



15.482 Healthcare Finance

Spring 2017

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Unit 4, Part 1: Volatility, Risk and Uncertainty

Unit Outline

- Risk & Reward
- The CAPM
- Applications
- Portfolio Theory
- Risk-Adjusted NPV

Risk and Reward

Valuing Assets

Basic Approach Is NPV: $PV(\text{Revenues}) - PV(\text{Costs})$

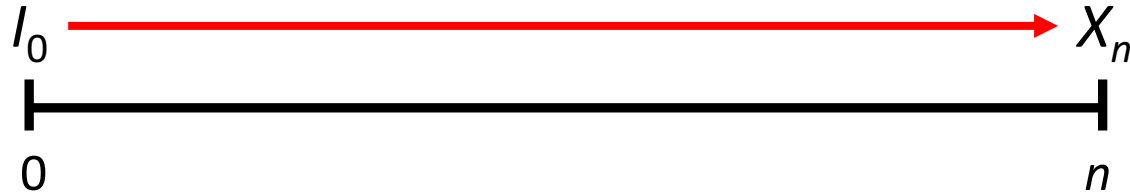
- If $NPV > 0$, go; if $NPV \leq 0$, stop!

$$NPV = \sum_{t=1}^{\infty} \frac{\text{Revenues}_t}{(1 + R_t)^k} - \sum_{t=1}^{\infty} \frac{\text{Costs}_t}{(1 + R_t)^k}$$

- Several challenges for biomedicine:
 1. Future revenues and costs are unknown (random variables)
 2. Cost of capital $\{R_t\}$ are also unknown
 3. Costs are very large and are incurred years before revenues, hence some type of financing is needed
- But these challenges are exactly why we have financial markets and services; they can all be addressed!

Measuring Risk and Reward

- Return on investment:



$$1 + R = \frac{X_n}{I_0} \quad \text{Gross Return}$$

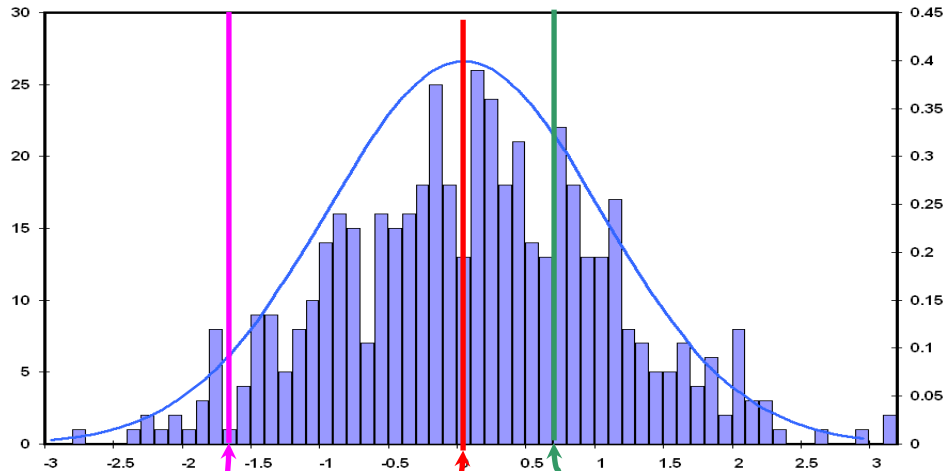
$$R = \frac{X_n}{I_0} - 1 \quad \text{Net Return}$$

$$R^{\text{annual}} = \left(\frac{X_n}{I_0} \right)^{1/n} - 1 \quad \text{Annualized Net Return}$$

$$X_n = I_0 \times (1 + R_1) \times (1 + R_2) \times \cdots \times (1 + R_n) \quad \text{Cumulative Total Return}$$

Measuring Risk and Reward

- Reward is typically measured by return
- Higher returns are better than lower returns.
- But what if returns are unknown?
- Assume returns R are random, and consider its distribution



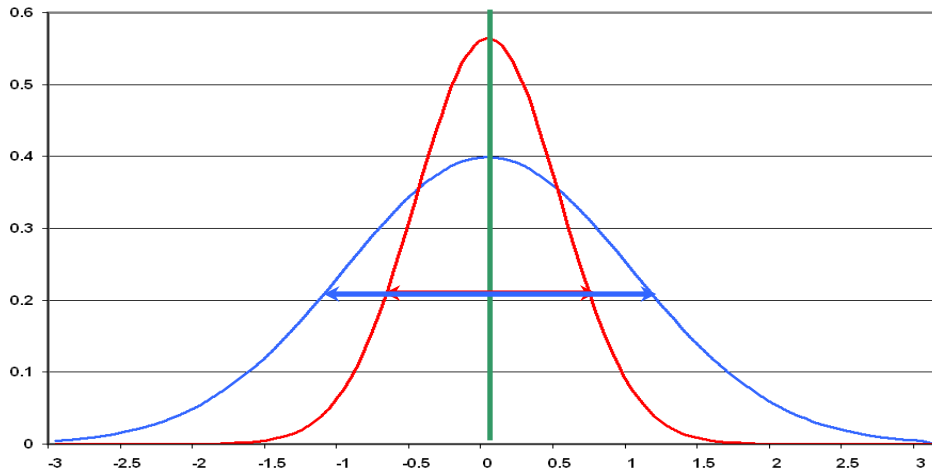
Several possible measures:

- Mean: central tendency
- 75%: upper quartile
- 5%: losses

Finance theory uses $E[R]$

Measuring Risk and Reward

- How about risk?
- Likelihood of loss (negative return)
- But loss can come from positive return (e.g., short position)
- Symmetric measure of dispersion is **variance** $\text{Var}[R]$ or **standard deviation** $\text{SD}[R]$



Variance Measures **Spread**:

- **Blue** distribution is “riskier”
- Extreme outcomes more likely
- This measure is symmetric

Measuring Risk and Reward

January 1926 to December 2015

	Large Stocks	Small Stocks	Long- Term Corporate Bonds	Long- Term Govt. Bonds	Intermed. Term Govt. Bonds	T-Bills
Average Return	10.0%	12.0%	6.0%	5.6%	5.2%	3.4%
Volatility	20.0%	32.0%	8.4%	10.0%	5.7%	3.1%
Cumulative Return	\$5,390	\$26,433	\$188	\$132	\$94	\$21

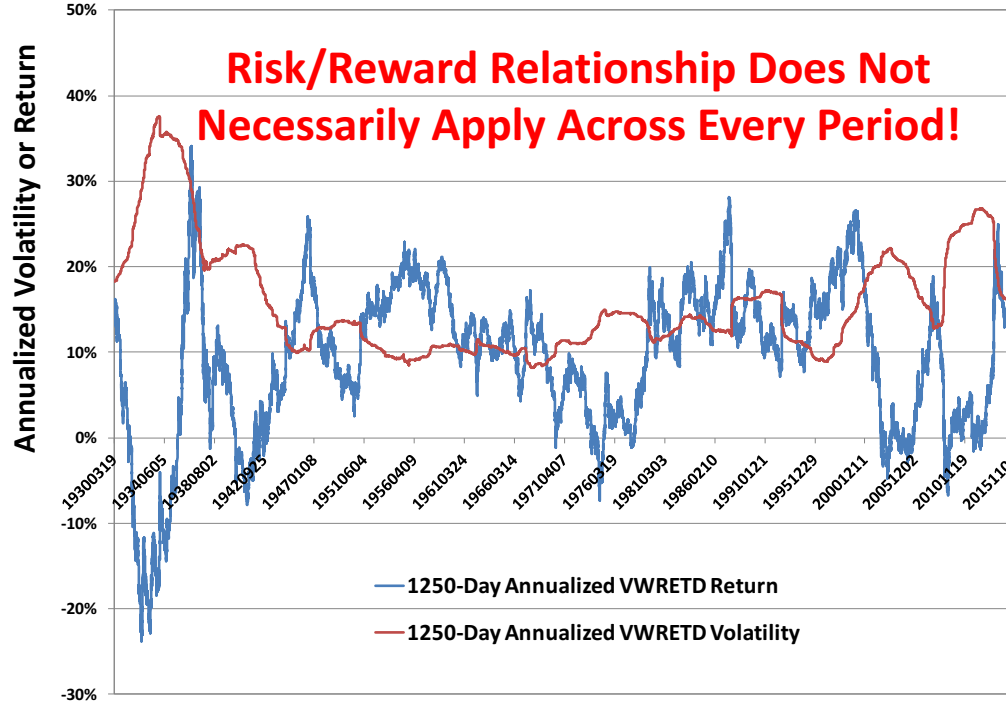
- Positive relation between risk and reward (expected return)
- Difference between risky and riskless reward is the **risk premium**
- Sharpe ratio is defined as:

$$\text{Sharpe Ratio} = \frac{\text{Reward}}{\text{Risk}} = \frac{E[R_i] - R_f}{\sigma_i}$$

Measuring Risk and Reward

1250-Day Rolling-Window Volatility and Return of CRSP Value-Weighted Return

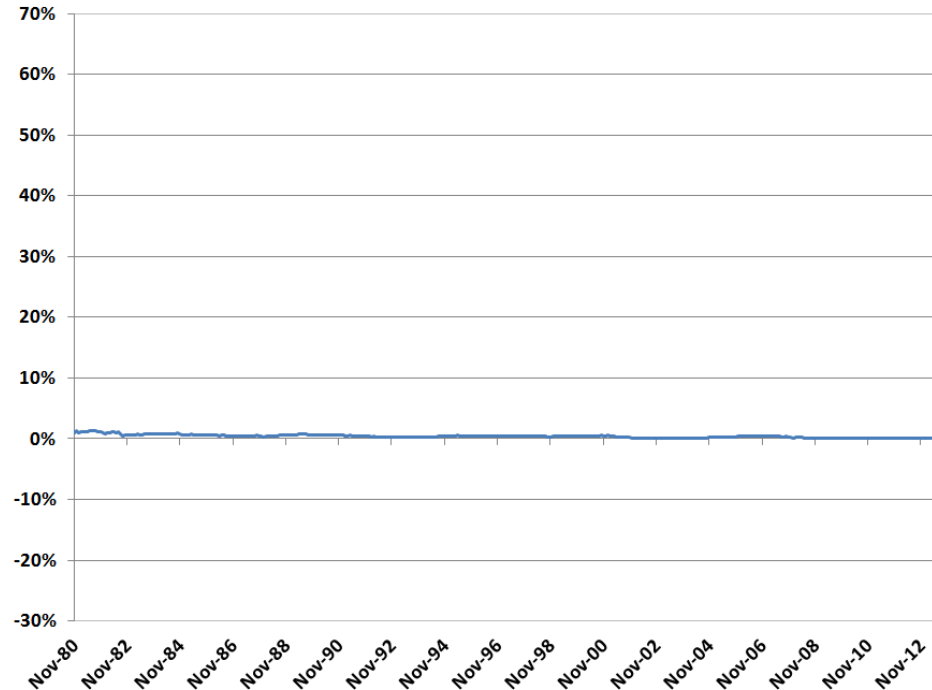
March 19, 1930 to December 31, 2015



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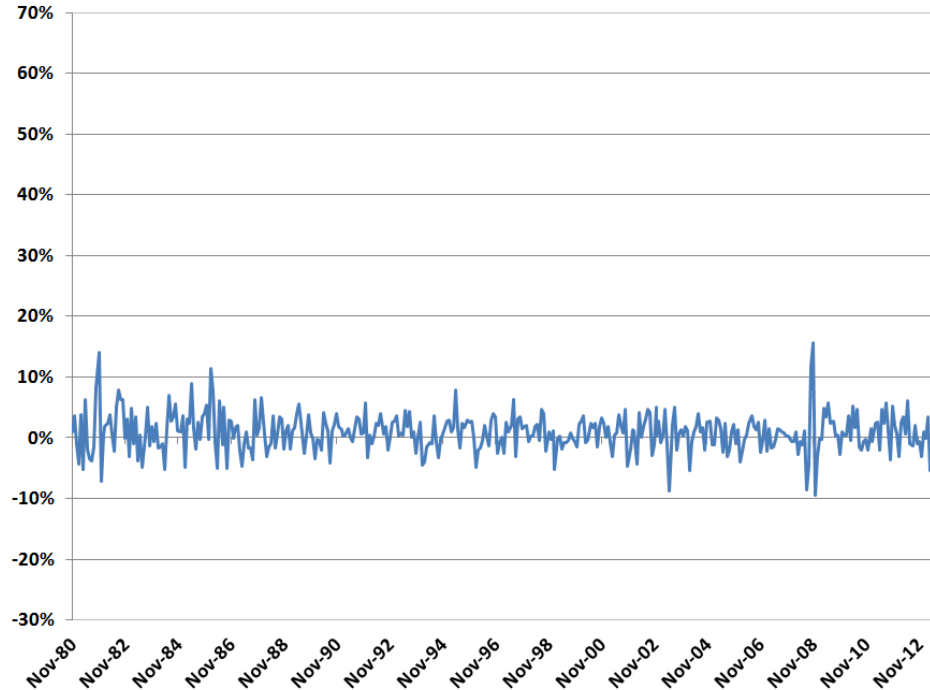
What Does Risk Look Like?

Monthly Returns of U.S. Treasury Bills
November 1980 to December 2013



What Does Risk Look Like?

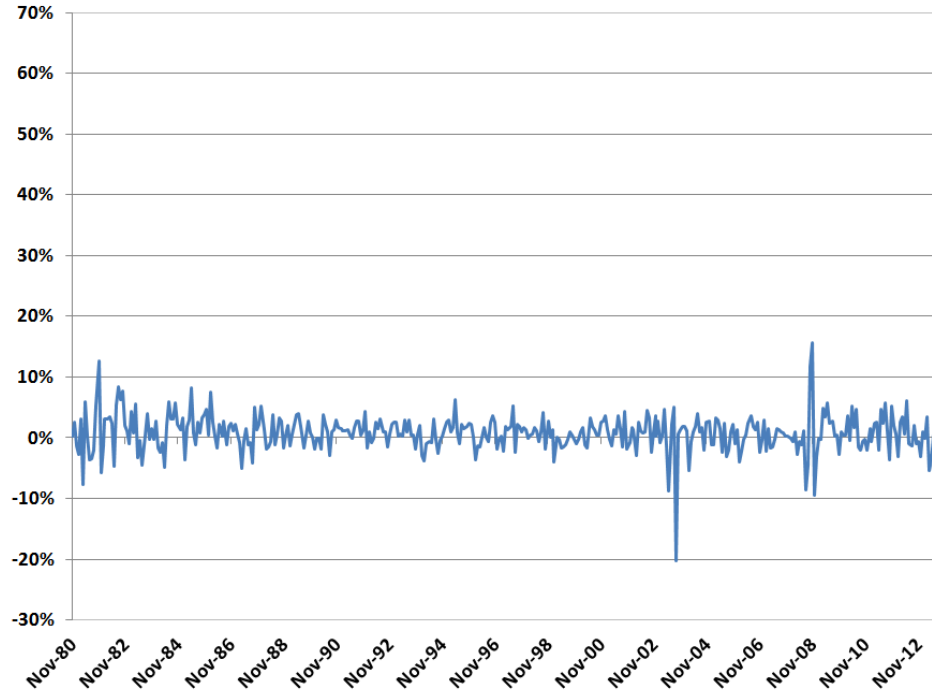
Monthly Returns of U.S. Long-Term Treasury Bonds November 1980 to December 2013



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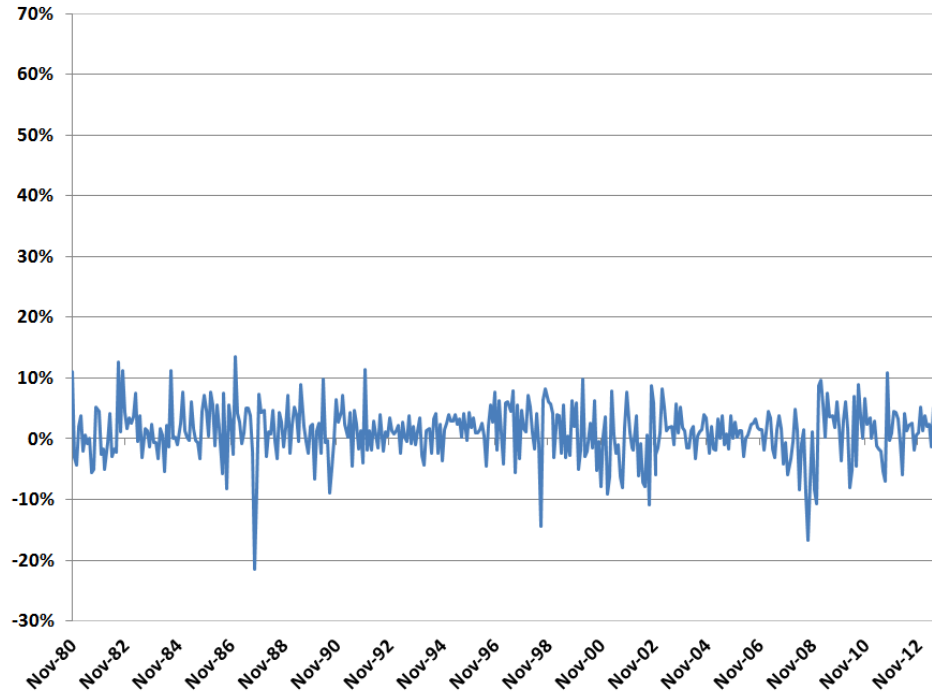
What Does Risk Look Like?

Monthly Returns of U.S. Long-Term Corporate Bonds November 1980 to December 2013



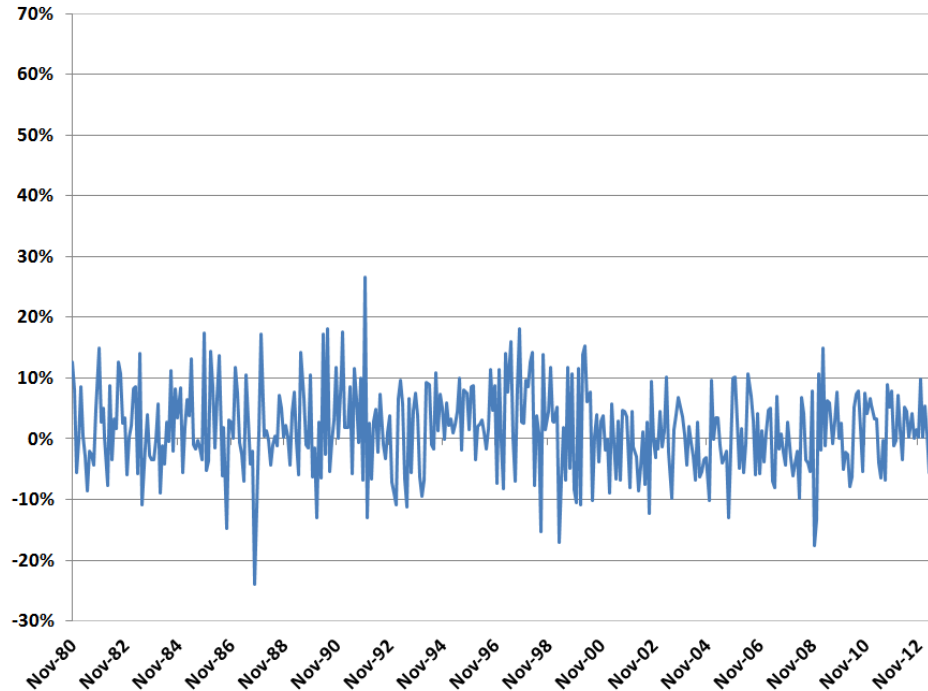
What Does Risk Look Like?

Monthly Returns of the S&P 500 November 1980 to December 2013



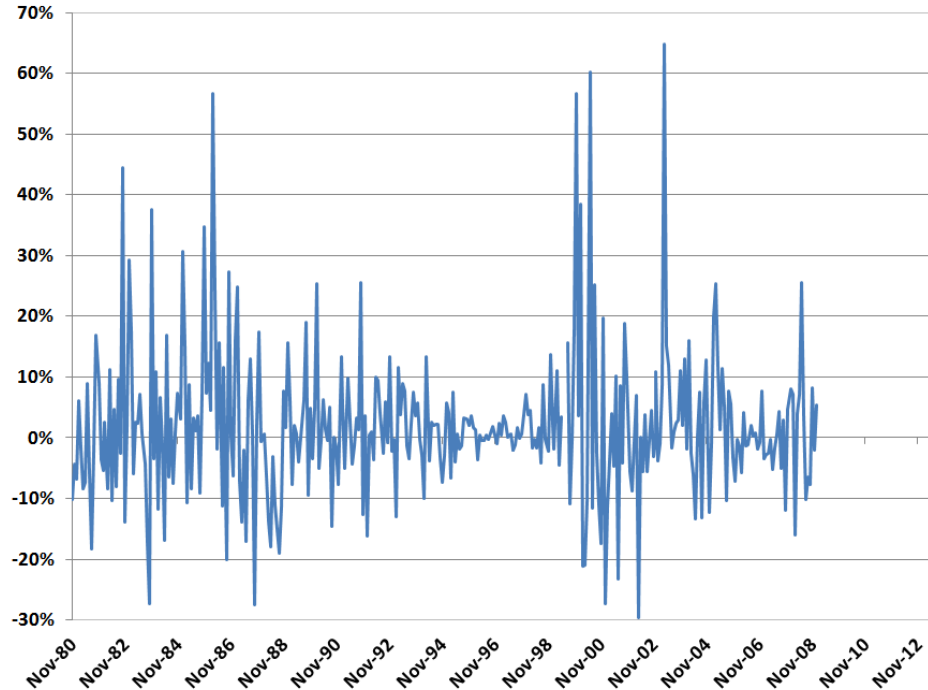
What Does Risk Look Like?

Monthly Returns of Pfizer Stock November 1980 to December 2013



What Does Risk Look Like?

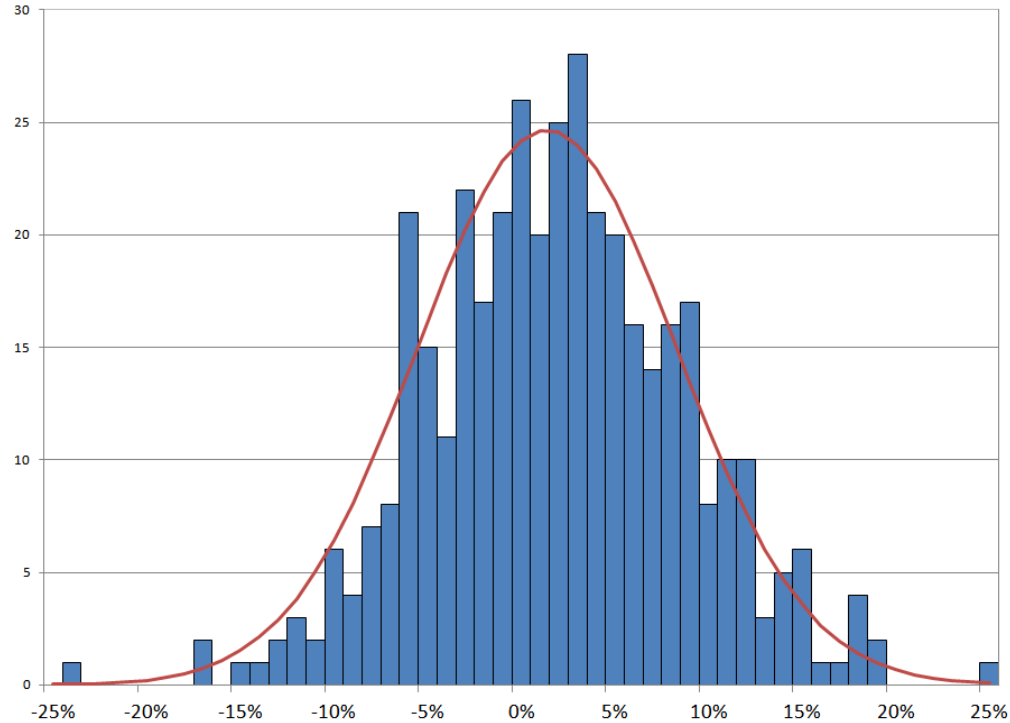
Monthly Returns of Genentech Stock November 1980 to December 2013



What Does Risk Look Like?

Histogram of Pfizer Monthly Returns

November 1980 to December 2013

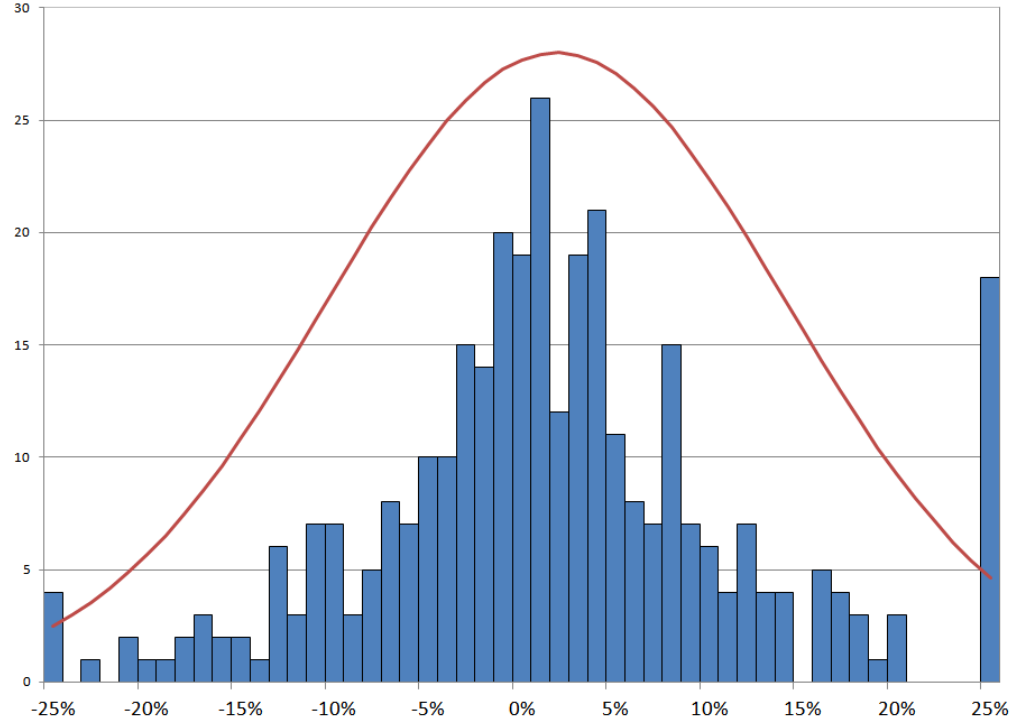


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What Does Risk Look Like?

Histogram of Genentech Monthly Returns

November 1980 to February 2009



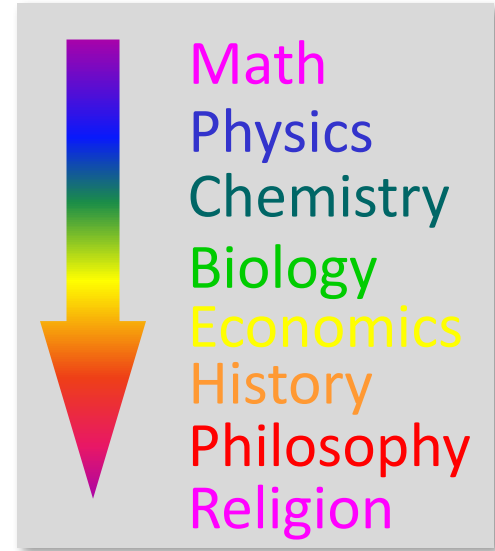
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Risk Spectrum

The Five Levels of Risk and Uncertainty (Lo and Mueller, 2010):

1. Complete Certainty
2. Risk without Uncertainty
3. Fully Reducible Uncertainty
4. Partially Reducible Uncertainty
5. Zen Uncertainty

All attempts at understanding
are futile, there is only suffering

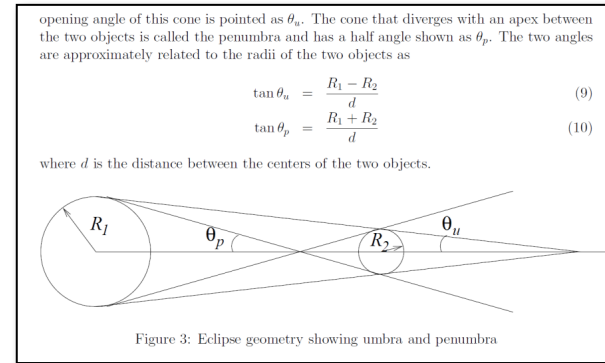


Risk Spectrum

Example:



- May 28, 585 BC, Level 5
- Religious portent
- Stops war between Lydians and Medes



- Today, Level 1
- Completely deterministic
- Stops traffic occasionally

What About Intermediate Levels?

Risk Spectrum


Implications for Drug Development:

- | | |
|-------------------------------------|-------------------------------|
| 1. Complete Certainty: | FDA approval |
| 2. Risk without Uncertainty: | Phase III |
| 3. Fully Reducible Uncertainty: | Phase IIb |
| 4. Partially Reducible Uncertainty: | Phase I |
| 5. Irreducible Uncertainty: | Preclinical and basic science |

Who Cares?

Risk Spectrum

Implications for Drug Development

- 
1. Complete Certainty: Banks, money market funds, mutual funds, pension funds, insurance companies, endowments, sovereign wealth funds, retail investors, etc.
 2. Risk without Uncertainty: Mutual funds, pension funds, insurance companies, endowments, sovereign wealth funds, retail investors
 3. Fully Reducible Uncertainty: Mutual funds, pension funds, insurance companies, endowments, private equity, venture capital
 4. Partially Reducible Uncertainty: Hedge funds, big pension funds, insurance companies, and endowments
 5. Irreducible Uncertainty: Philanthropists, patient advocacy groups, government

We Should All Care! Risk and Uncertainty Are Rising In Biomedicine