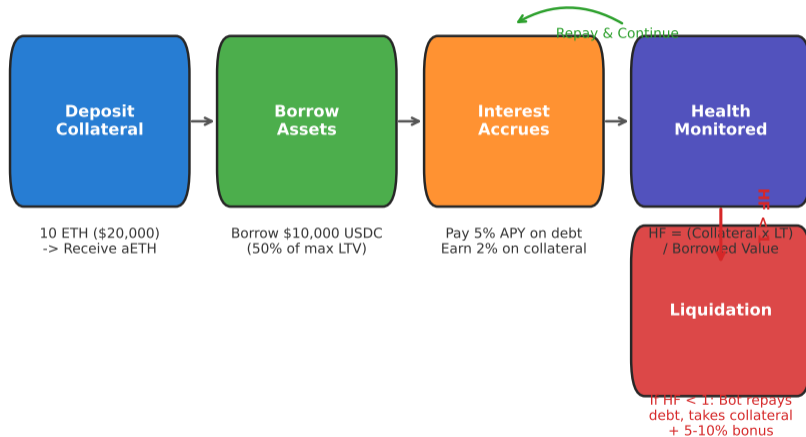
- 1 **On-Chain Credit Scores:** Track repayment history (Credora, ARCx)
- 2 **Real-World Identity:** KYC-linked, legal recourse (Goldfinch, TrueFi)
- 3 **Social Collateral:** Community vouching (Teller Protocol)

**Trade-off:** Undercollateralization requires identity or trust, reducing permissionlessness.

*Key point: Current Limitation*

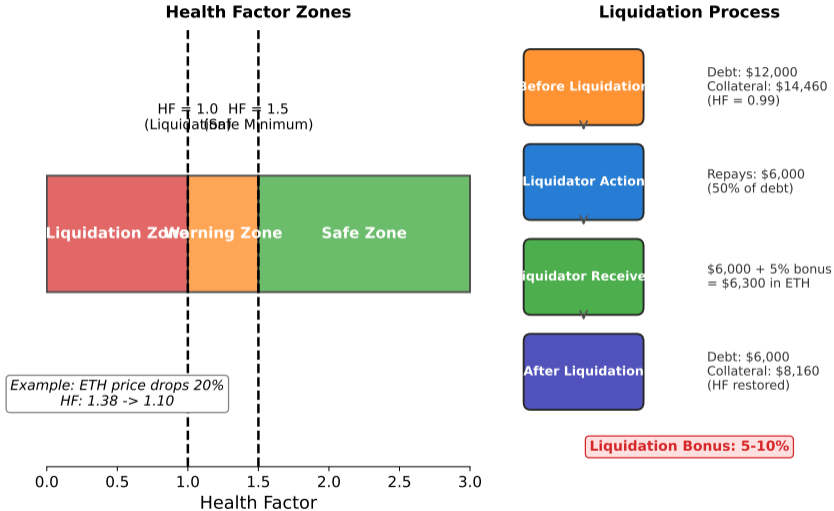
# How Does the Complete Lending Cycle Work?

## DeFi Lending Protocol Mechanics



Complete lifecycle: deposit collateral, borrow assets, accrue interest, monitor health, avoid liquidation.

# How Does Liquidation Actually Work?



Liquidators profit from the 5-10% bonus, incentivizing them to maintain protocol solvency.

## The Original Problem

*How do we lend without credit scores?*

## How Lending Protocols Solves It

- Borrowers deposit more value than they borrow, eliminating default risk entirely
- Smart contracts enforce liquidation when health factor  $\leq 1$ , no courts needed
- Utilization-based models adjust rates to balance supply/demand without central authority

## Remaining Limitations

- Must lock \$150 to borrow \$100 (vs traditional lending at 20-30% down payment)
- Market volatility can trigger mass liquidations, amplifying price drops

## Open Questions

- Can undercollateralized DeFi lending work without sacrificing permissionlessness?
- Risk: Identity-based credit systems (Goldfinch, TrueFi) reintroduce centralization and exclusion

*Lending protocols solve trustless lending but trade capital efficiency for permissionless access*

## Incentive Structure

- Creating systems with desired properties
- Mechanism design for target behaviors
- Complexity vs simplicity

## Economic Security

- Attack cost must exceed potential gain
- Honest behavior = Nash equilibrium

*Cryptoeconomic security: Honest behavior must be the Nash equilibrium*

## Key Economic Question

### Who Pays, Who Earns?

Complexity vs simplicity

## Design Principle

Attack Cost  $>$  Potential Gain

## Alternatives Considered

- 1 **Chosen Design:** Architecture patterns, upgrade mechanisms
- 2 **Alternative:** Alternative design patterns

## Trade-offs Made

- Every design optimizes some properties
- ... at the expense of others

## Design Questions

- What would YOU change?
- What's optimized? What's sacrificed?
- Are there other approaches?

## Key Insight

### No Perfect Solution

All blockchain designs involve trade-offs between decentralization, security, and scalability.

*Every design is a trade-off. Understanding alternatives reveals the "why" behind choices.*

## Critical Failure Mode

- Unintended consequences, edge cases
- Economic incentives misaligned

## Root Cause

- Assumption violated
- Incentive structure broken
- External shock

## Historical Context

- Multiple real-world failures documented
- Patterns repeating across protocols

## Early Warning Signs

- ! Unusual economic behavior
- ! Incentive misalignment
- ! Centralization drift

*Prediction: What could cause this to fail? How would you detect it early?*

**Continued**

# Why Do Liquidations Cascade?

## [COMIC: Liquidation cascade]

*Placeholder for comic showing dominos falling: ETH price drops, triggers liquidation, forced selling drops price more, triggers more liquidations – cascade effect*

*In a cascade, your safe health factor can become unsafe in minutes*

## The Danger

- One liquidation = forced selling
- Forced selling = price drops further
- More price drops = more liquidations

## Protect Yourself

- Keep health factor above 1.5
- Set alerts for price drops
- Have collateral ready to add

## Key Takeaways:

- DeFi lending: permissionless but requires overcollateralization
- LTV ratios vary by asset risk (ETH 80%, low-cap 45%)
- Health factor must stay above 1 to avoid liquidation
- Interest rates adjust algorithmically based on utilization
- Flash loans enable zero-collateral borrowing within one tx
- Aave dominates (\$31B TVL); Compound pioneered the model
- Future: undercollateralized lending via credit scoring

**Next Lecture:** Stablecoin Mechanisms.

**Next Lesson:** L38 – Stablecoin Mechanisms

*Key point: Key Takeaways*

# Questions for Reflection

- 1 Calculate health factor: \$30k collateral, \$20k borrowed, 85% liq threshold.
- 2 Why is overcollateralization necessary in DeFi lending?
- 3 How do interest rates adjust to prevent bank runs?
- 4 What risks do flash loans pose to DeFi protocols?
- 5 Variable or stable rates for 1-year borrow?

*Key point: Questions for Reflection*

## Quiz Questions (1–5)

**Q1. What is the main difference between traditional lending and DeFi lending?**

- A) Traditional requires KYC, DeFi doesn't   B) Traditional is faster   C) DeFi allows undercollateralized loans   D) Traditional is 24/7

**Answer: A** – DeFi lending is permissionless with no KYC, while traditional requires credit checks and identity verification.

**Q2. If you deposit 10 ETH worth \$20,000 with 80% LTV, what is the maximum you can borrow?**

- A) \$20,000   B) \$16,000   C) \$10,000   D) \$25,000

**Answer: B** – Maximum borrow = Collateral Value  $\times$  LTV = \$20,000  $\times$  0.80 = \$16,000.

**Q3. What happens when your health factor drops below 1?**

- A) Interest rate increases   B) You get a warning email   C) Your position gets liquidated   D) Nothing happens

**Answer: C** – Health factor  $\leq 1$  triggers liquidation; liquidators repay debt and receive collateral plus a bonus.

**Q4. Why do volatile assets like altcoins have lower LTV ratios than stablecoins?**

- A) Less popular   B) Higher price volatility risk   C) Lower liquidity   D) Regulatory restrictions

**Answer: B** – Volatile assets need larger buffers (lower LTV) to protect against price swings and prevent immediate liquidations.

**Q5. What is the health factor for \$30,000 collateral, \$20,000 borrowed, 85% liquidation threshold?**

- A) 1.00   B) 1.28   C) 1.50   D) 0.67

**Answer: B** – HF =  $(30,000 \times 0.85) / 20,000 = 25,500 / 20,000 = 1.275 \approx 1.28$ .

Quiz

## Quiz Questions (6–10)

**Q6. What is the liquidation penalty received by liquidators on Aave?**

- A) 1-2%   B) 5-10%   C) 15-20%   D) 25-30%

**Answer: B** – Liquidators receive a 5-10% bonus on top of the collateral they claim as incentive for maintaining protocol solvency.

**Q7. How is the utilization rate calculated?**

- A) Total Supplied / Total Borrowed   B) Total Borrowed / Total Supplied   C) Total Borrowed - Total Supplied   D) Interest Rate / LTV

**Answer: B** – Utilization Rate = Total Borrowed / Total Supplied, measuring what percentage of available liquidity is being used.

**Q8. What happens to borrow interest rates when utilization exceeds 90%?**

- A) They decrease   B) They stay constant   C) They increase steeply   D) Protocol shuts down

**Answer: C** – High utilization triggers steep rate increases to discourage borrowing and encourage repayment, preventing liquidity crises.

**Q9. Which protocol has the largest DeFi lending market share as of December 2025?**

- A) Compound   B) MakerDAO   C) Aave   D) dYdX

**Answer: C** – Aave leads with \$31B TVL and 60%+ market share through multi-chain expansion and innovative features.

**Q10. What unique feature does Aave offer that Compound does not?**

- A) Interest-bearing tokens   B) Flash loans   C) Governance token   D) Overcollateralized loans

**Answer: B** – Aave pioneered flash loans (uncollateralized borrowing within one transaction), which Compound does not offer.

## Quiz Questions (11–15)

**Q11. What must happen for a flash loan to succeed?**

- A) Collateral must be posted   B) Loan must be repaid within same transaction   C) Loan duration must be 1 block   D) KYC verification

**Answer: B** – Flash loans are atomic: borrow, use, and repay (plus fee) must all happen in the same transaction or the entire transaction reverts.

**Q12. What is the typical flash loan fee on Aave?**

- A) 0.09%   B) 1%   C) 5%   D) 10%

**Answer: A** – Aave charges a 0.09% fee on flash loans, making them very capital-efficient for arbitrage and other single-transaction strategies.

**Q13. Why is Supply APY always lower than Borrow APY in lending protocols?**

- A) Protocol keeps the difference as revenue   B) Gas costs   C) Reserve factor and utilization   D) Regulatory requirements

**Answer: C** –  $\text{Supply APY} = \text{Borrow APY} \times \text{Utilization} \times (1 - \text{Reserve Factor})$ ; the reserve factor and  $\approx 100\%$  utilization ensure supply rates are lower.

**Q14. What tokens do lenders receive when depositing assets on Aave?**

- A) cTokens   B) aTokens   C) COMP tokens   D) LP tokens

**Answer: B** – Aave issues aTokens (e.g., aETH, aUSDC) that accrue interest in real-time and represent the deposited assets plus earned interest.

**Q15. Which event sparked “DeFi Summer” in 2020?**

- A) Aave launch   B) Compound COMP mining   C) Uniswap v2   D) Bitcoin halving

**Answer: B** – Compound’s COMP token liquidity mining program in June 2020 sparked explosive DeFi growth known as “DeFi Summer.”

## Quiz Questions (16–20)

**Q16. What is the main risk that flash loans pose to DeFi protocols?**

- A) High gas costs   B) Oracle manipulation attacks   C) Regulatory scrutiny   D) Network congestion

**Answer: B** – Flash loans provide large capital for oracle manipulation attacks, allowing attackers to distort price feeds and exploit protocols.

**Q17. What is Aave's E-Mode designed for?**

- A) Emergency shutdowns   B) Higher LTV for correlated assets   C) Lower gas costs   D) Faster liquidations

**Answer: B** – E-Mode allows higher LTV ratios for highly correlated assets (e.g., ETH-stETH), improving capital efficiency for low-risk pairs.

**Q18. What happened to CeFi lenders Celsius and BlockFi in 2022?**

- A) They merged   B) They went public   C) They collapsed   D) They launched tokens

**Answer: C** – Both Celsius and BlockFi collapsed in 2022 due to mismanagement and contagion, while DeFi protocols remained operational.

**Q19. What is needed for undercollateralized DeFi lending to work?**

- A) Higher interest rates   B) Credit scores or identity systems   C) Longer loan terms   D) More liquidators

**Answer: B** – Undercollateralized lending requires reputation, on-chain credit scores, or KYC/identity to enable legal recourse.

**Q20. What is the trade-off of introducing identity-based undercollateralized lending?**

- A) Higher fees   B) Slower transactions   C) Reduced permissionlessness   D) Lower yields

**Answer: C** – Adding identity or credit requirements reduces DeFi's core benefit of permissionless access, trading accessibility for capital efficiency.