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We will not do that.

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we are right, and they are wrong.

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- As we defined them, PRGs are limited
  - They have fixed-length output
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  - They have fixed-length output
  - They produce output in "one shot"
- In practice, Psuedo 1-Time Pads use **Stream Ciphers**
  - Can be viewed as producing an "infinite" stream of pseudorandom bits, on demand
  - More flexible, more efficient

Stream ciphers

A **Stream Cipher** is basically a **recurrence** that generates bits.
Formally a **Stream Cipher** is a pair of efficient, deterministic algorithms (Init, GetBits) such that:

1. Init does the following:
   1.1 **Input** **private** seed s. Think of as truly random.
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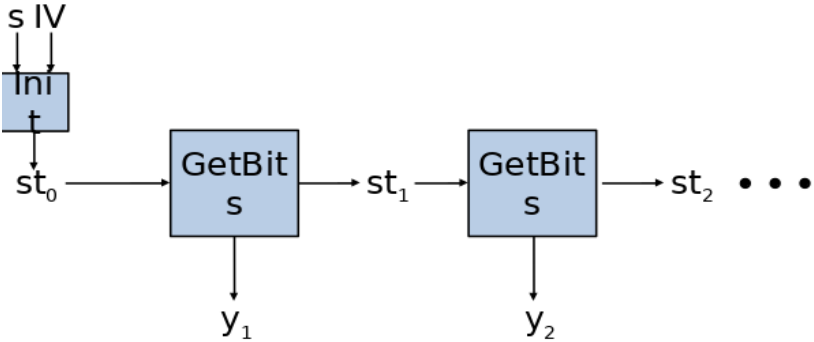
2. GetBits does the following:
   2.1 **Input** Given $y_0, \ldots, y_m$ (likely depends on less of the past).
   2.2 **Output** the bit y_{m+1}.

Note In practice, y_i is a block rather than a bit.

Stream ciphers

- Can use (Init, GetBits) to generate any desired number of output bits from an initial seed



Stream ciphers

- A stream cipher is **secure** (informally) if the output stream generated from a uniform seed is pseudorandom
  - I.e. regardless of how long the output stream is (so long as it is polynomial)
  - We omit formal definition which is in terms of games.

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Under reasonable crypto assumptions can construct Secure Stream Cipher.

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Over time, constructions that are **too slow** are worked on and become fast enough.

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Attempts at Stream Ciphers:

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3. Rivest Cipher 4. Fast! Used! No longer secure!

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Note But having the rigor gives the practitioners (1) a target to shoot for, and (2) pitfalls to watch out for.

Linear Feedback Shift Registers (LFSR): Example

Degree 3 LFSR, 3 constants : $c_3, c_2, c_1 \in \{0, 1\}$. $+$ is mod 2.

Key is 3 bits: (y_0, y_1, y_2).

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$$(\forall t \geq 3)[y_t = c_1 y_{t-1} + c_2 y_{t-2} + c_3 y_{t-3}].$$

Note Leave it to you to generalize to degree n LFSR.

LFSRs

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Example of Bad Security

Degree 3. c_0, c_1, c_2 unknown. If $y_1, y_2, y_3, y_4, y_5, y_6$ become known then:

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3 linear equations in 3 variables. Can find c_0, c_1, c_2. **Cracked!**

For n-degree LFSR can crack after $2n$ iterations.
Moral: Linearity is *bad* cryptography.

LFSR and Linearity

Linearity makes LFSR's **fast**

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Who first said:

Those who lives by linearity, dies by linearity!

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> **Those who lives by linearity, dies by linearity!**

It was Irene!

The Essence of Crypto

Recall: The Essence of Crypto is to make computation

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LFSR makes computation easy for all three!

Nonlinear Feedback Shift Registers (NFSRs)

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1. Add nonlinearity to prevent attacks
2. Nonlinear feedback
3. Output is a nonlinear function of the state
4. Multiple (coupled) LFSRs
5. . . . or any combination of the above
6. Still want to preserve statistical properties of the output, and long cycle length

Nonlinear Feedback Shift Registers

Assume n even. $+$ is mod 2.
Initialize with x_1, x_2, x_3, x_4
$(\forall n \geq 5)[x_n = x_{n-1}x_{n-2} + x_{n-2}x_{n-3} + x_{n-3}x_{n-4}]$.

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UNKNOWN
I made up this cipher last year for example of nonlinear.
On the HW you will tell me if its a good stream cipher.

Trivum

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- Intended to be simple and efficient (especially in hardware).
- Essentially no attacks better than brute-force search are known.

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- Three coupled Feedback Shift Registers (FSR) of degree 93, 84, and 111.
- Initialization:
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  - Remaining registers set to 0, except for three right-most registers of third FSR
  - Run for 4 x 288 clock ticks to finish init.

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Note No random bits output. This is just initialization.

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5. $(a_1, \ldots, a_{93}) \leftarrow (t_3, a_1, \ldots, a_{92})$
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Too bad. They called my post **Great** .

Second Comment on Blog

An 80-bit key/IV is not secure enough for many modern uses (like encryption on the Internet), though I am not sure what exactly Trivium and other "lightweight ciphers" consider a threat. Their primary intended deployment scenarios are IoT and hardware tokens like auto door locks. For that purpose it is secure.

Salsa20 Stream Cipher

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Note: Scrambles up a, b, c, d **a lot!** .

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Security: Salsa20 was introduced in 2005 and has not been broken. See Wikipedia page for partial attacks (e.g., Salsa8).

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>
> *Trivium, in particular, always struck me as so simple that it cannot possibly be secure. And yet, there are no attacks. But I don't think it has been subject to the same scrutiny as AES, or even RC4. ChaCha is actually used, so people care about its security. Hence its security seems solid. For now.*

Good Science and Bad Science

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Wages go down – Capitalists exploiting the worker.
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I tried asking them but they wouldn't tell me!