Preuve *zero-knowledge* pour NP relativistes et réalisables

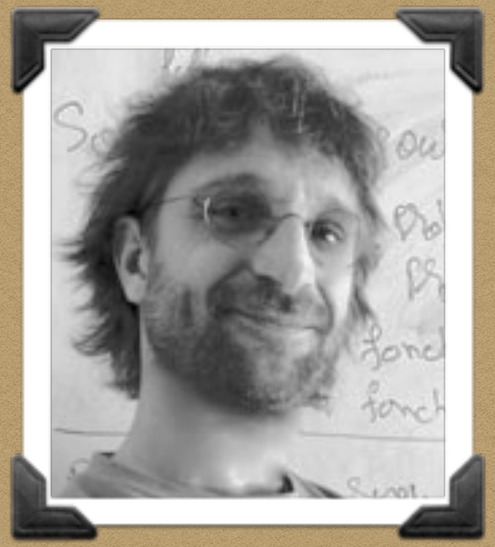
Claude Crépeau

McGill

Preuve *zero-knowledge* pour NP relativistes et réalisables (cohérente malgré l'intrication)

Claude Crépeau

McGill



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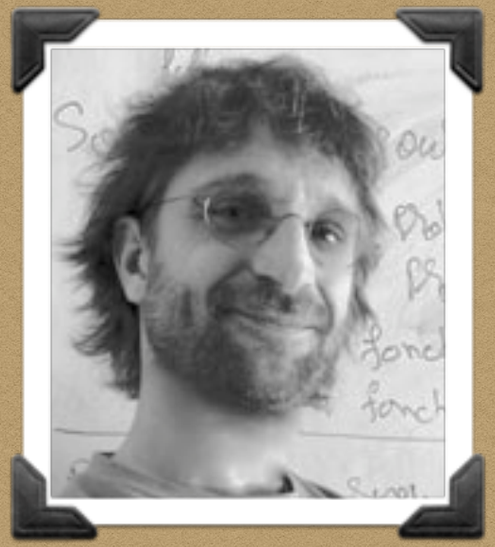
Arnaud Yoh Massenet-Oshima

Louis Salvail

Lucas Shigeru Stinchcombe

Nan Yang



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PREUVE *ZERO-KNOWLEDGE* POUR NP RELATIVISTES ET RÉALISABLES (COHÉRENTE MALGRÉ L'INTRICATION)

Claude Crépeau

McGill

INTRODUCTION

(P-V-D)

PERSONNAGES

PERSONNAGES

prouveur

PERSONNAGES

prouveur

vérificateur

PERSONNAGES

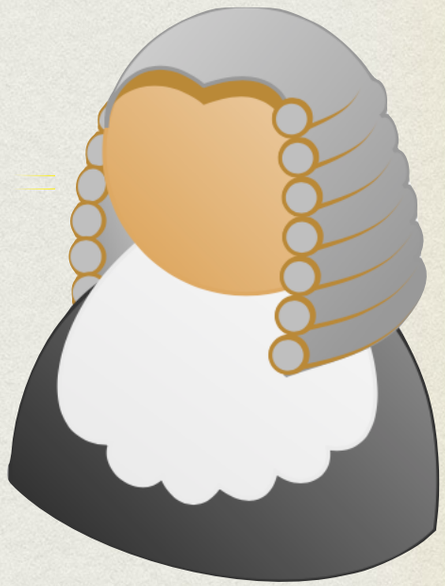
prouveur

vérificateur

PERSONNAGES

prouveur

vérificateur



distingueur

INTRODUCTION

(ZK) IPs


Goldwasser


Micali


Rackoff

1985

W

Goldwasser

Micali

Rackoff

1985

W

a

Goldwasser

Micali

Rackoff

1985

W

a

x

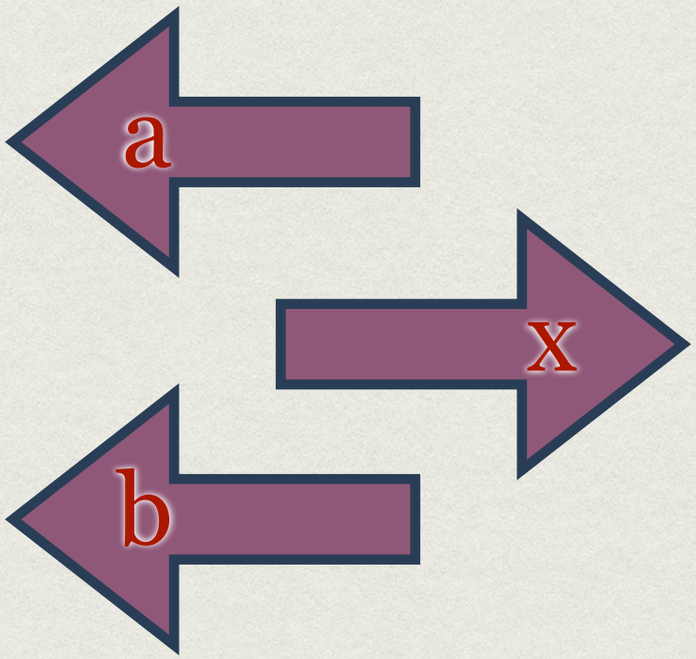
Goldwasser

Micali

Rackoff

1985

W



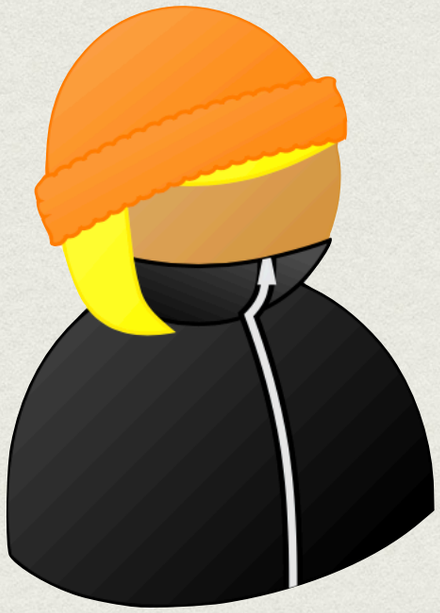

Goldwasser

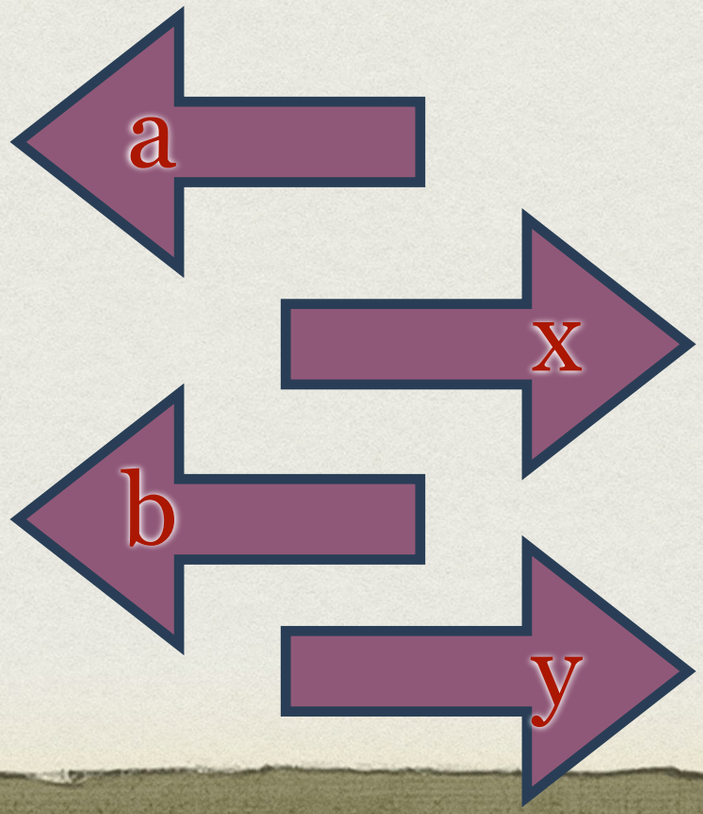

Micali


Rackoff

1985

W






Goldwasser

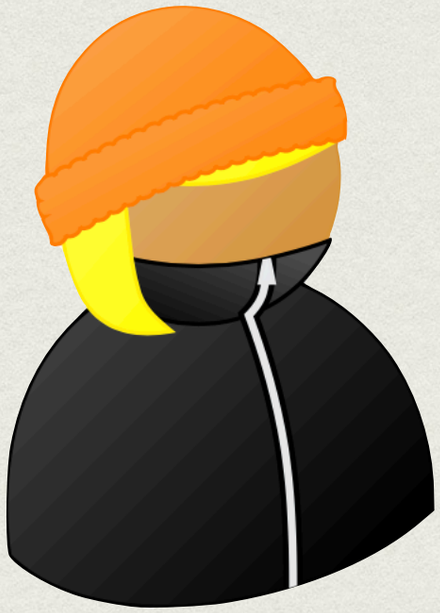

Micali


Rackoff

1985

wEL

w



a

x

b

y


Goldwasser


Micali

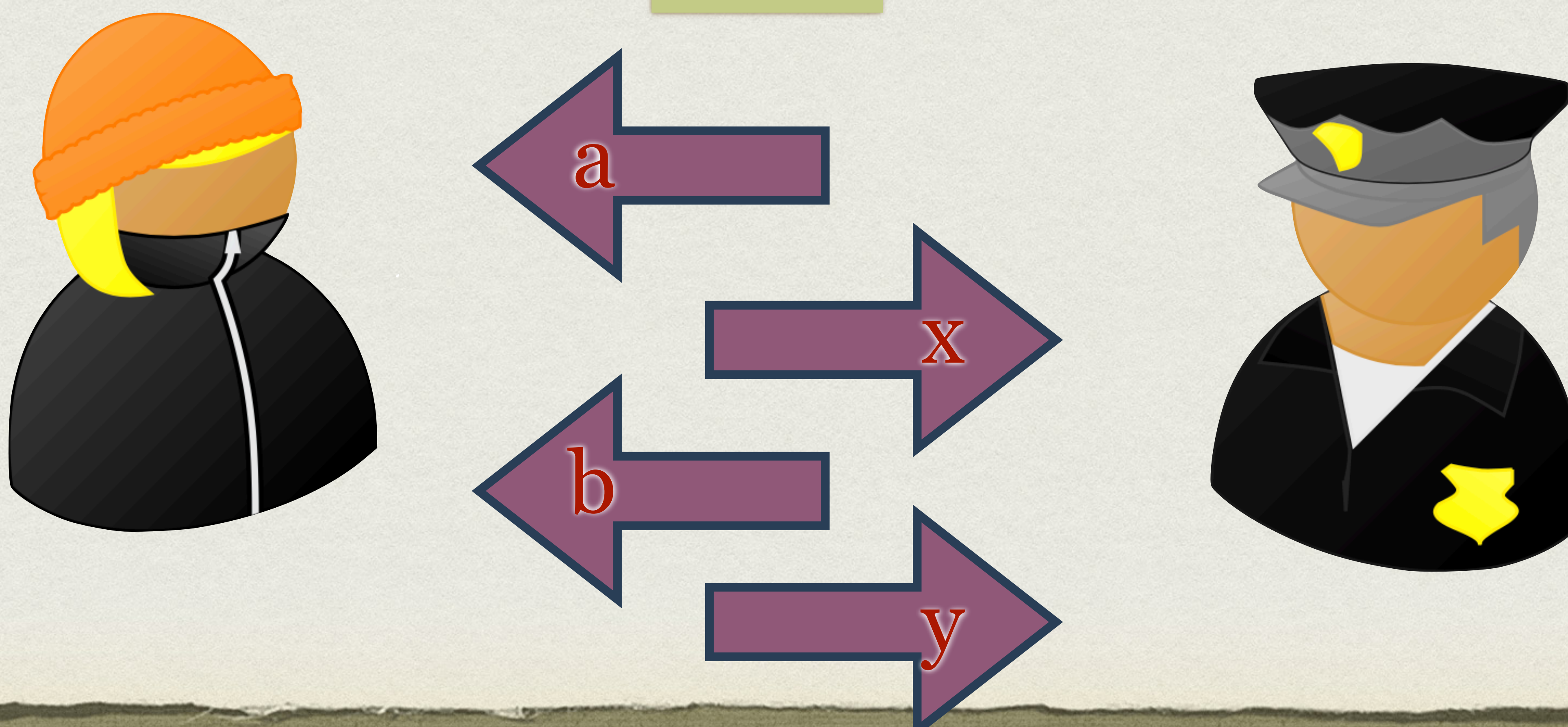

Rackoff

1985

$L \in IP$

$w \in L$

w



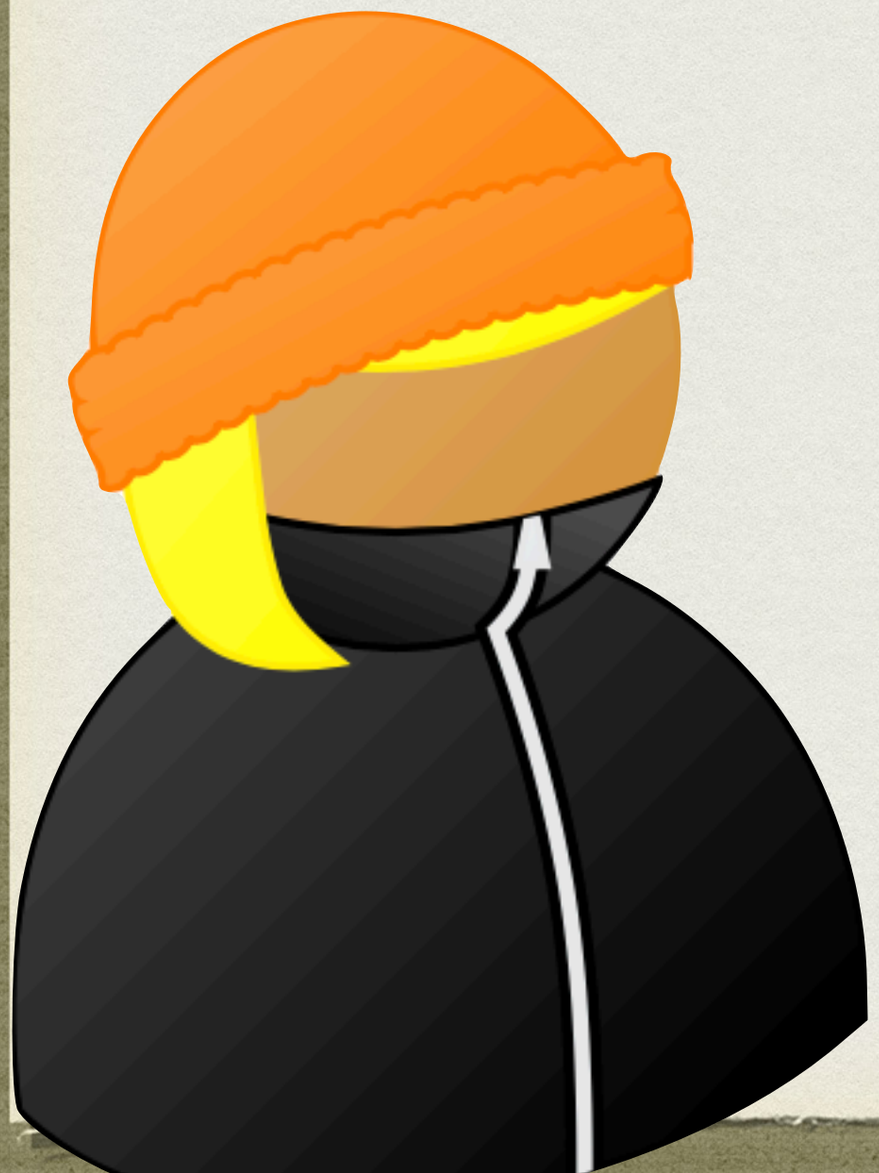
Goldwasser

Micali

Rackoff

1985

LeIP weL



w

a

x

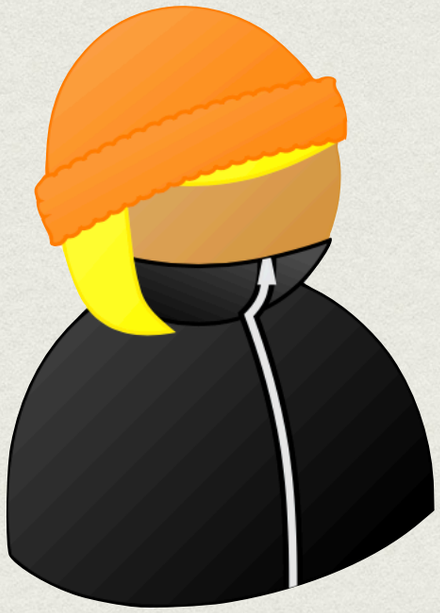
b

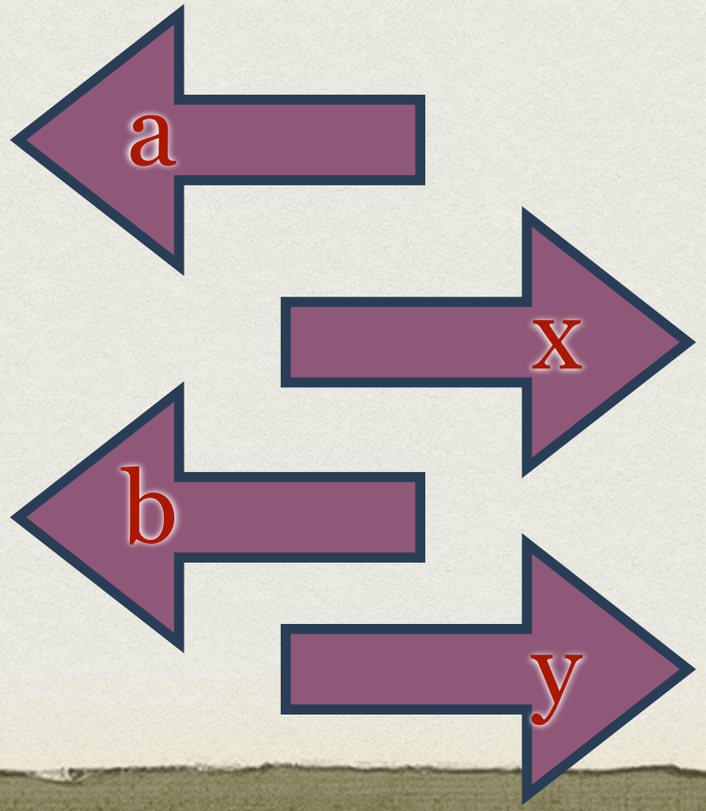
y

Complétude

$\exists$  , $\exists$  , $\forall w \in L$, **Prob**[( : ) accèpte] $\geq 1 - \epsilon$

w



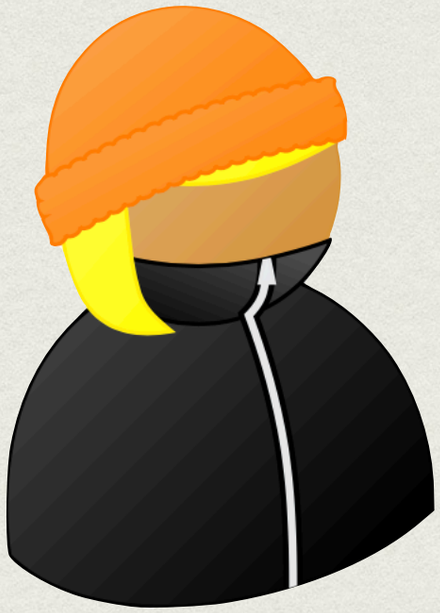


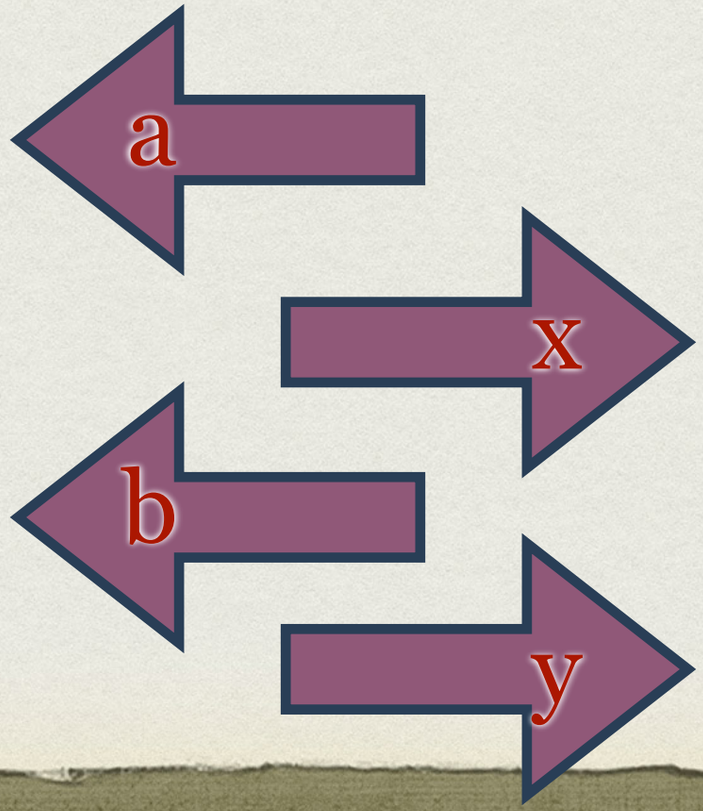
Complétude

$w \in L$

$\exists$  , $\exists$  , $\forall w \in L$, **Prob**[( : ) accèpte] $\geq 1 - \epsilon$

w





Complétude

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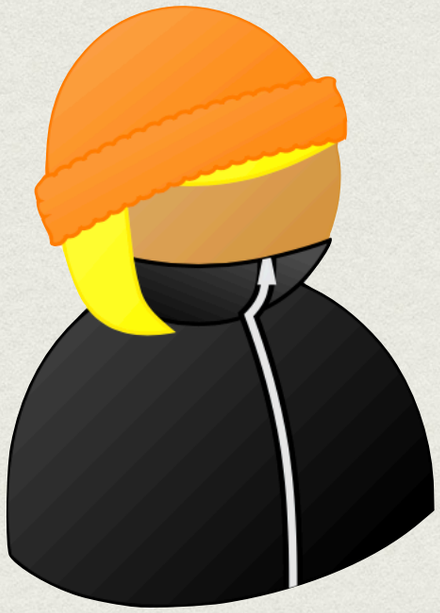
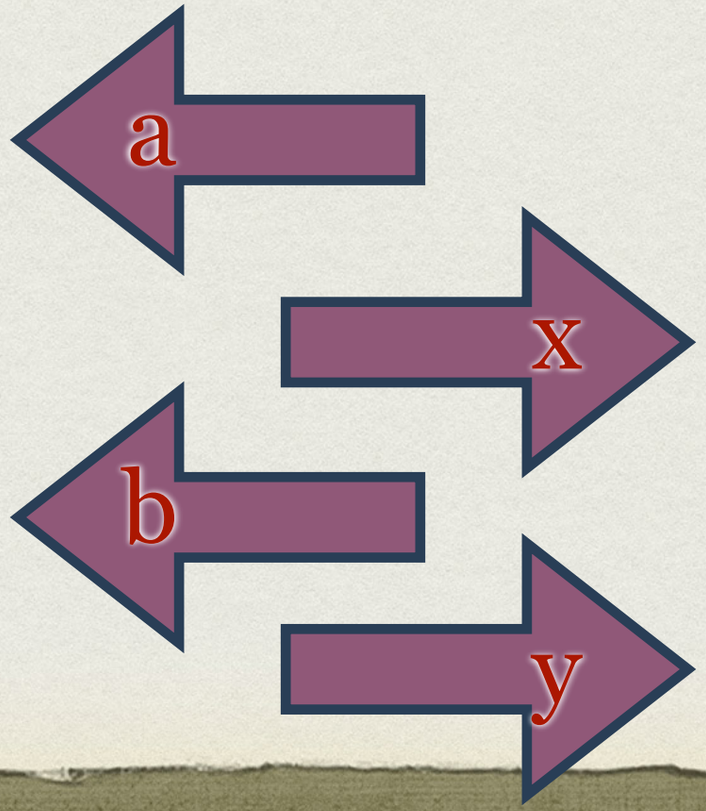
w

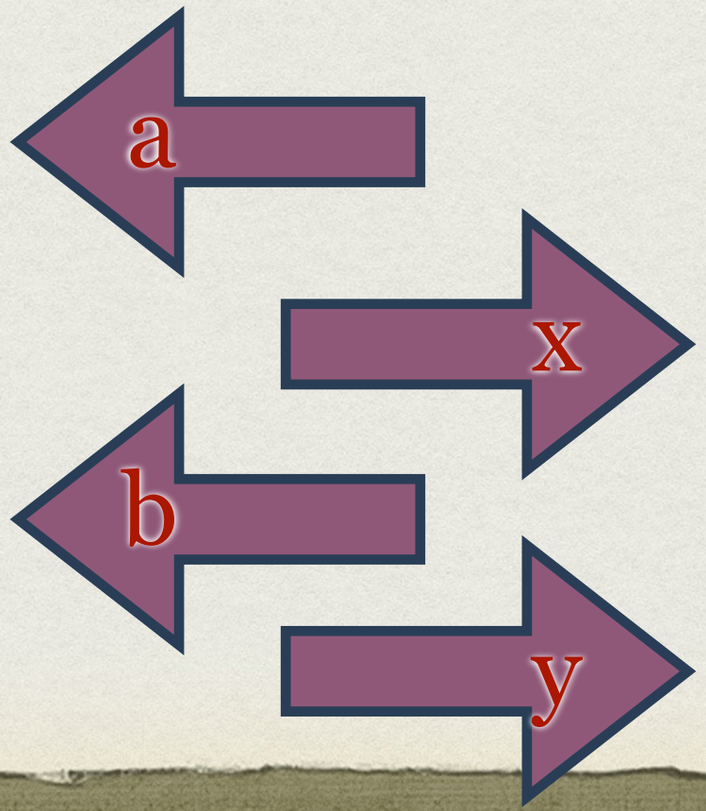




Cohérence

$\exists$  , et $\forall$  , $\forall w \notin L$, **Prob**[( : ) accepte] $\leq \epsilon$

w

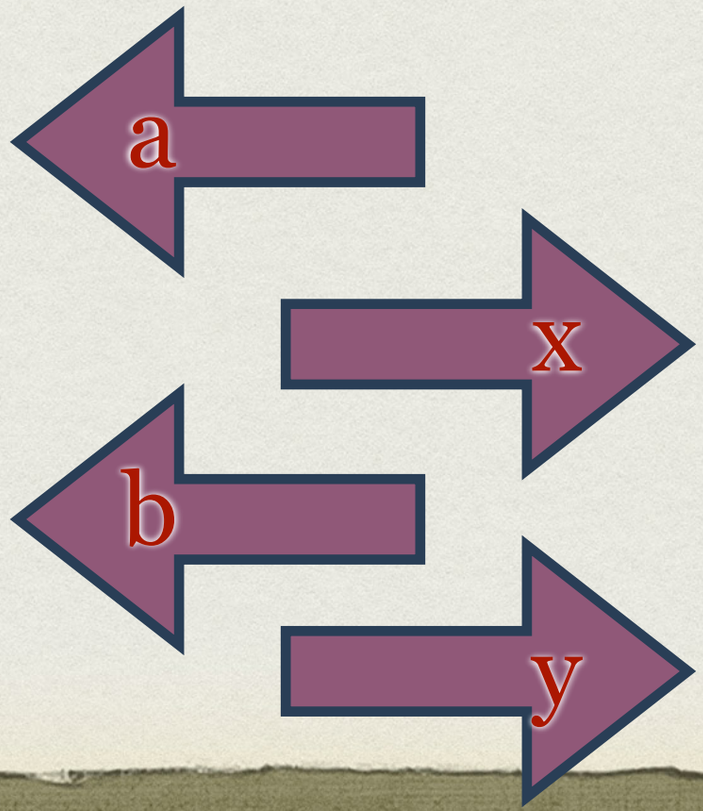


Cohérence

$w \notin L$

$\exists$  , et $\forall$  , $\forall w \notin L$, **Prob**[( : ) accepte] $\leq \epsilon$

w

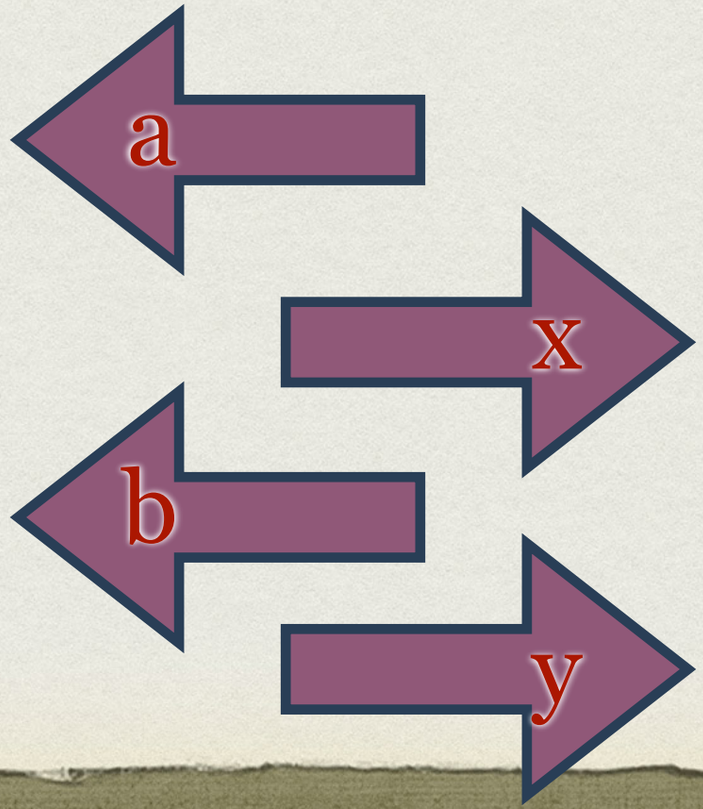


Cohérence

$w \notin L$

$\exists$  , et $\forall$  , $\forall w \notin L$, **Prob**[( : ) accepte] $\leq \epsilon$

w



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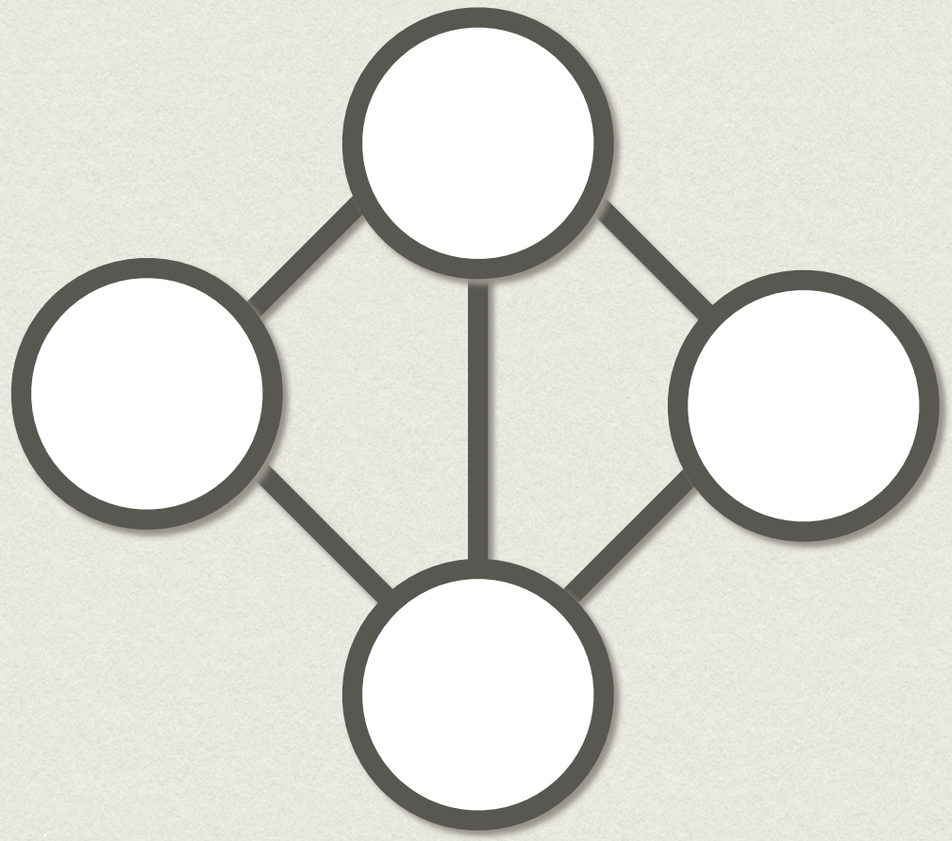

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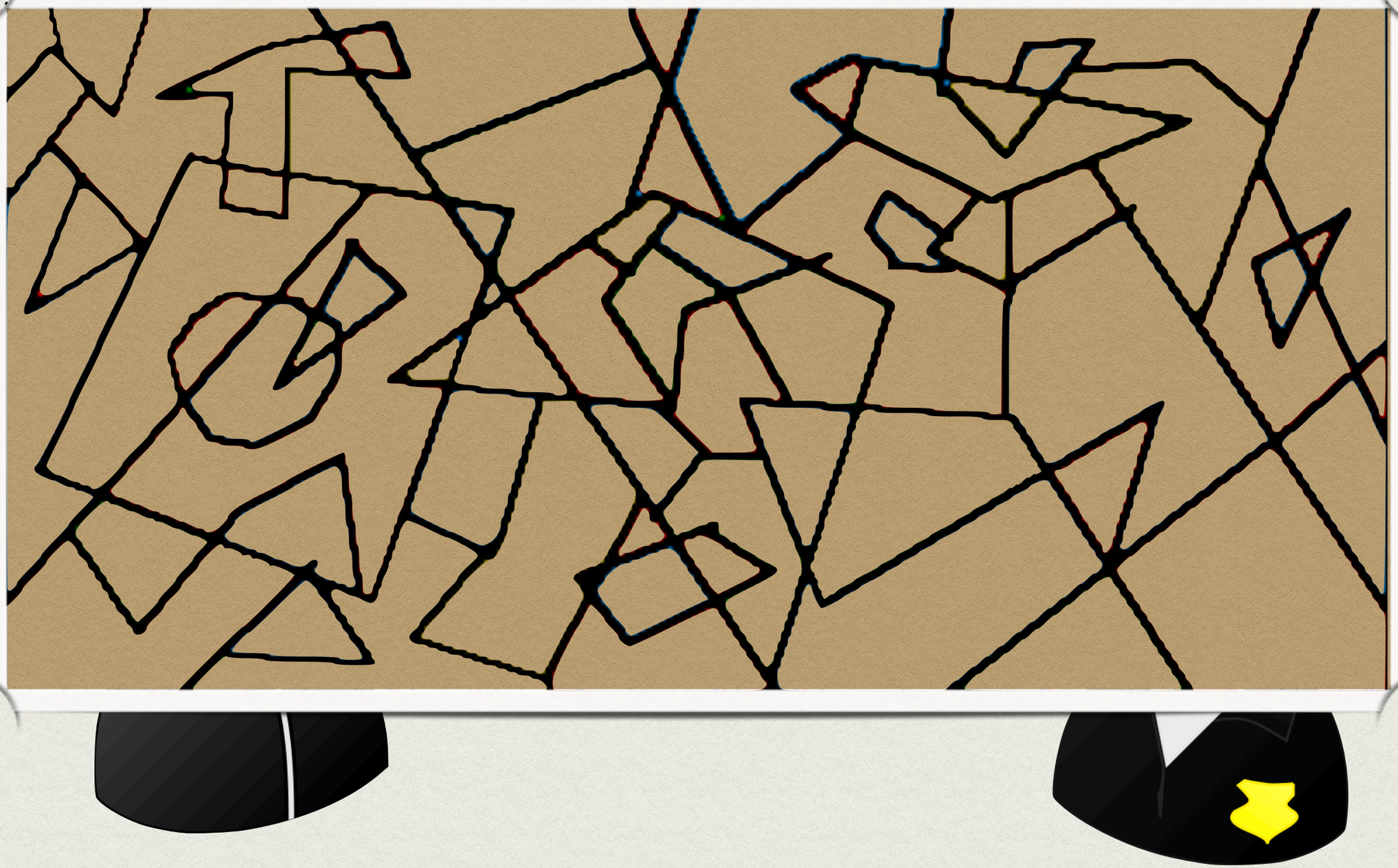

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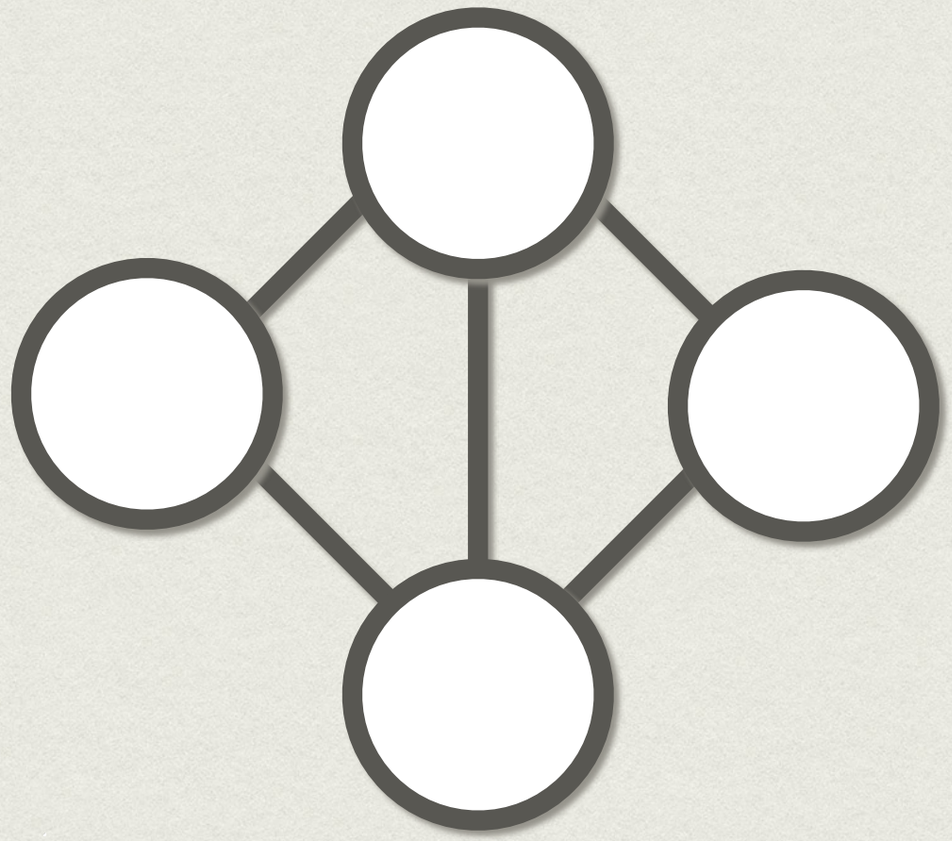

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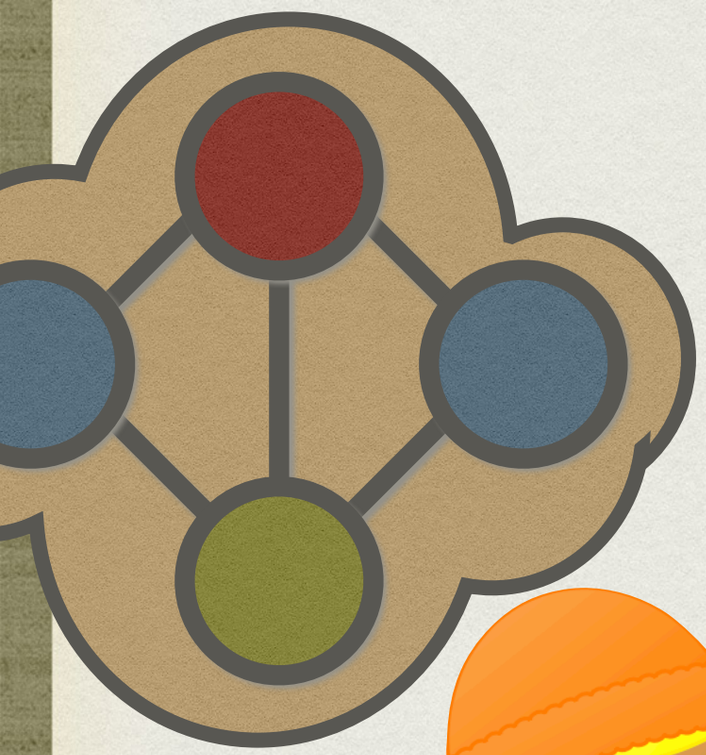
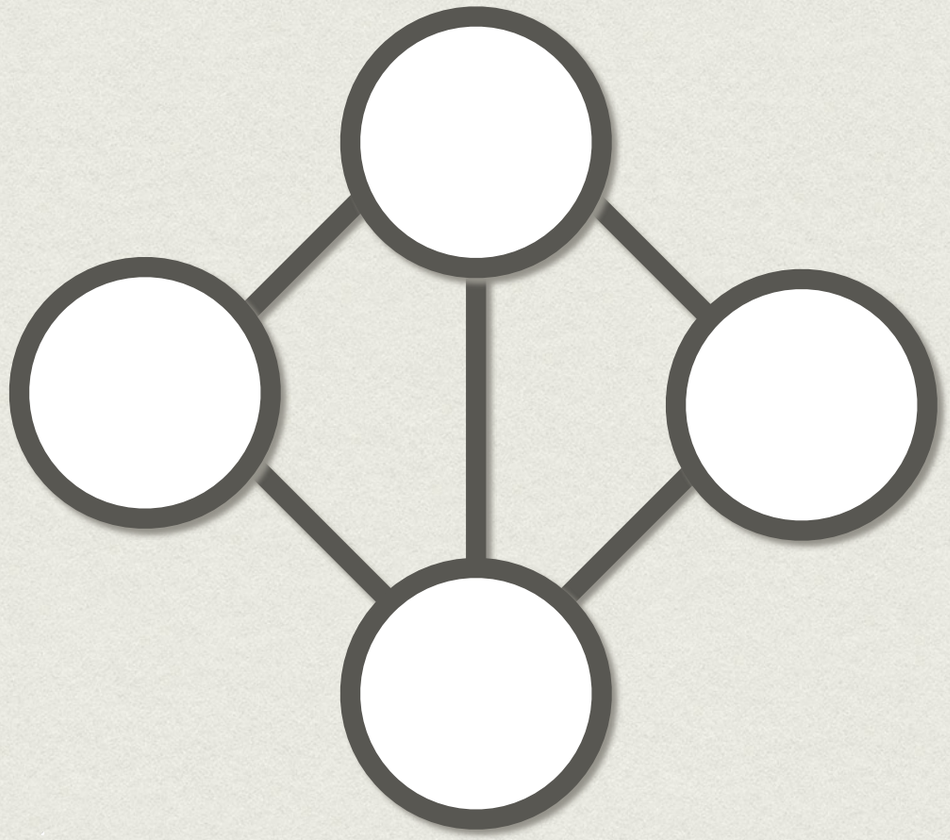
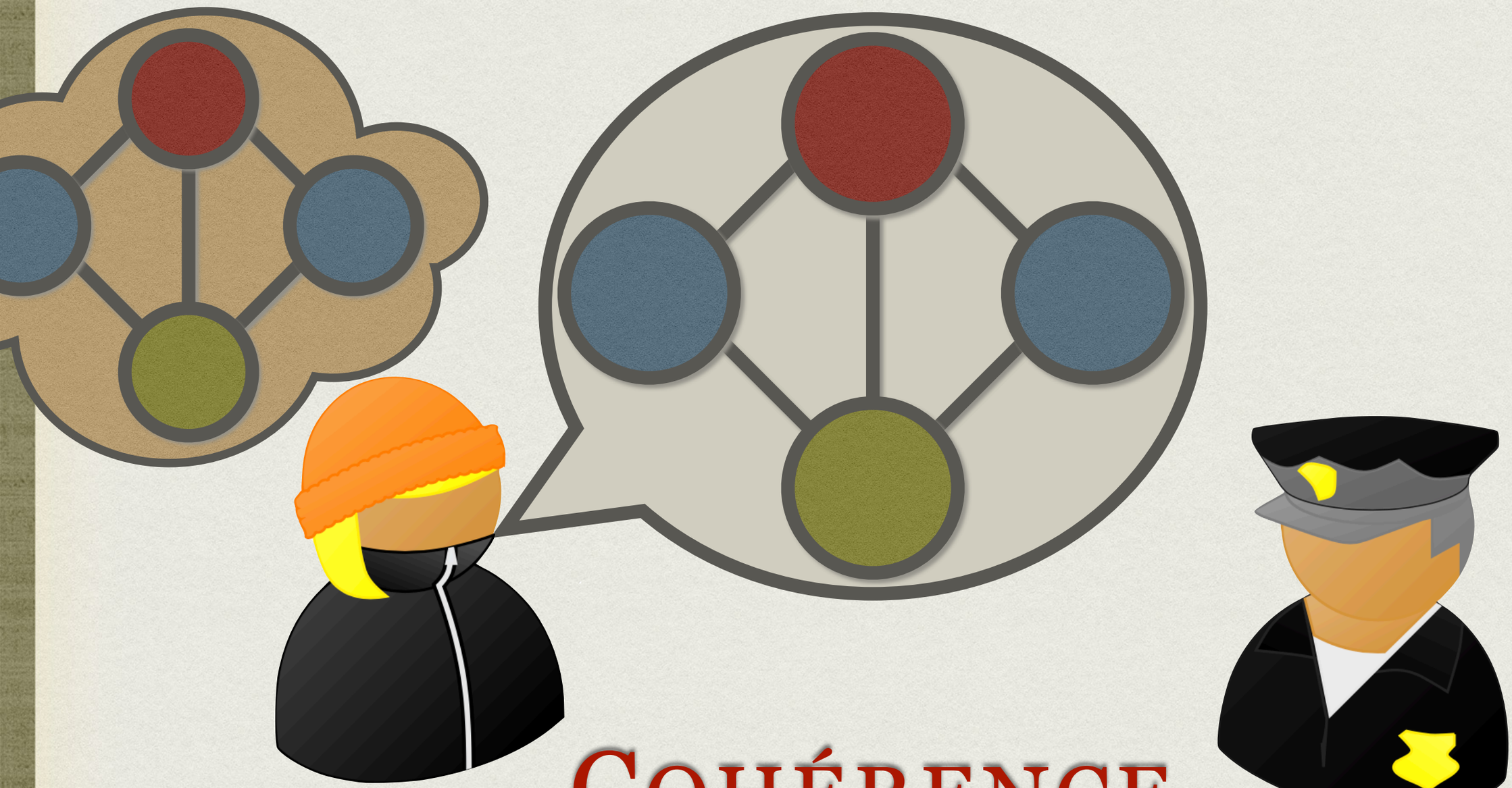




3-COL

COMPLÉTUDE



COHÉRENCE

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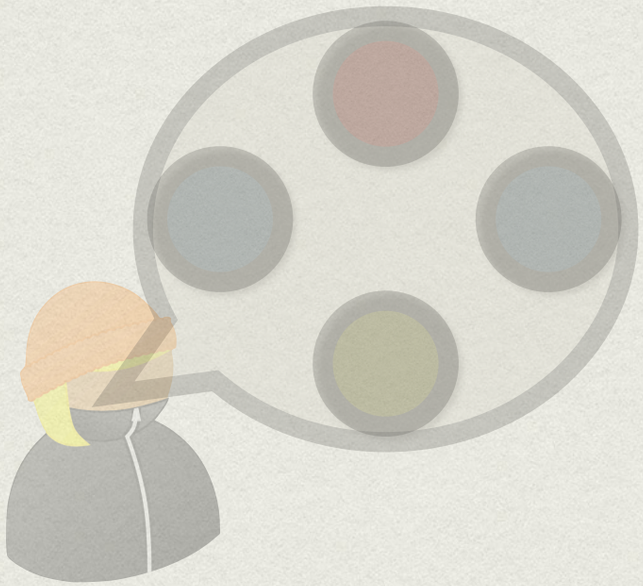
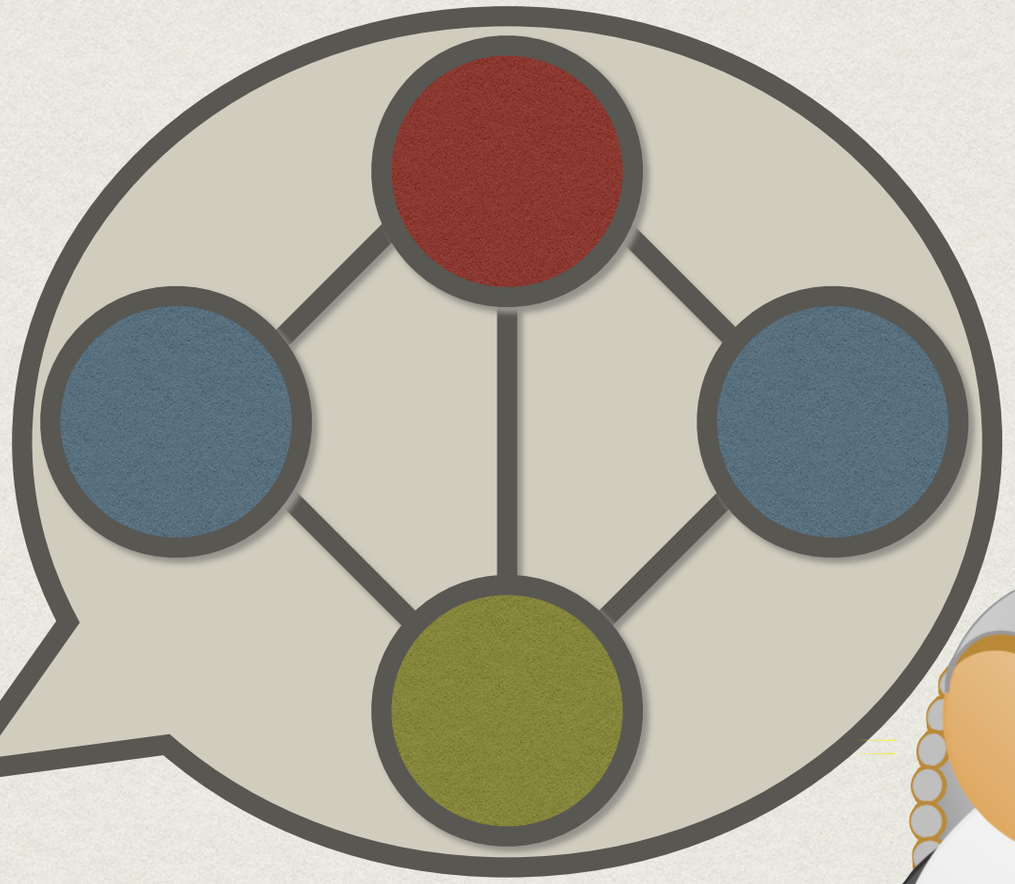




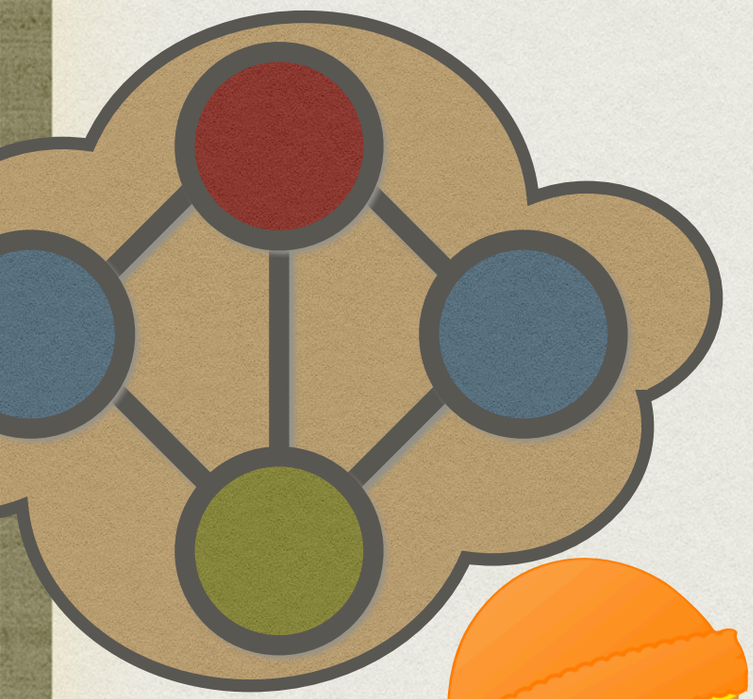
TRANSFÉRABLE

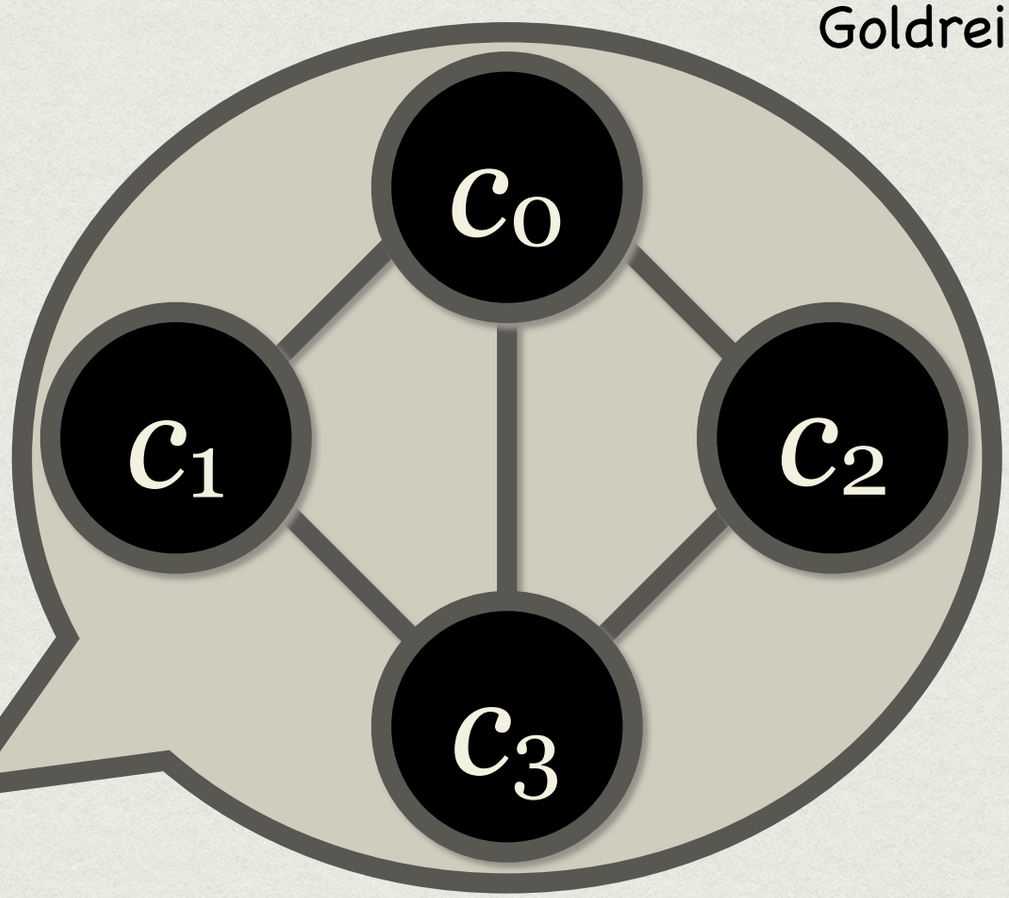
3-COL (86)

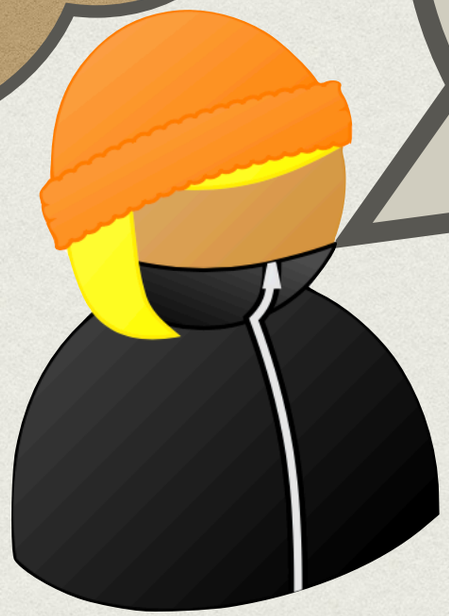

Goldreich


Micali


Wigderson







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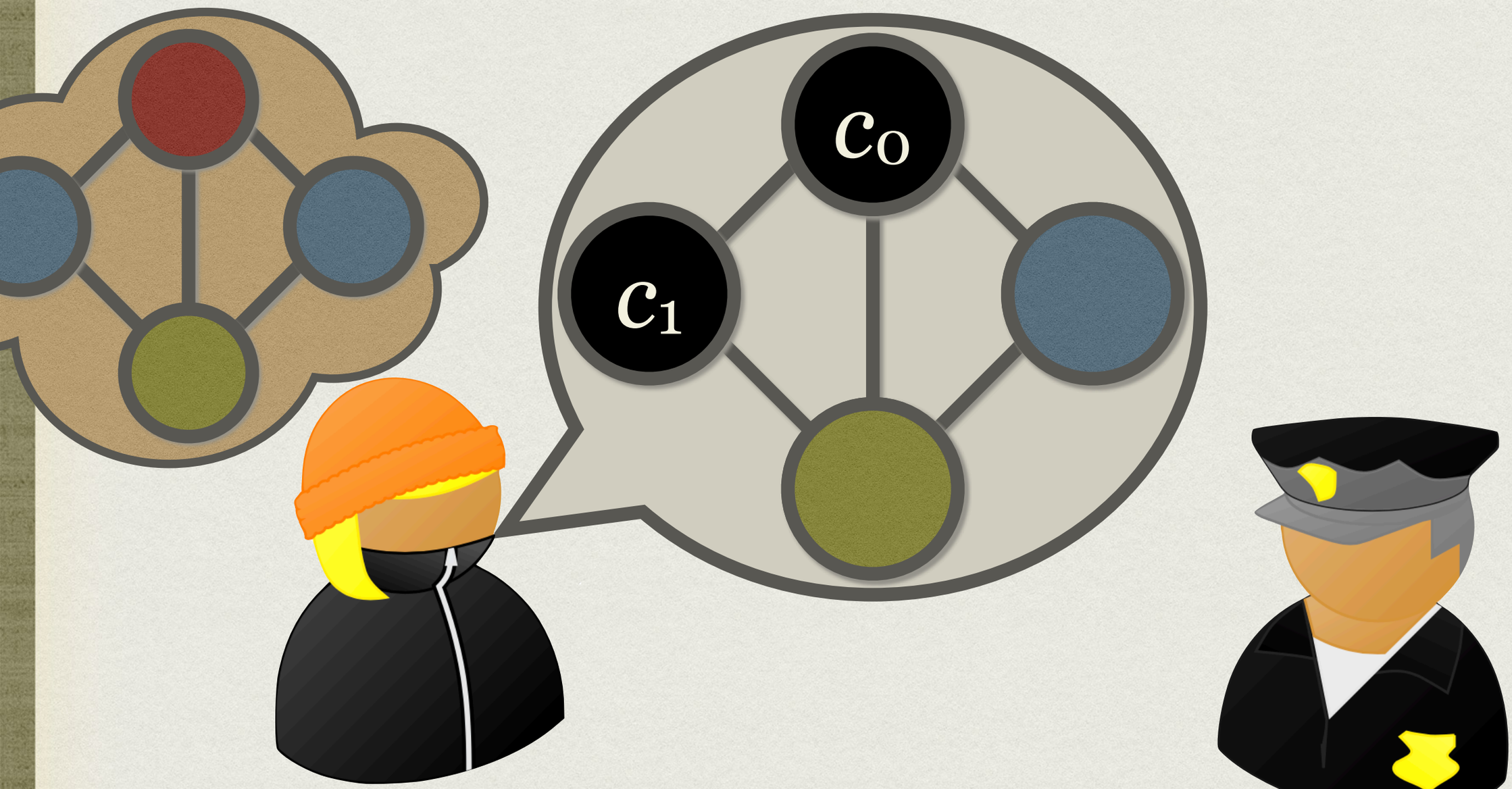

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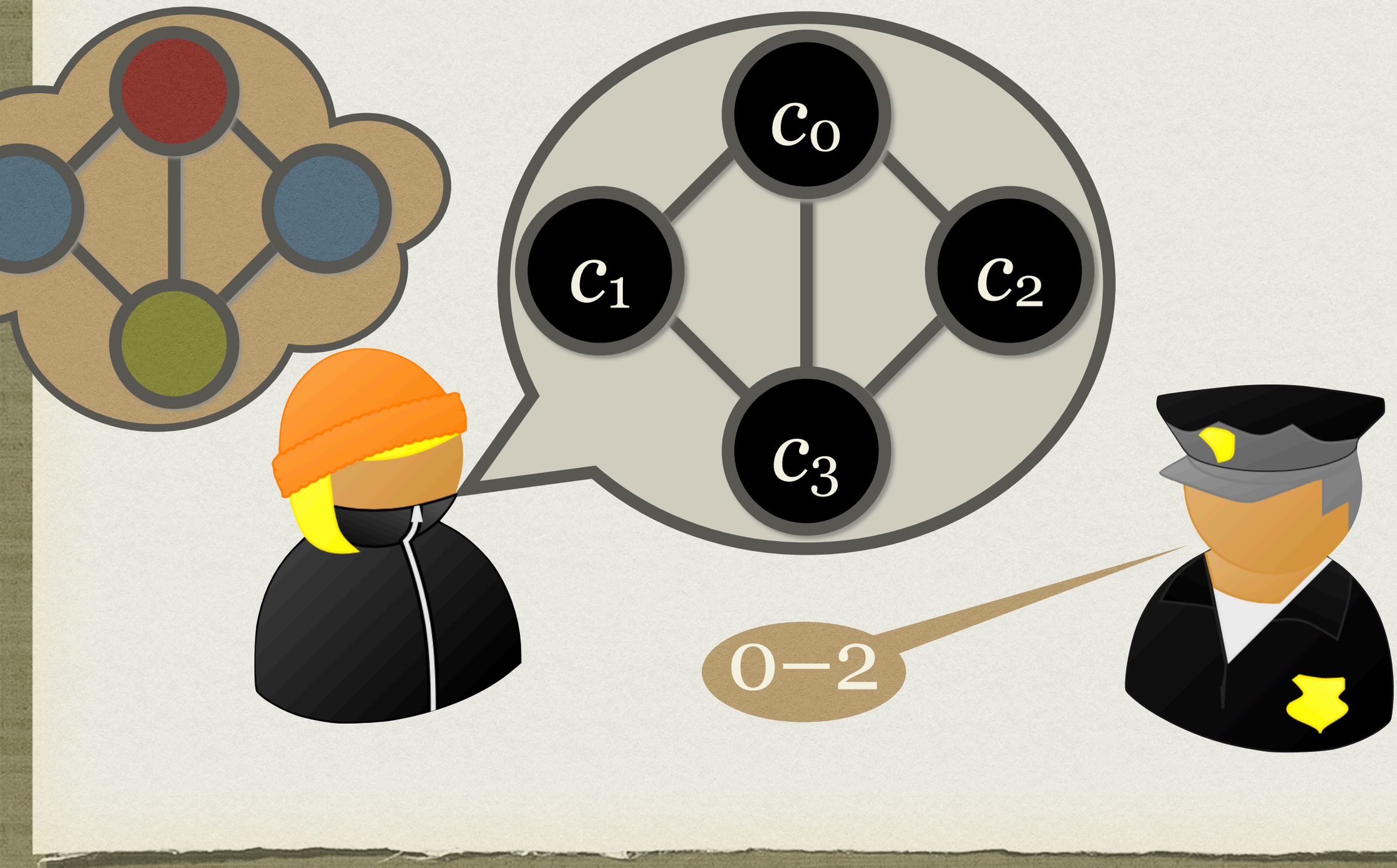

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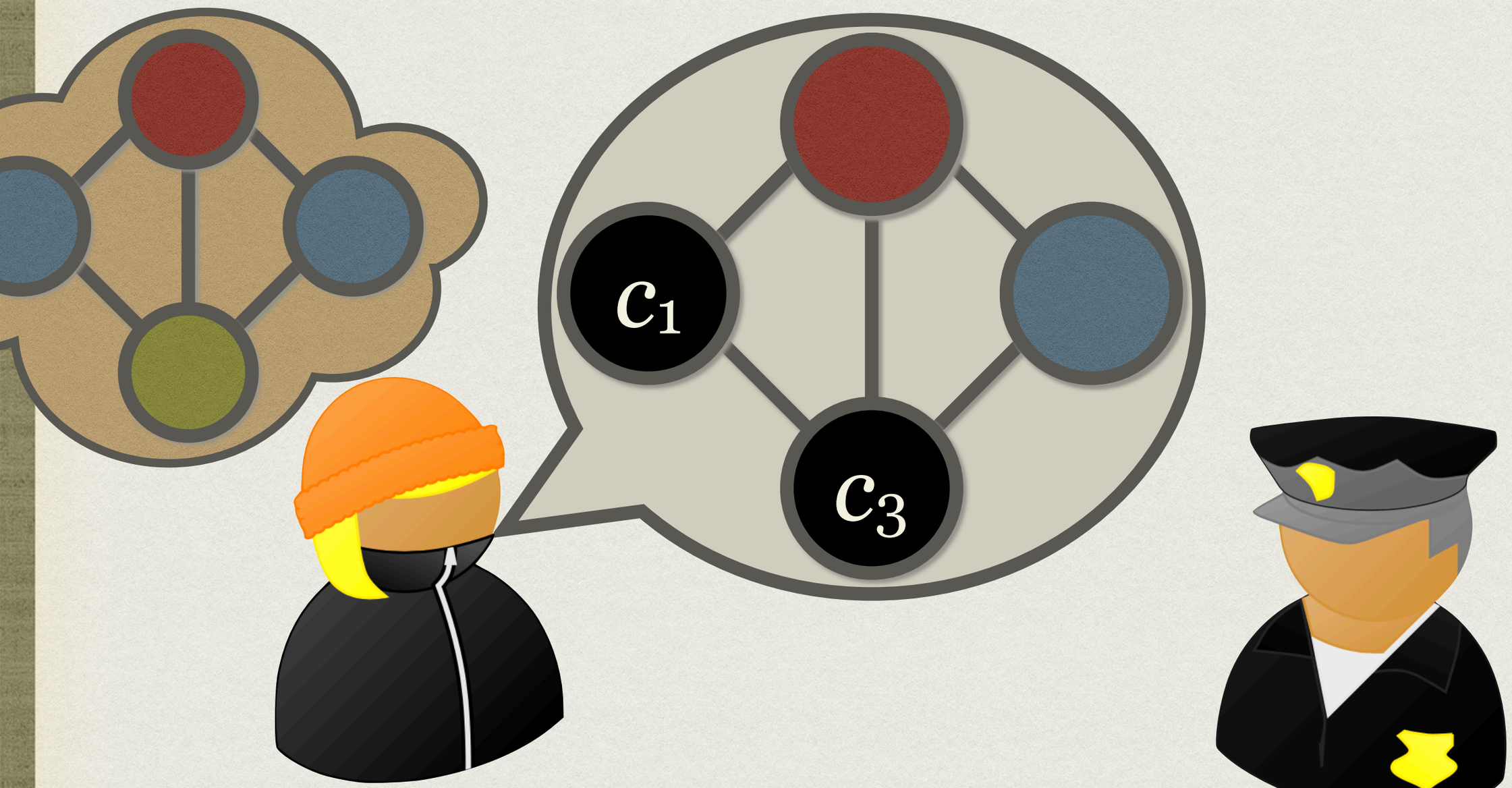

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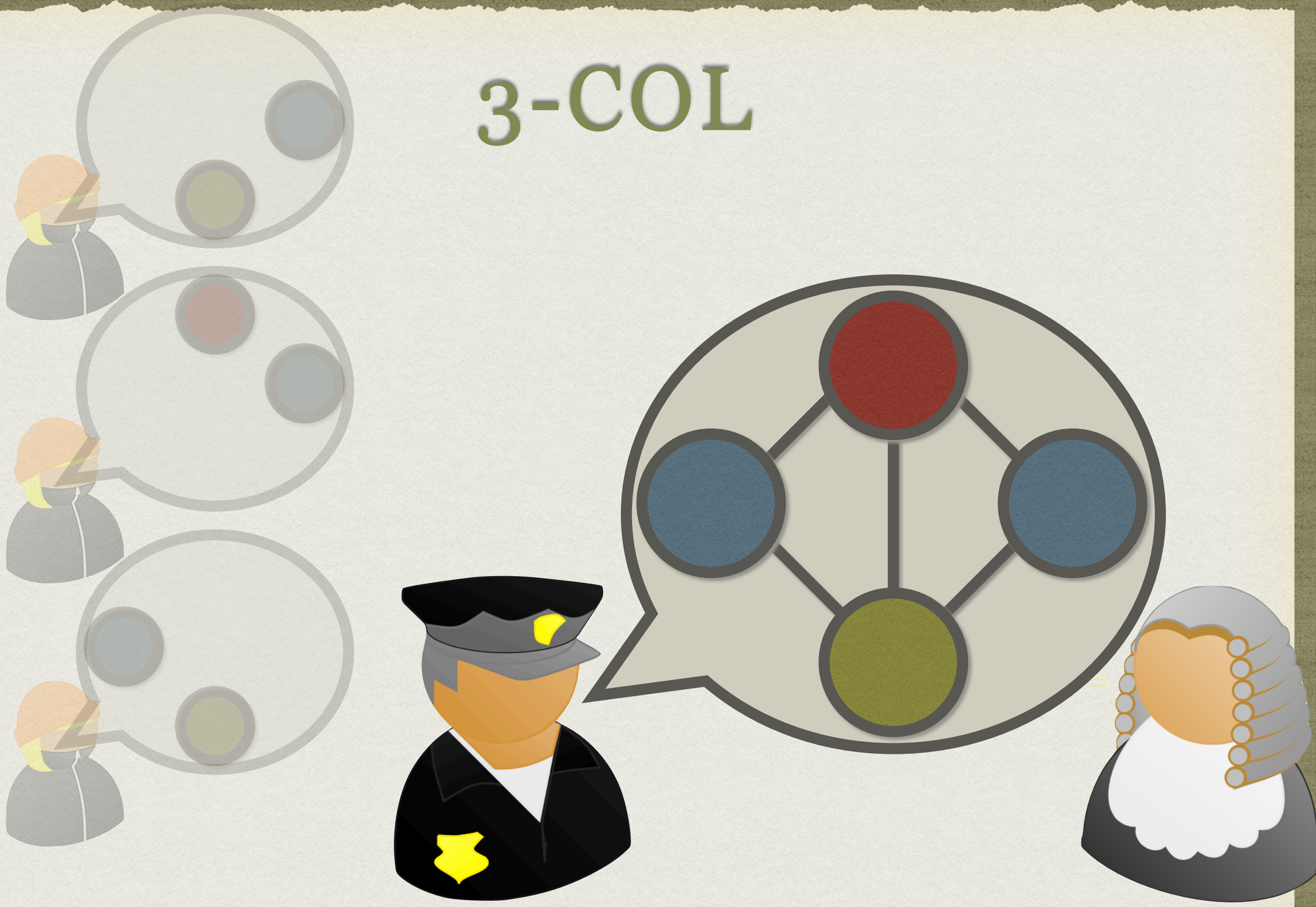

TRANSFÉRABLE

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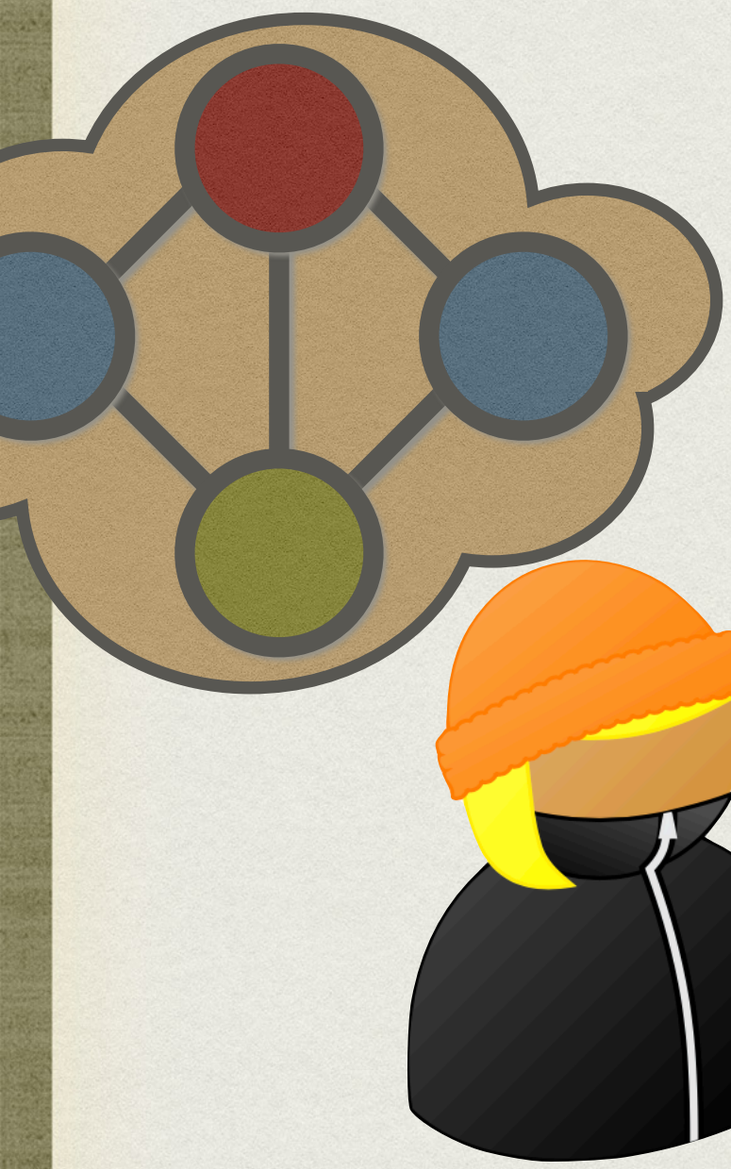

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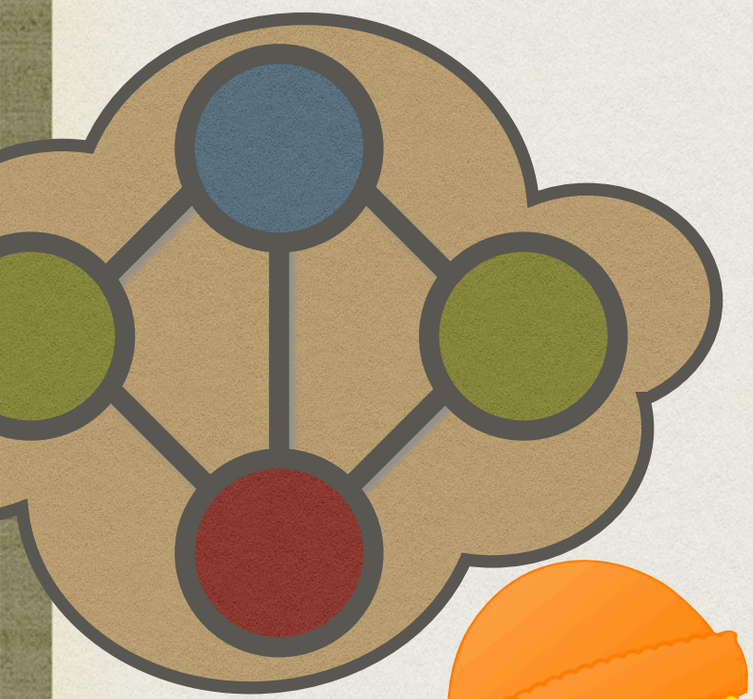

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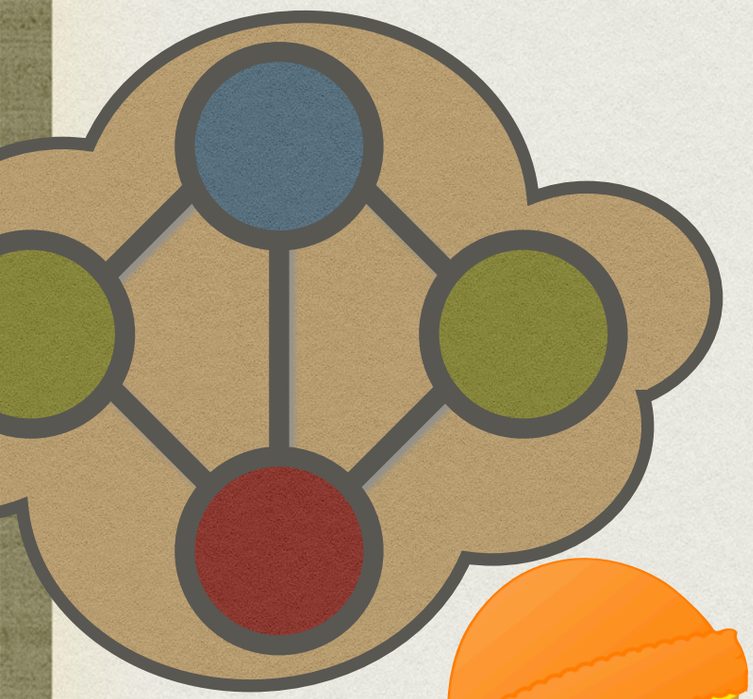

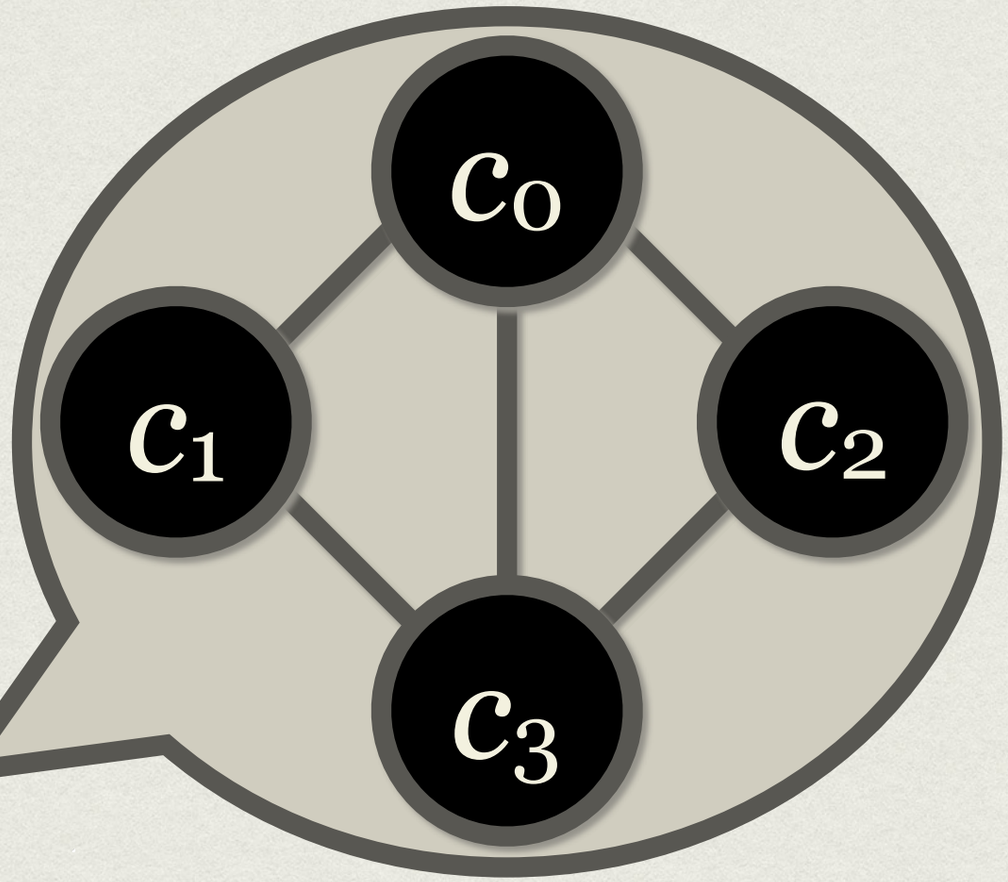

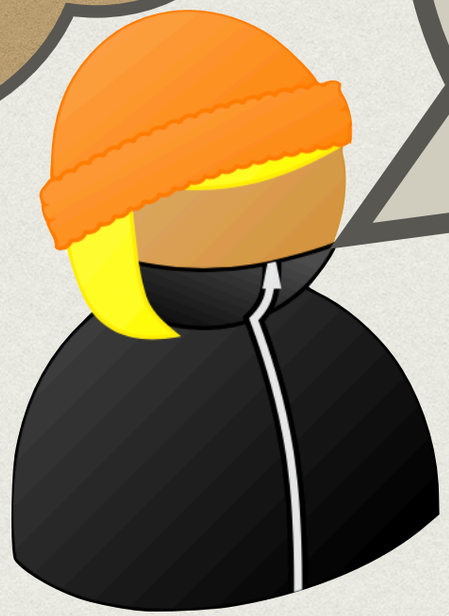

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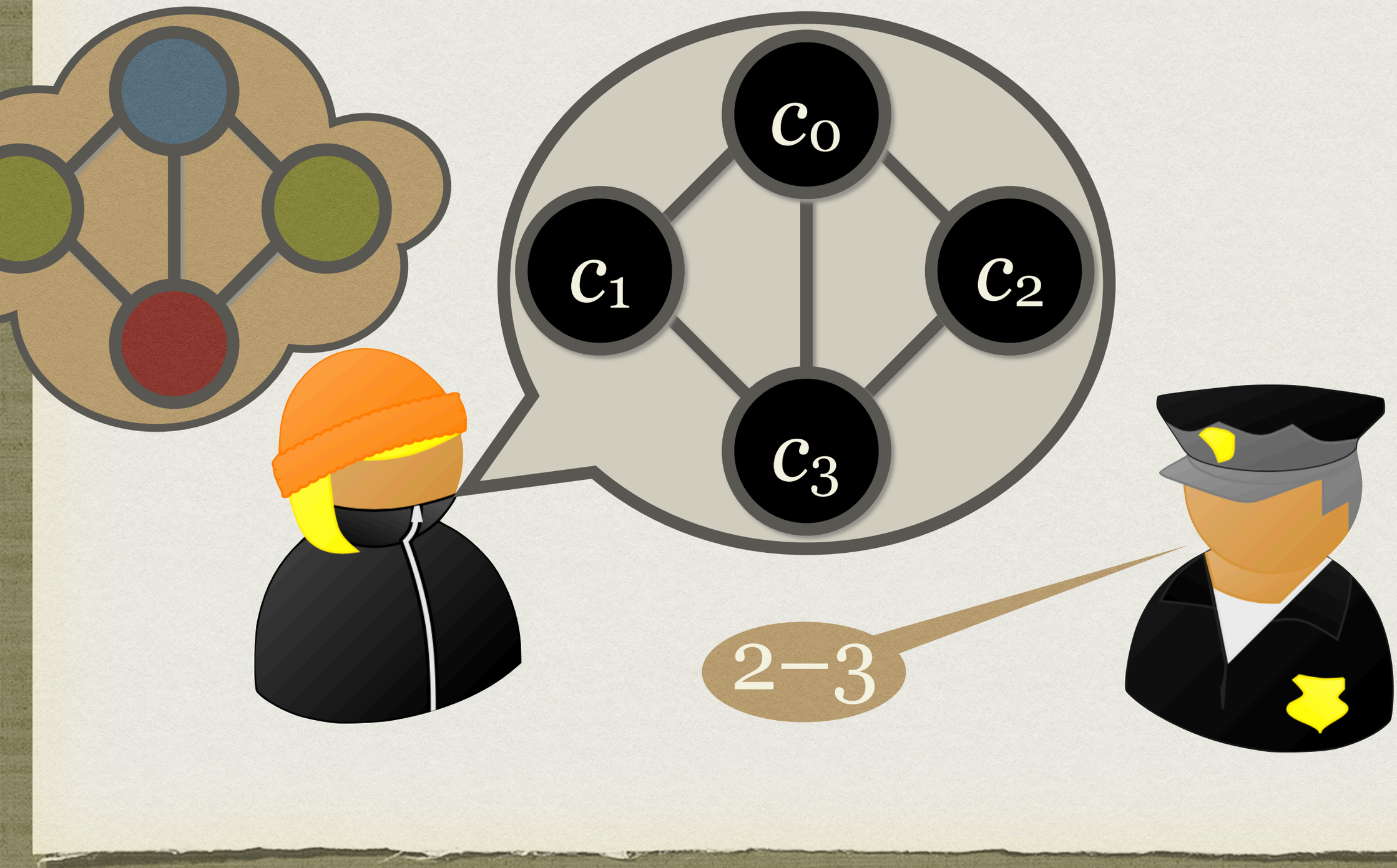

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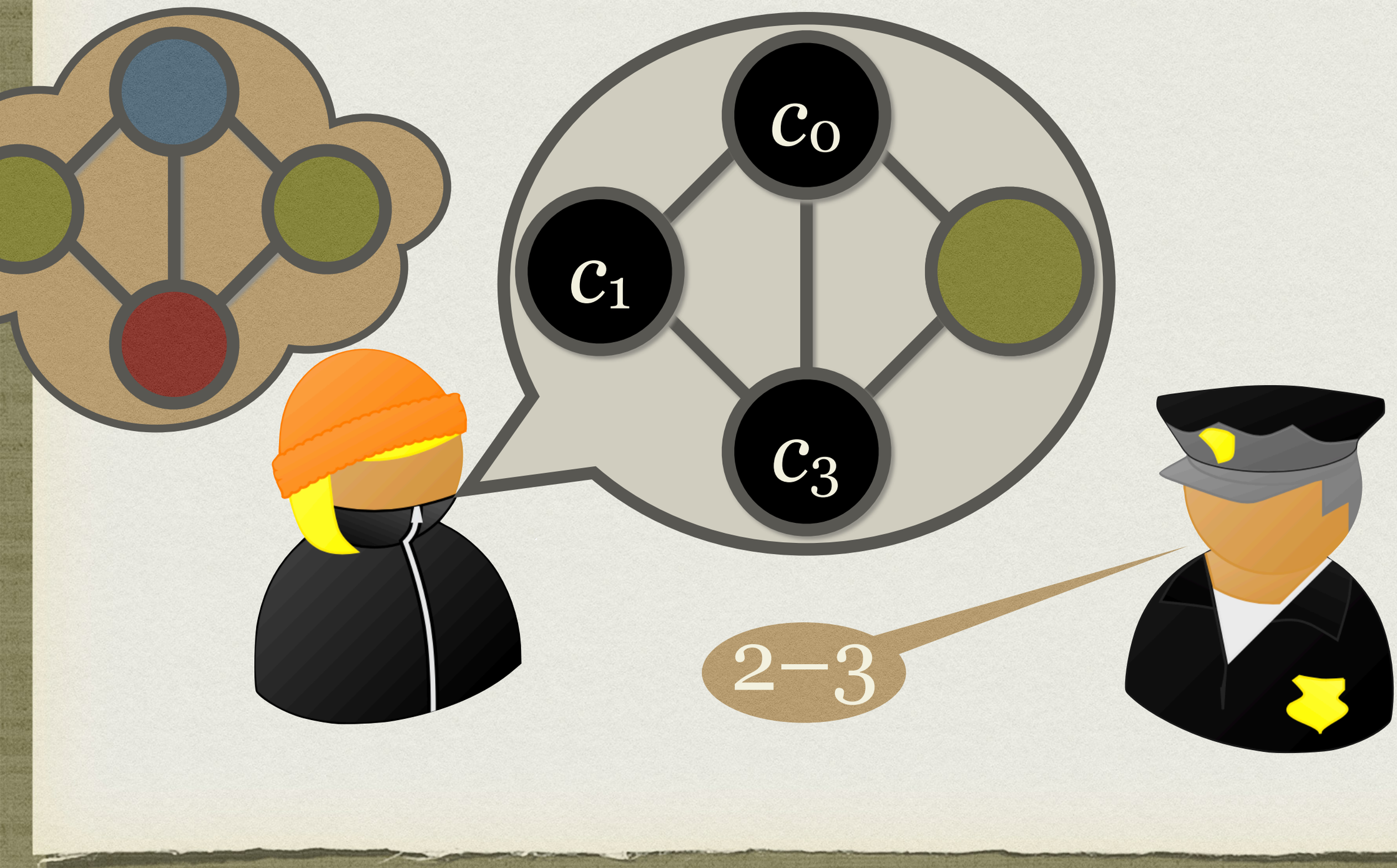

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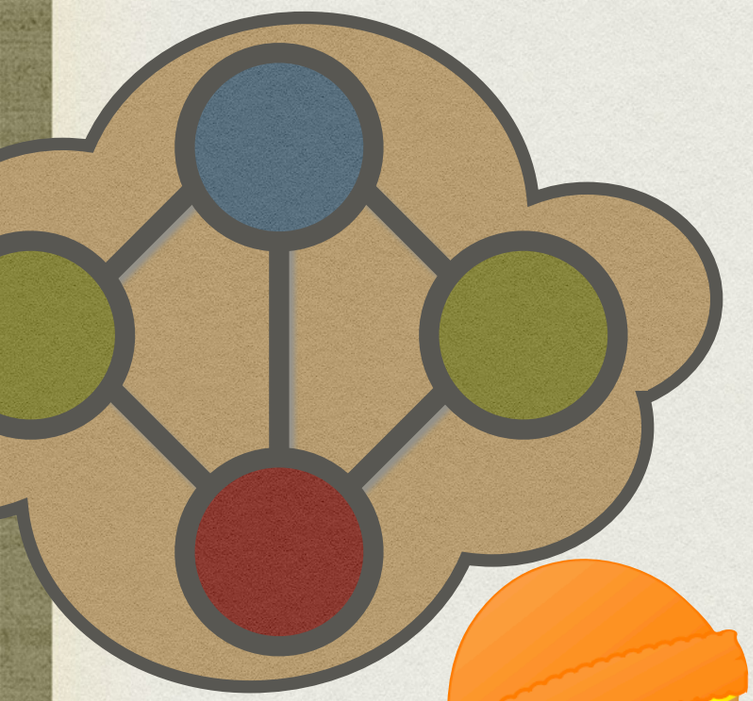

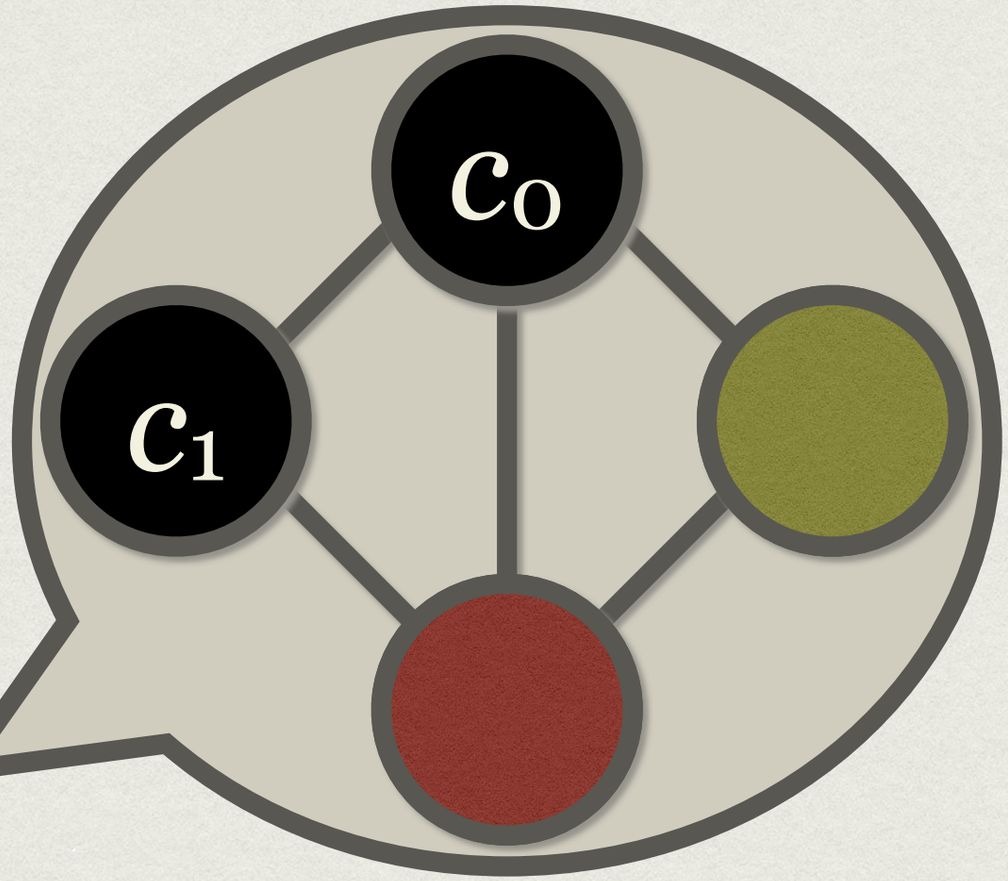

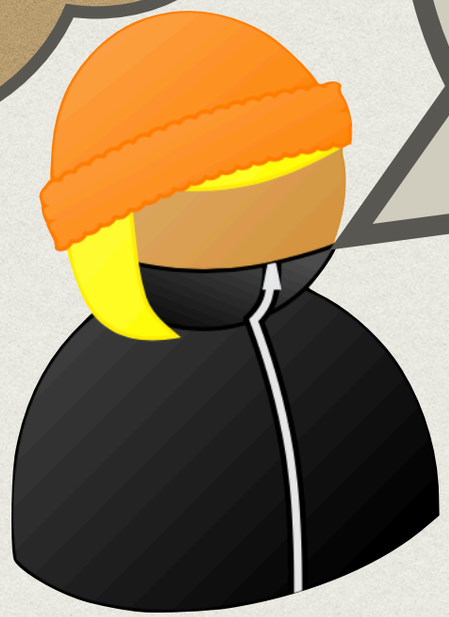

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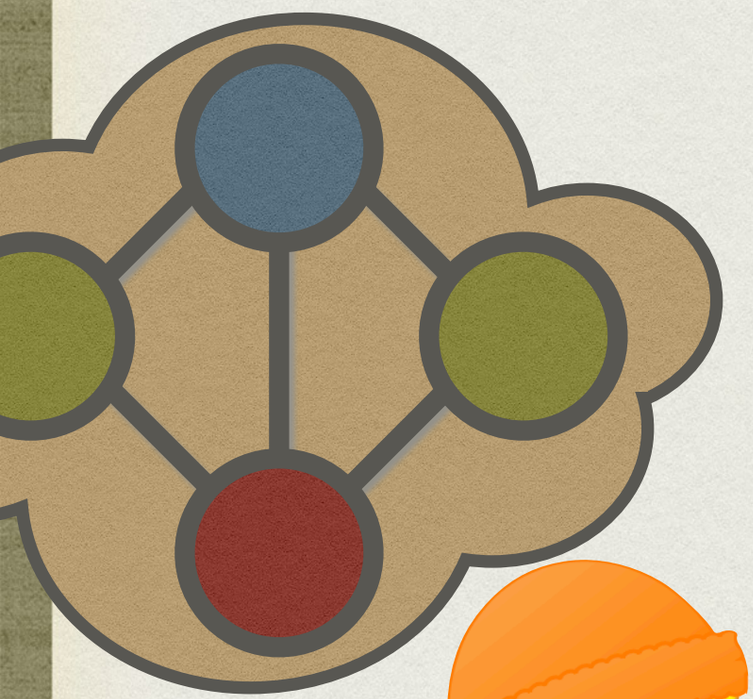

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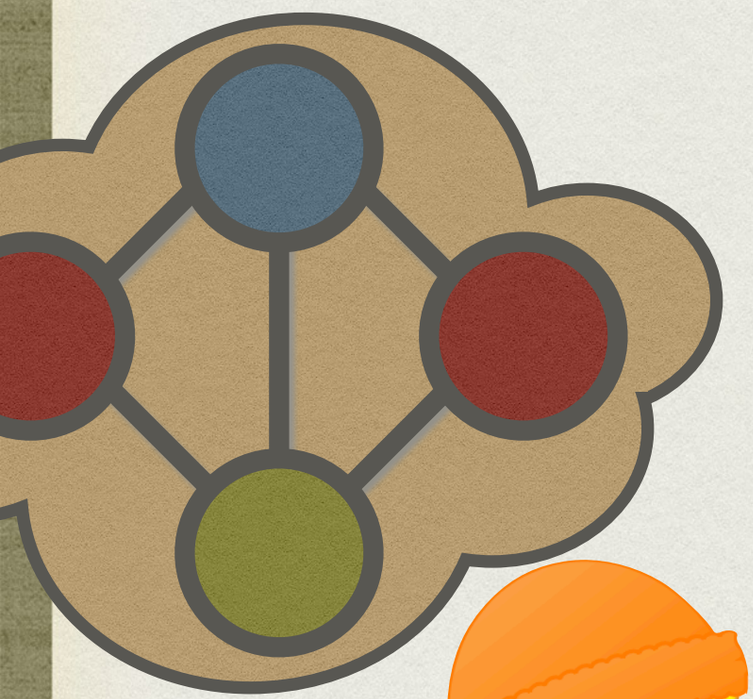

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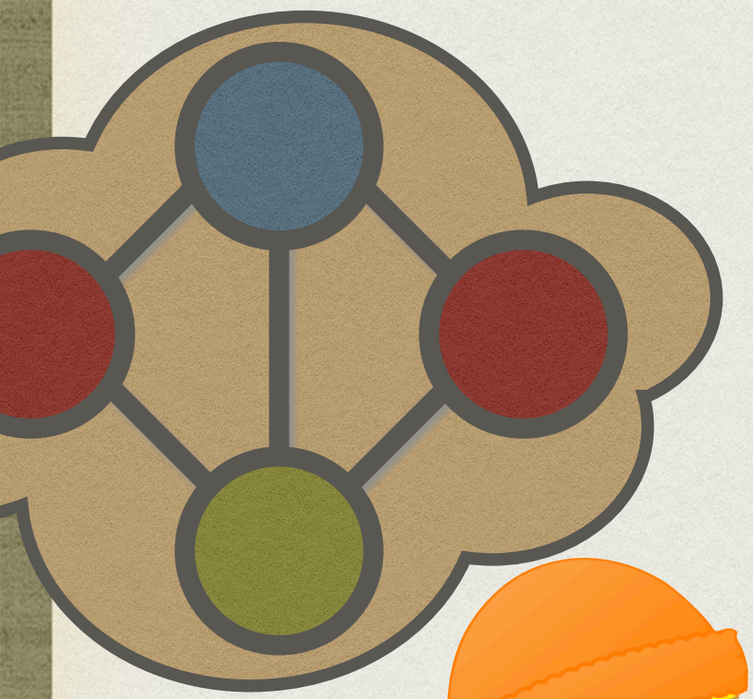

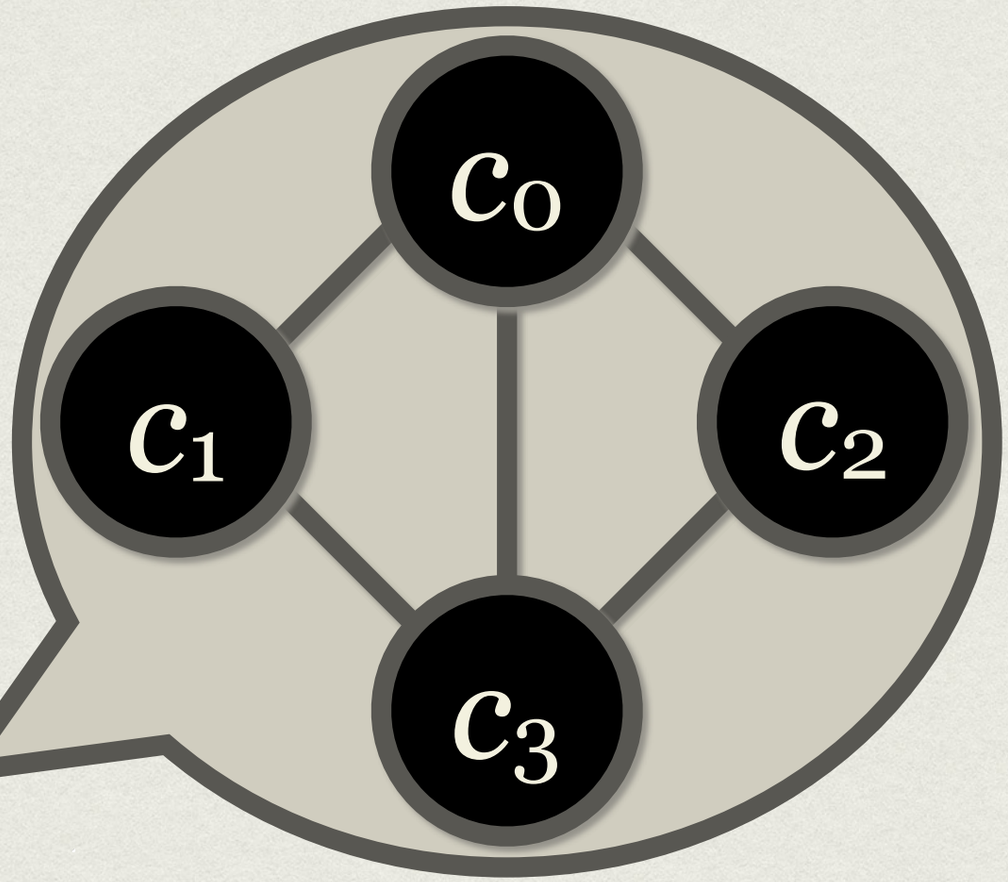

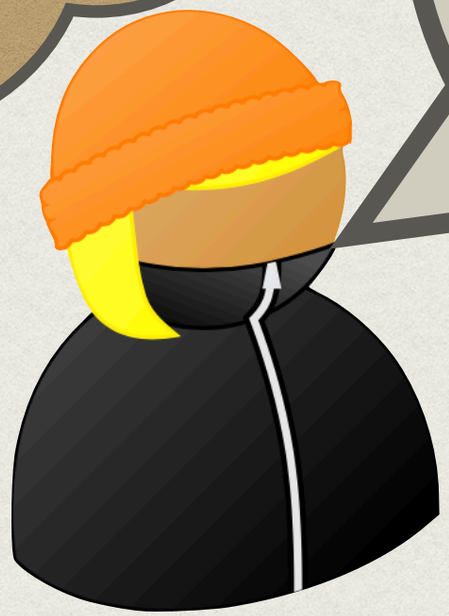

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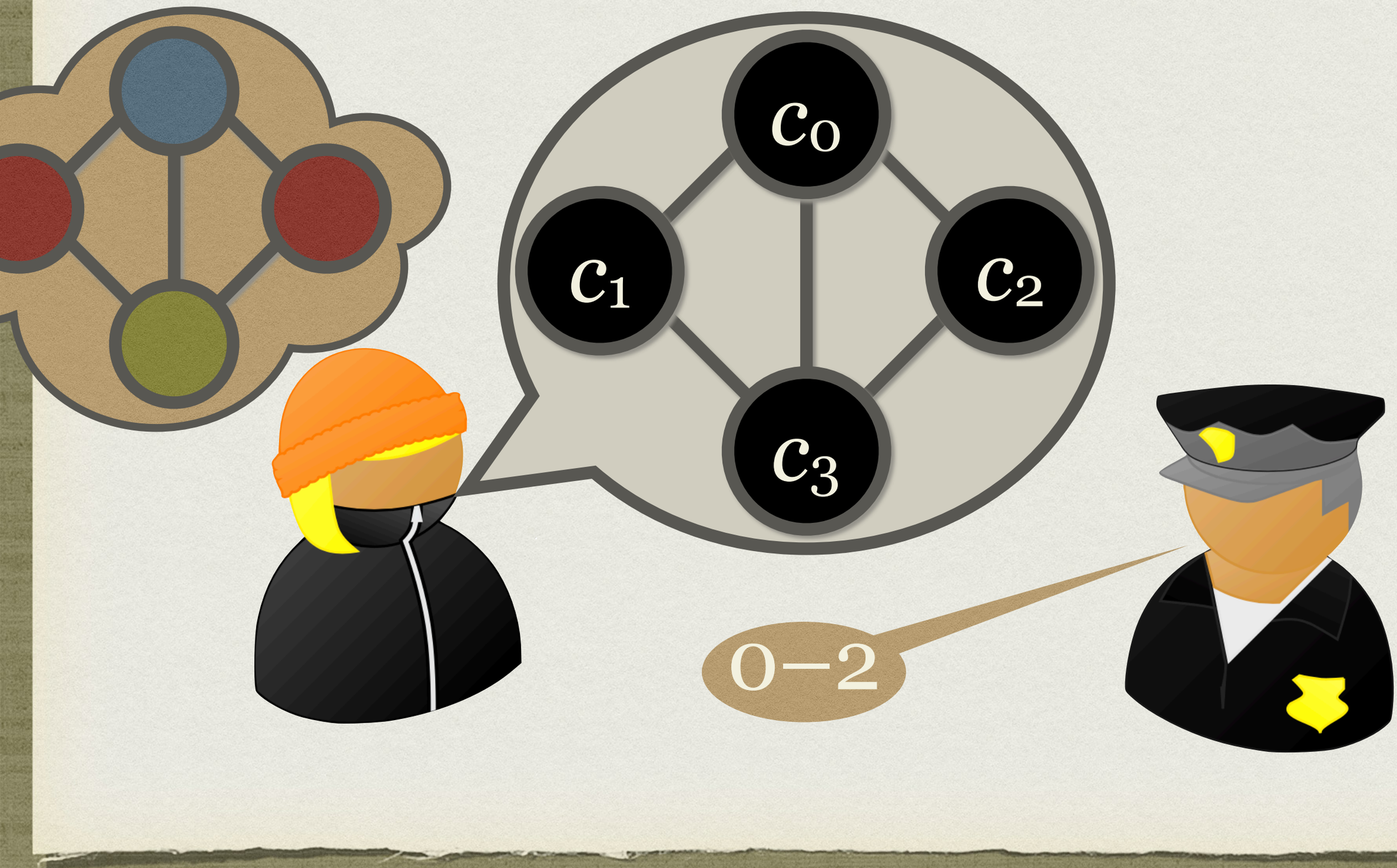

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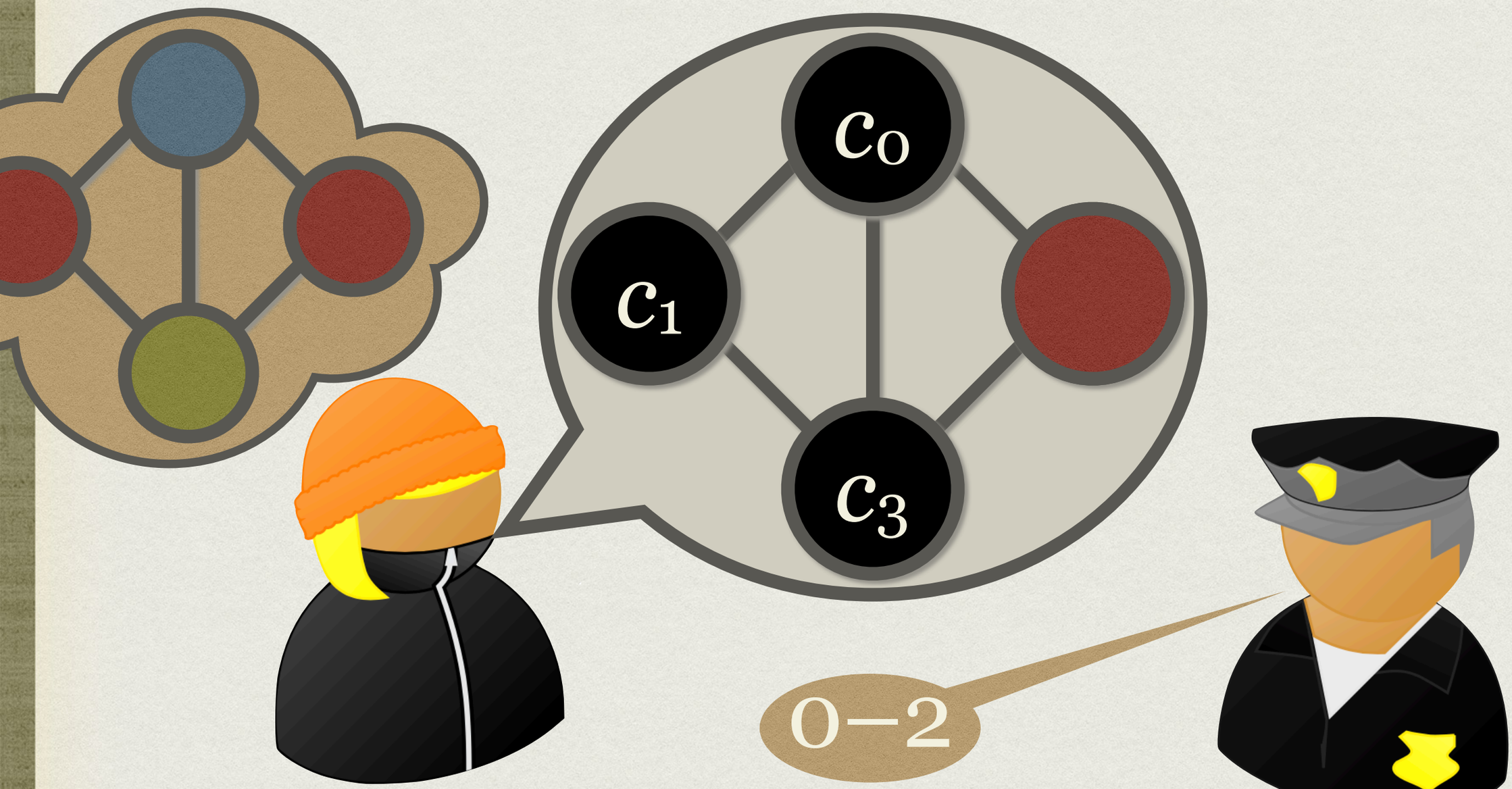

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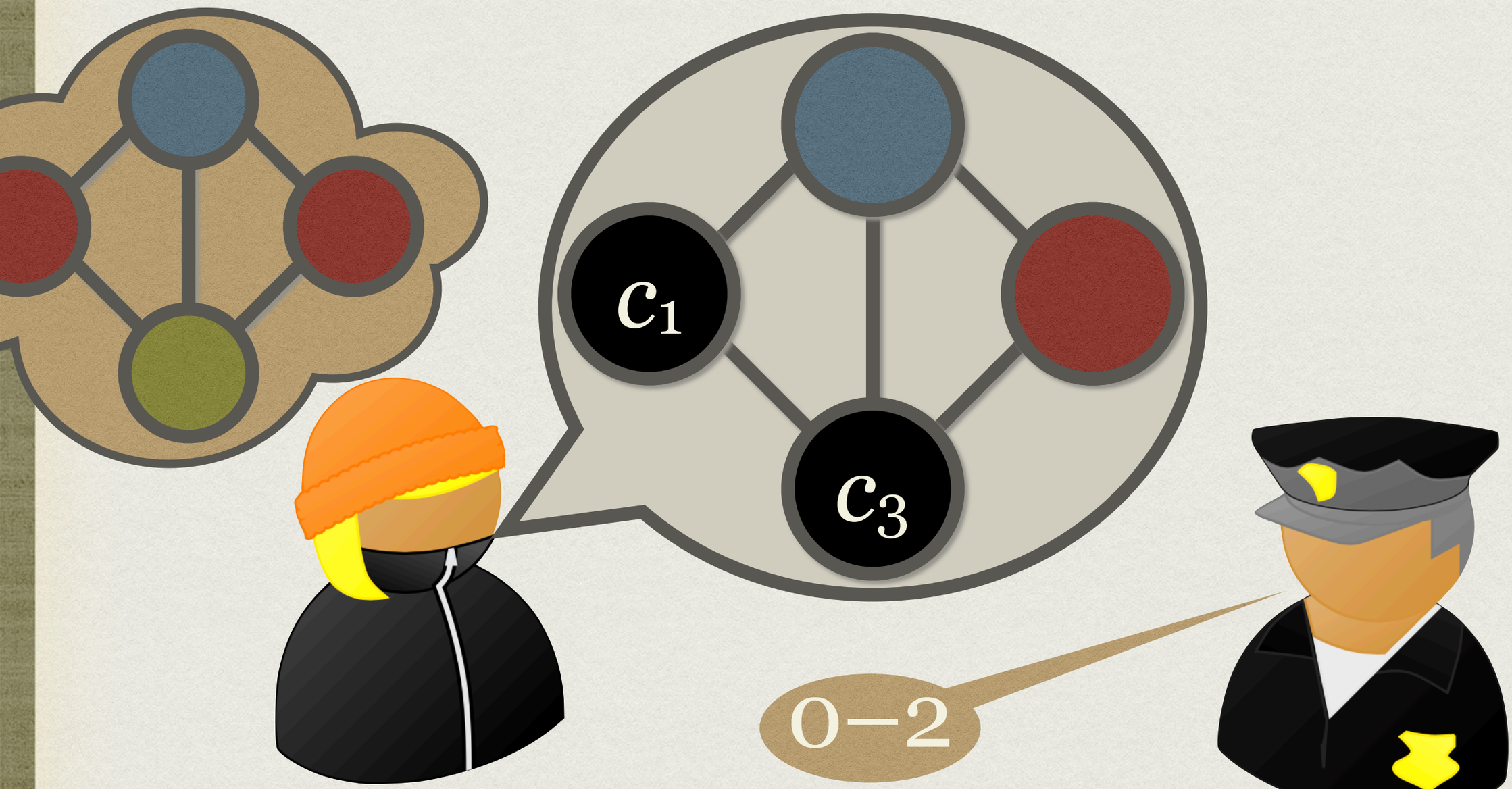

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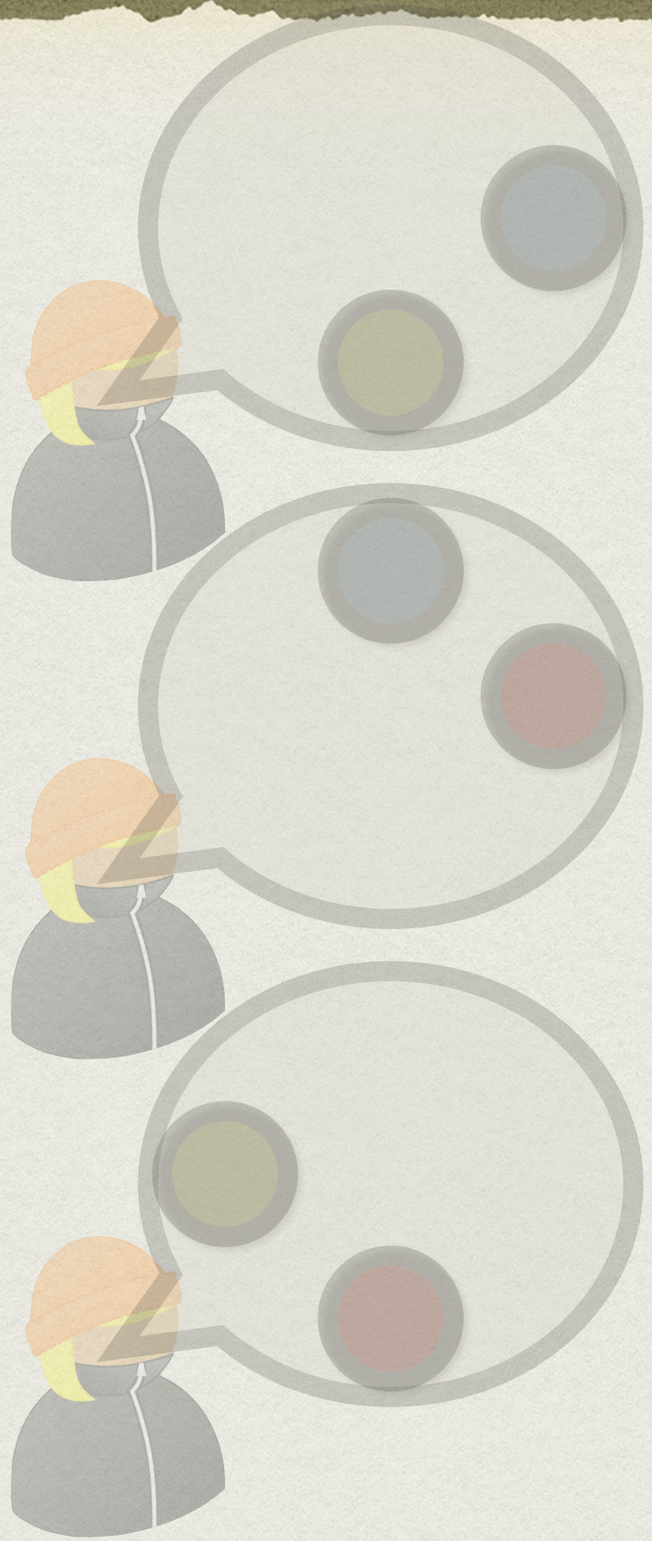
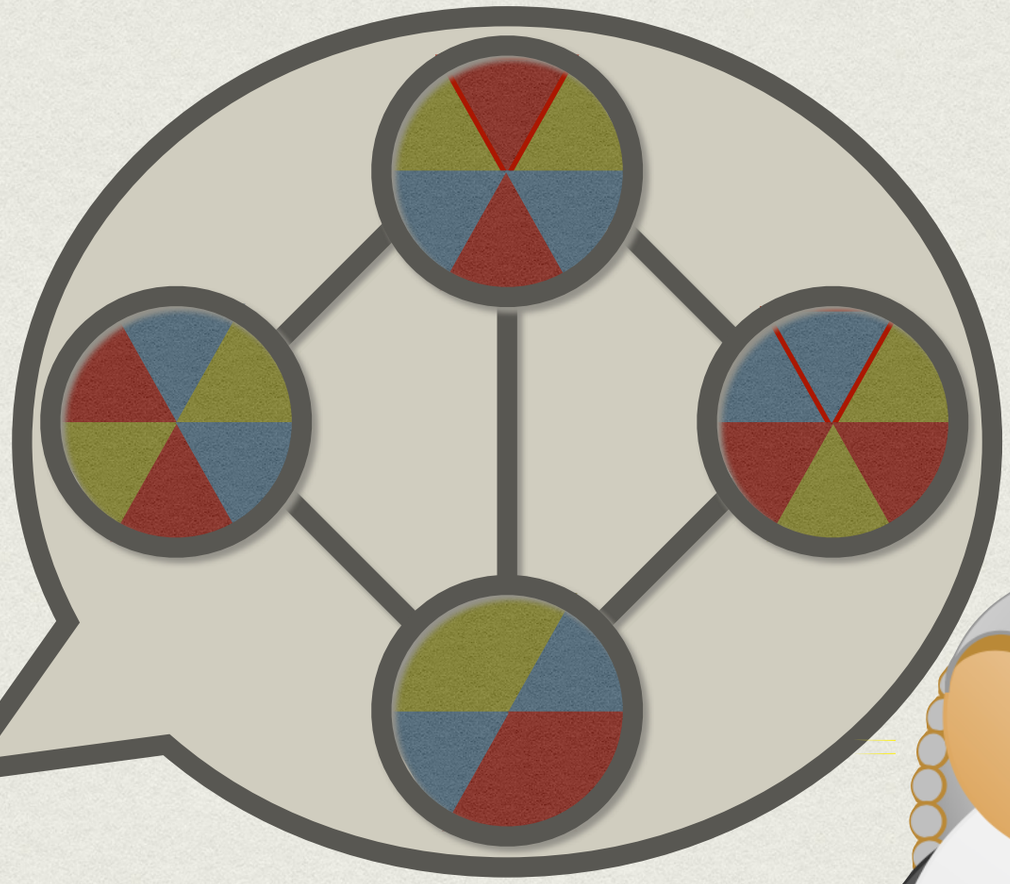
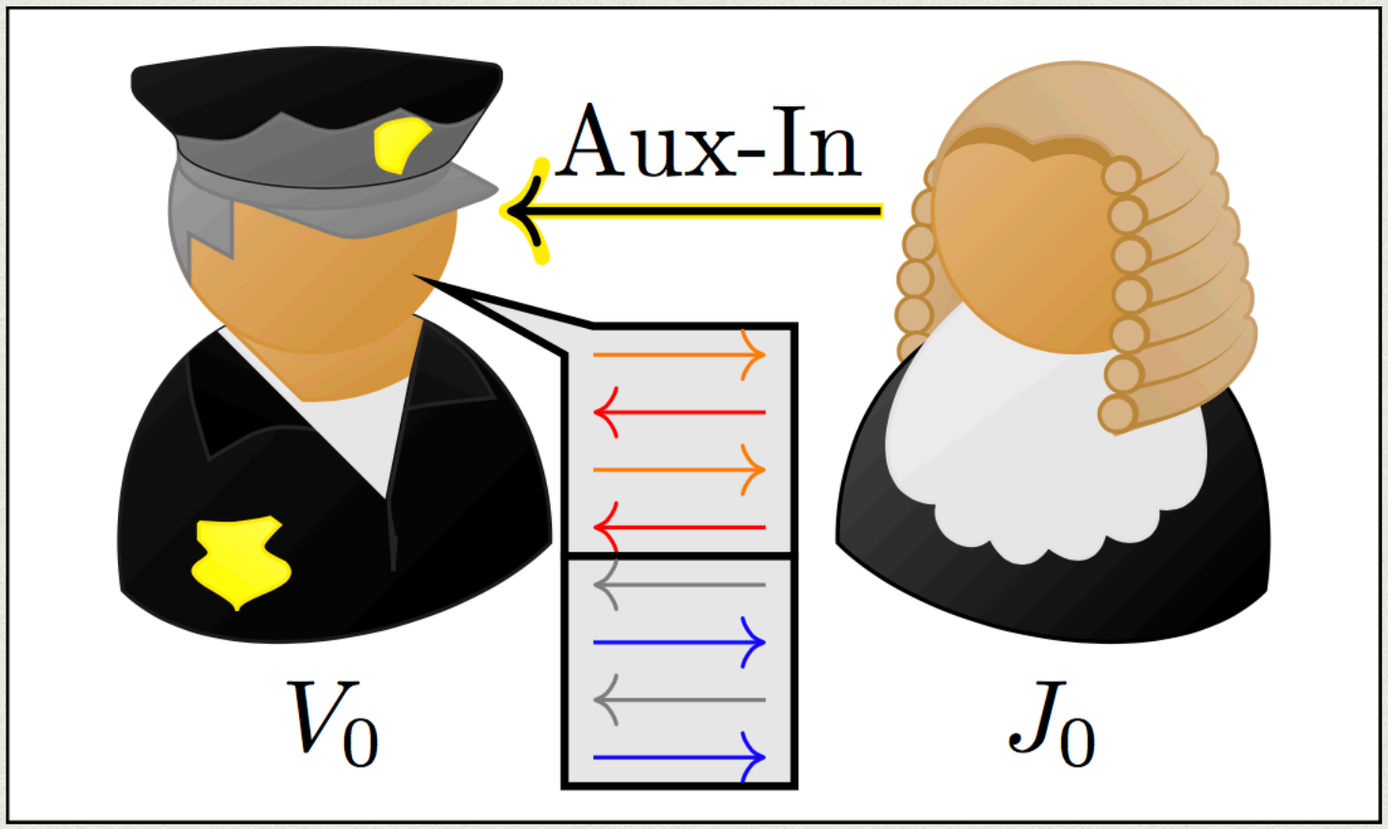




NON TRANSFÉRABLE !

ZERO-KNOWLEDGE

∋ NON TRANSFÉRABLE



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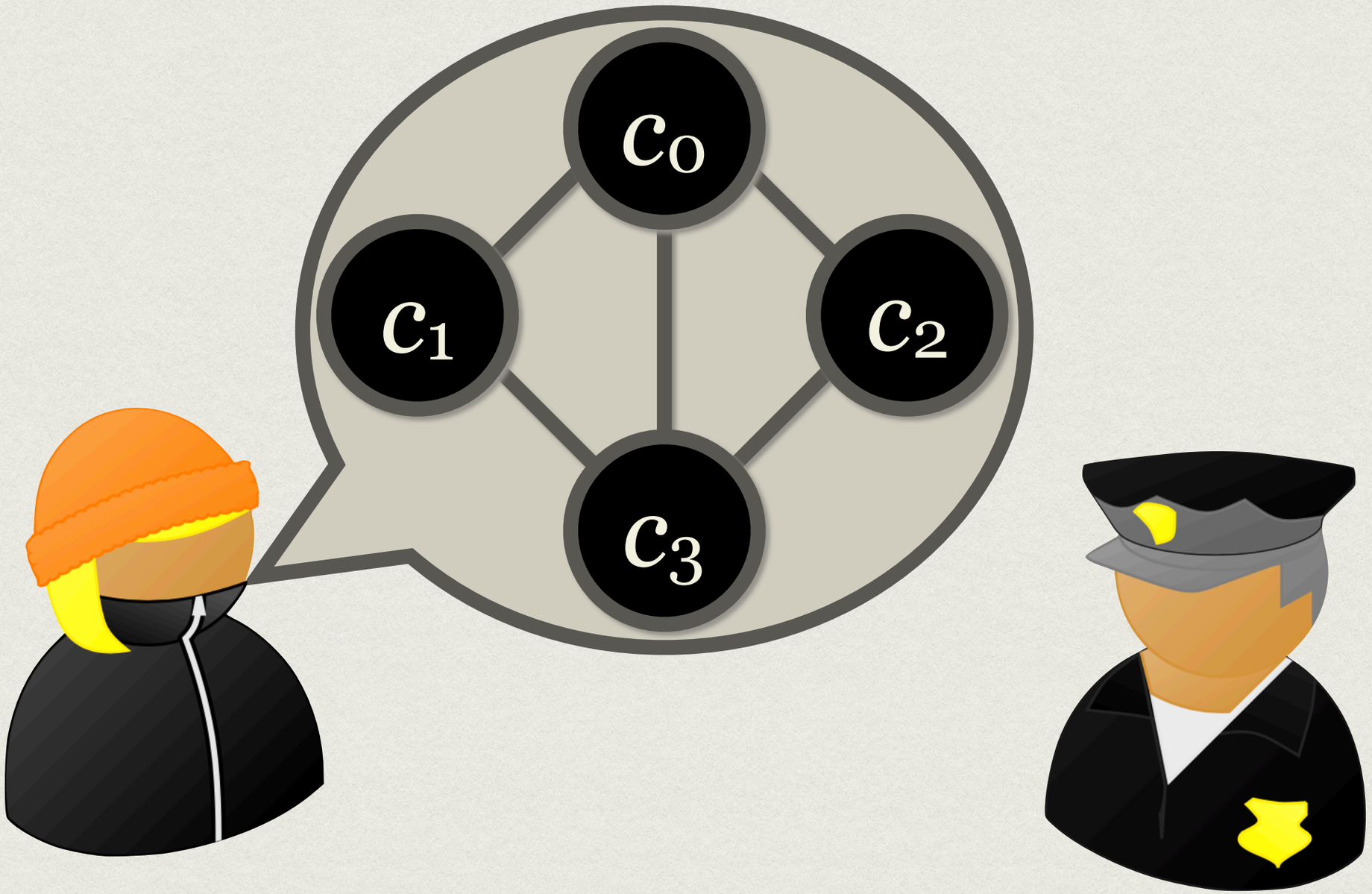
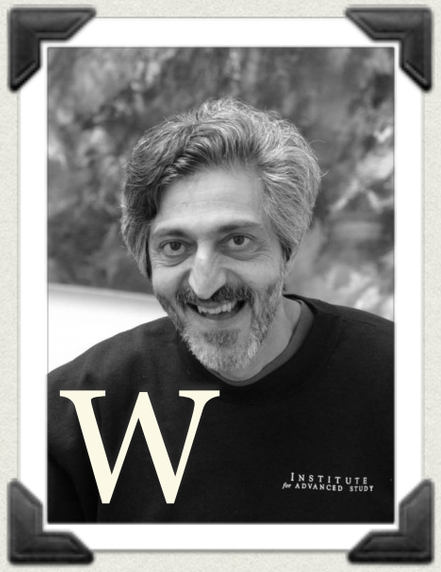
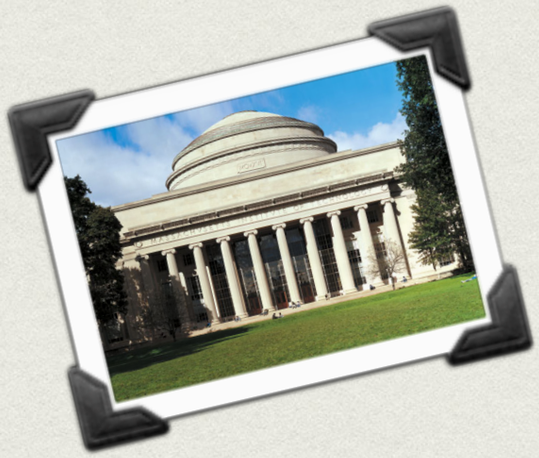


INTRODUCTION

(ZK)MIPs





‘88

BGKW88

BGKW88

LEMIP

W

$$$$

$\exists$  , $\exists$  ,  , $\forall w \in L$,

Prob[( :  : ) accepte] $\geq 1 - \epsilon$

a

b

X

Y

W

$$

$$

$\exists$  , $\exists$  ,  , $\forall w \in L$,

Prob[( :  : ) accepte] $\geq 1 - \epsilon$

w∈L

a

b

X

Y

W

$$

$$

$\exists$  , $\exists$  ,  , $\forall w \in L$,

Prob[( :  : ) accepte] $\geq 1 - \epsilon$

accepte $w \in L$

a

b

X

Y

W

$$

$$

$\exists$  ,

et $\forall$  ,  , $\forall w \notin L$,

Prob[( :  : ) accepte] $\leq \epsilon$

a

b

X

Y

W

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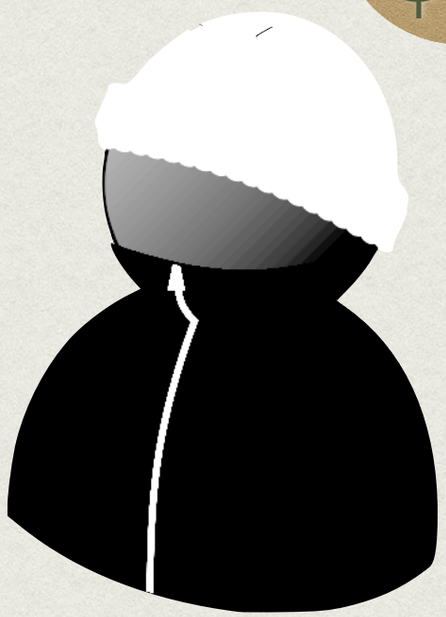

$\exists$  ,

et $\forall$  ,  , $\forall w \notin L$,

Prob[( :  :  **)** accepte] $\leq \epsilon$

w∉L

a

b

X

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W

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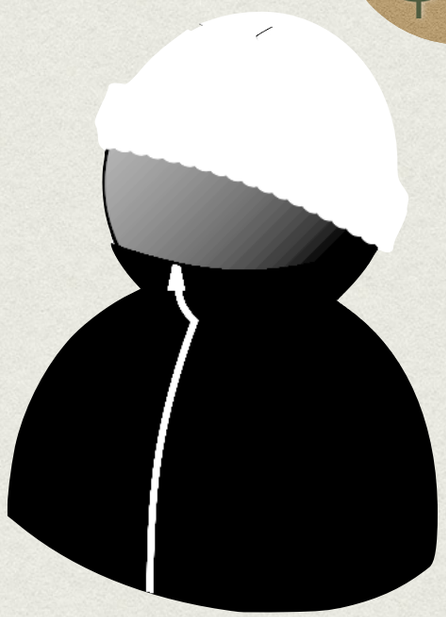

$\exists$  ,

et $\forall$  ,  , $\forall w \notin L$,

Prob[( :  : ) accepte] $\leq \epsilon$

rejète w$\notin$L

a

b

x

y

w

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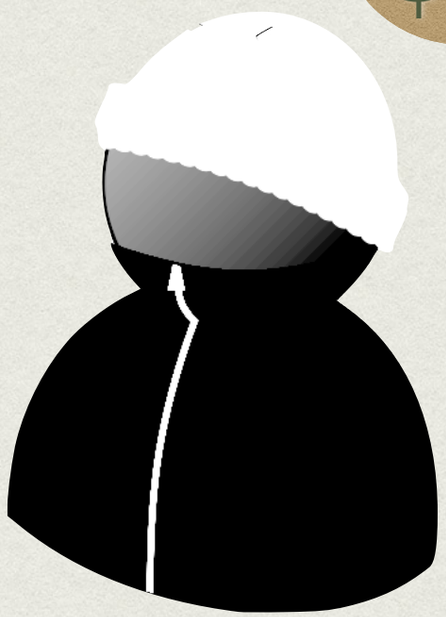
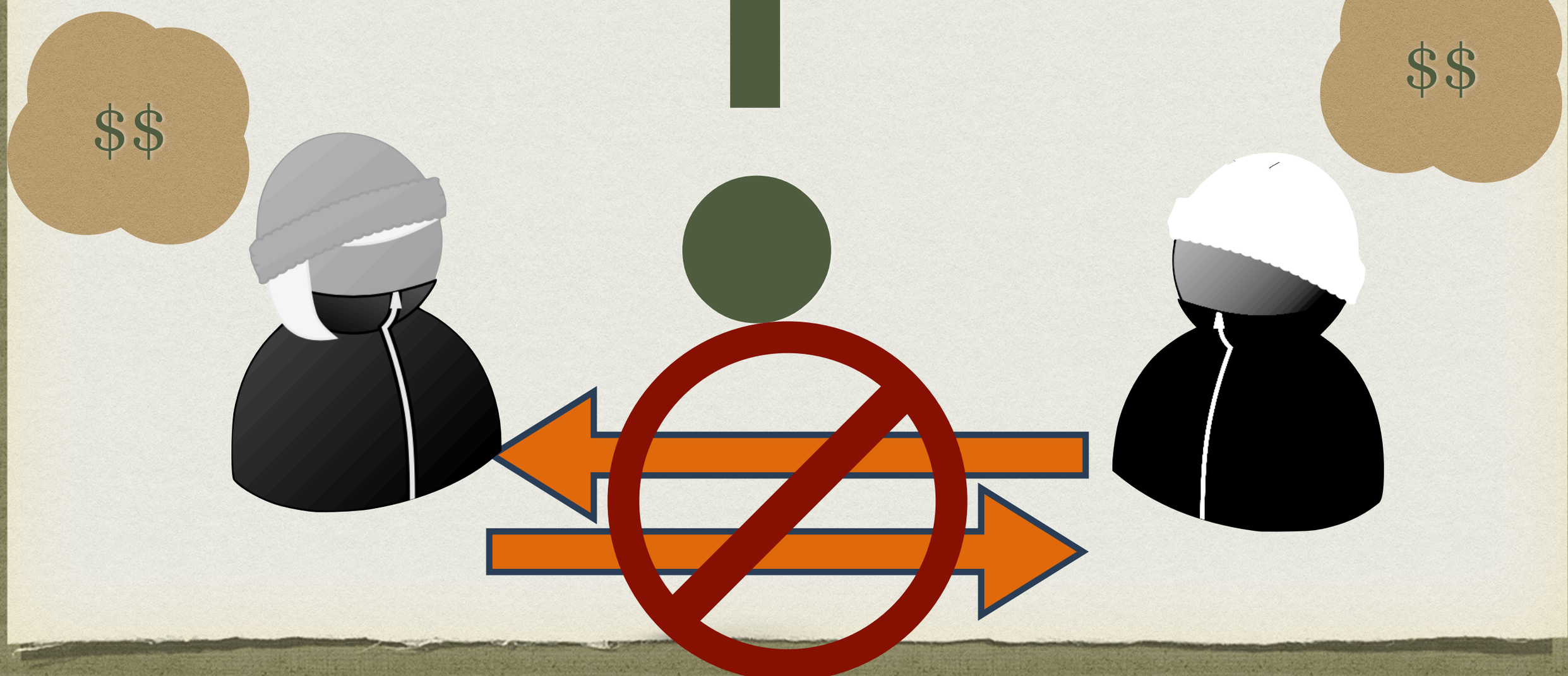


B?KW?8

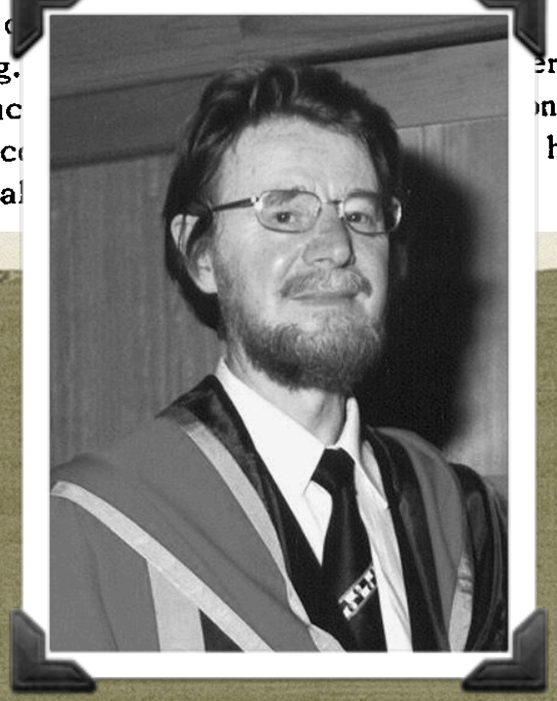


III.5 ON THE EINSTEIN PODOLSKY ROSEN PARADOX*

JOHN S. BELL†

1. Introduction

THE paradox of Einstein, Podolsky and Rosen [1] was advanced as an argument that quantum mechanics could not be a complete theory but should be supplemented by additional variables. These additional variables were to restore to the theory causality and locality [2]. In this note that idea will be formulated mathematically and shown to be incompatible with the statistical predictions of quantum mechanics. It is the requirement of locality, or more precisely that the result of a measurement on one system be unaffected by operations on a distant system with which it has interacted in the past, that creates the essential difficulty. There have been attempts [3] to s[illegible]hat even without such a [illegible]arability or locality requirement no "hidden variable" interpretation [illegible] These attempts have been examined elsewhere [4] and found wanting. [illegible]erpretation of elementary quantum theory [5] has been explicitly construc[illegible]n has indeed a grossly non-local structure. This is characteristic, ac[illegible] here, of any such theory which reproduces exactly the quantum mechanical



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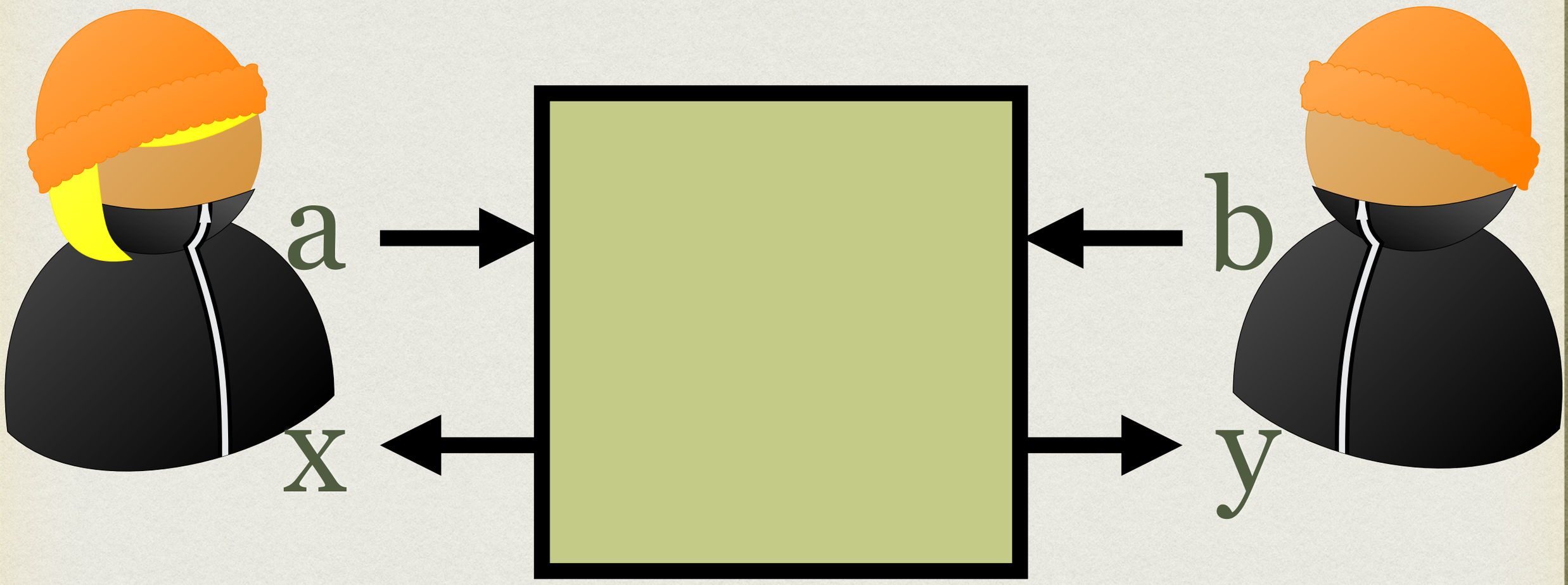

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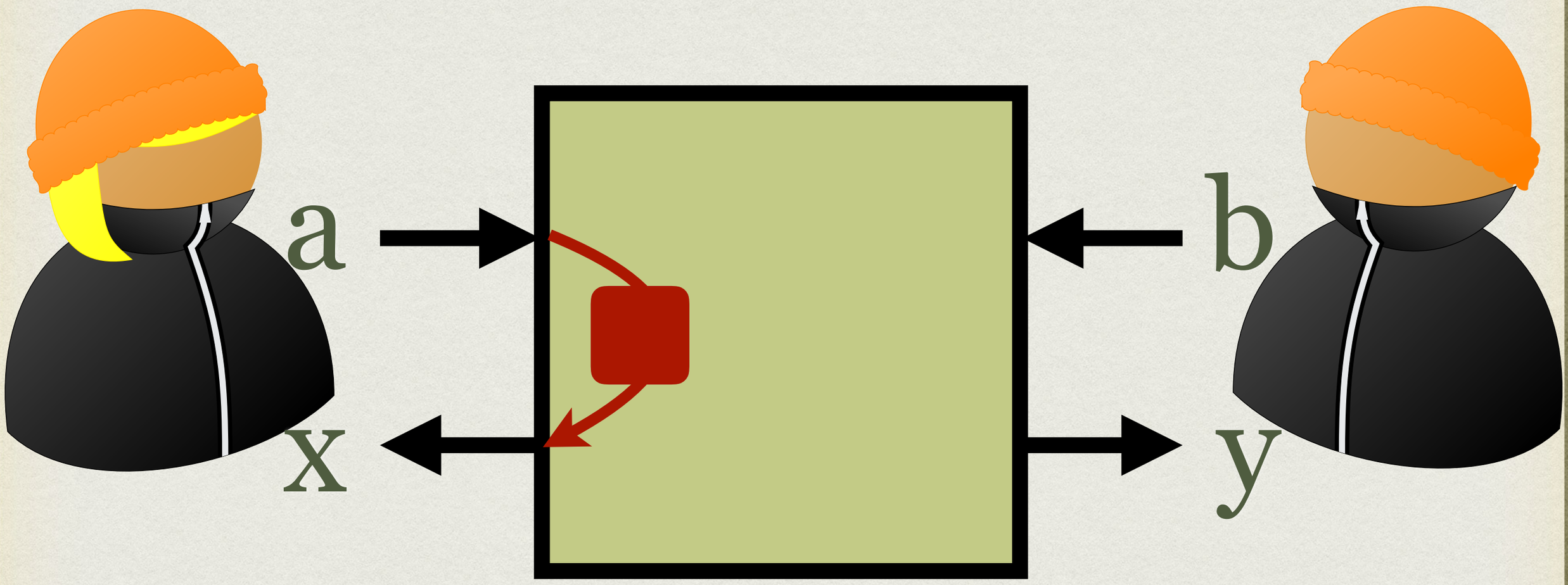

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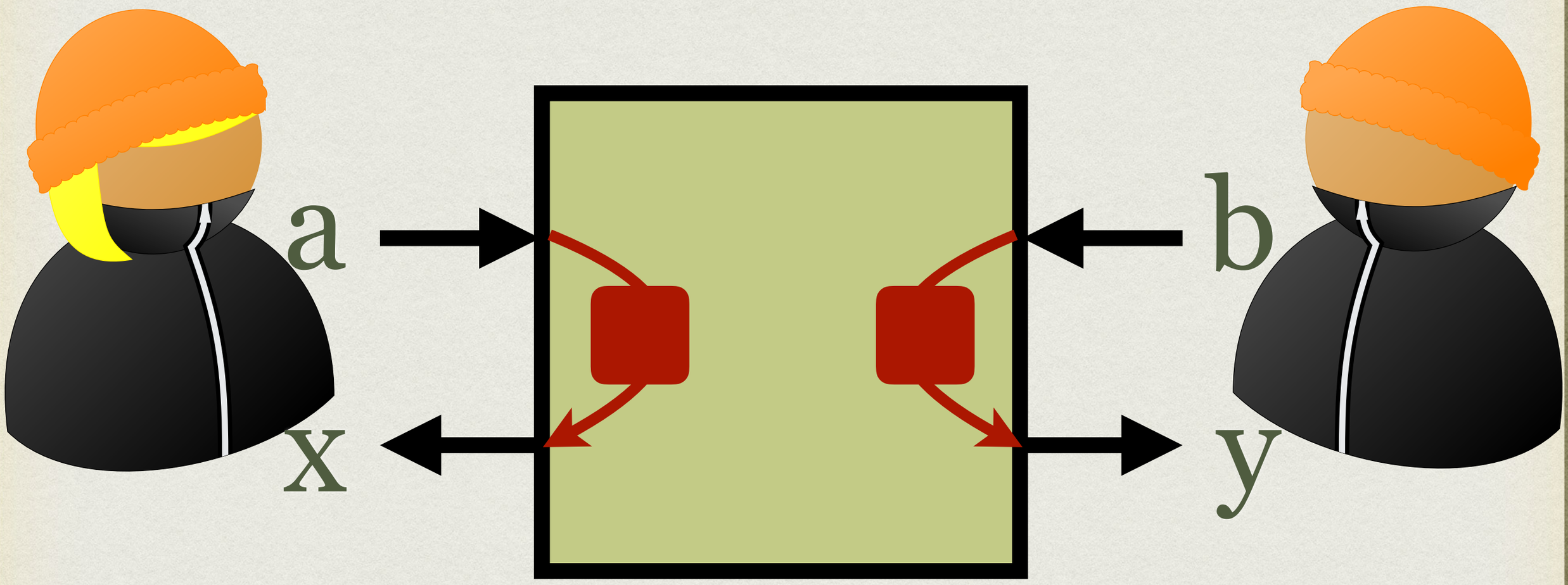

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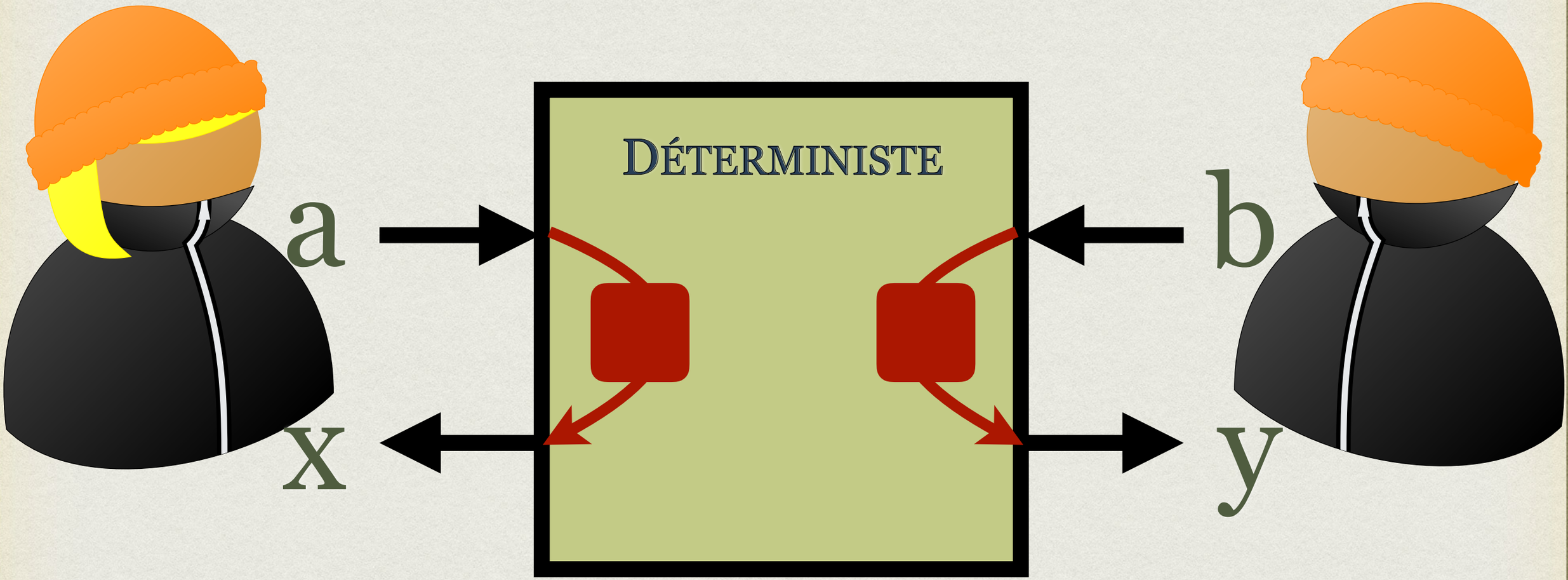

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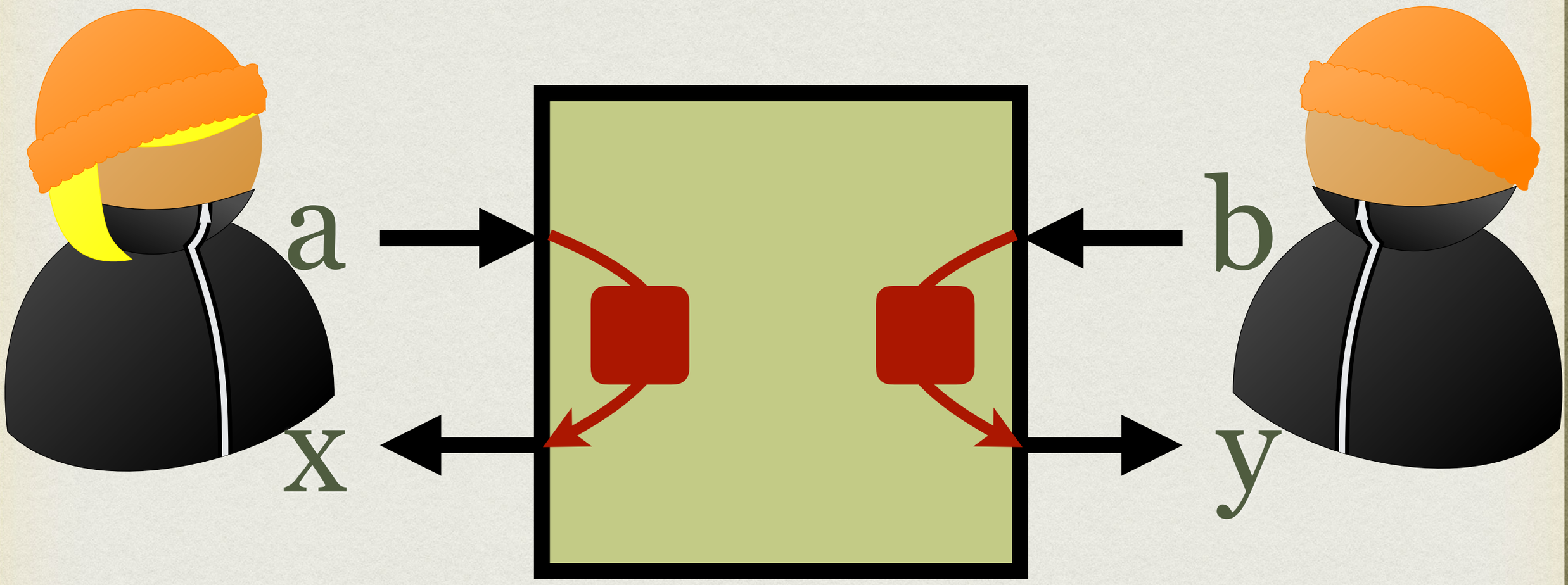

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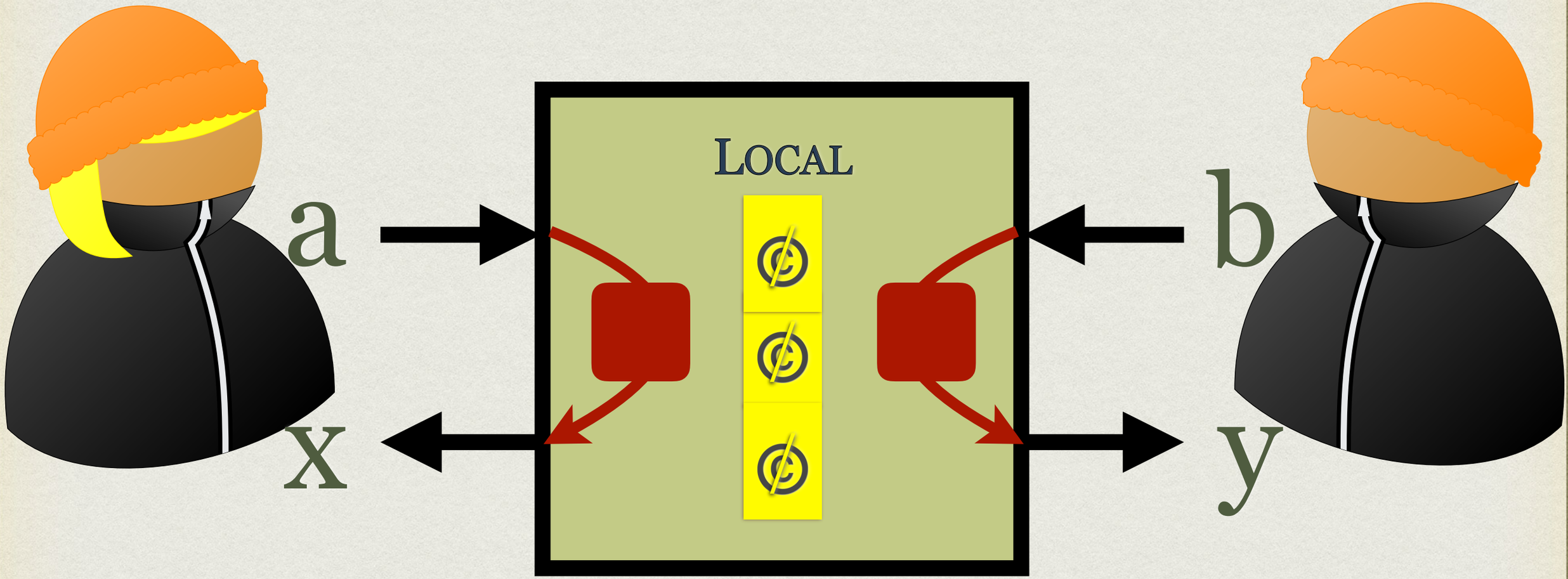

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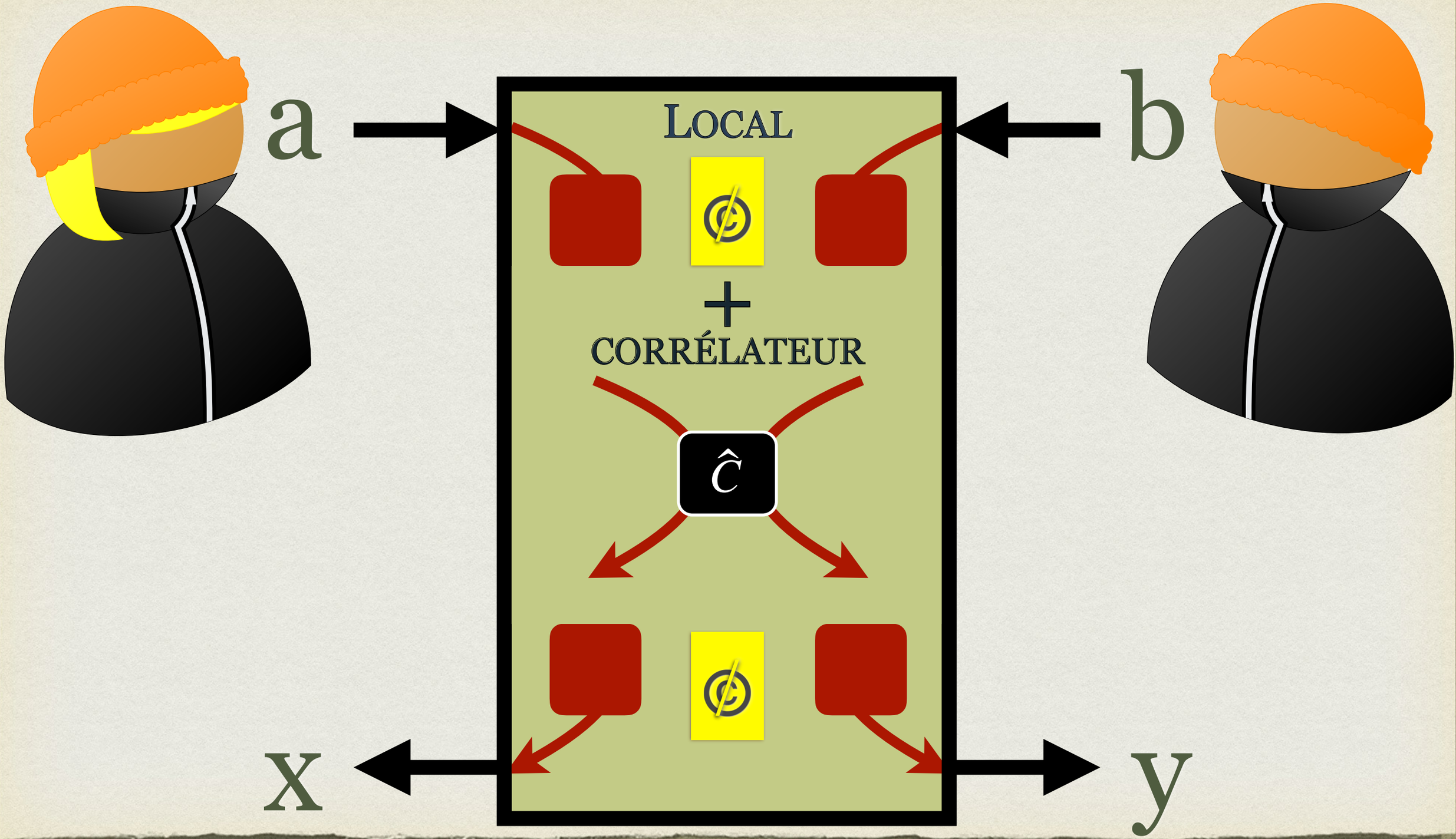

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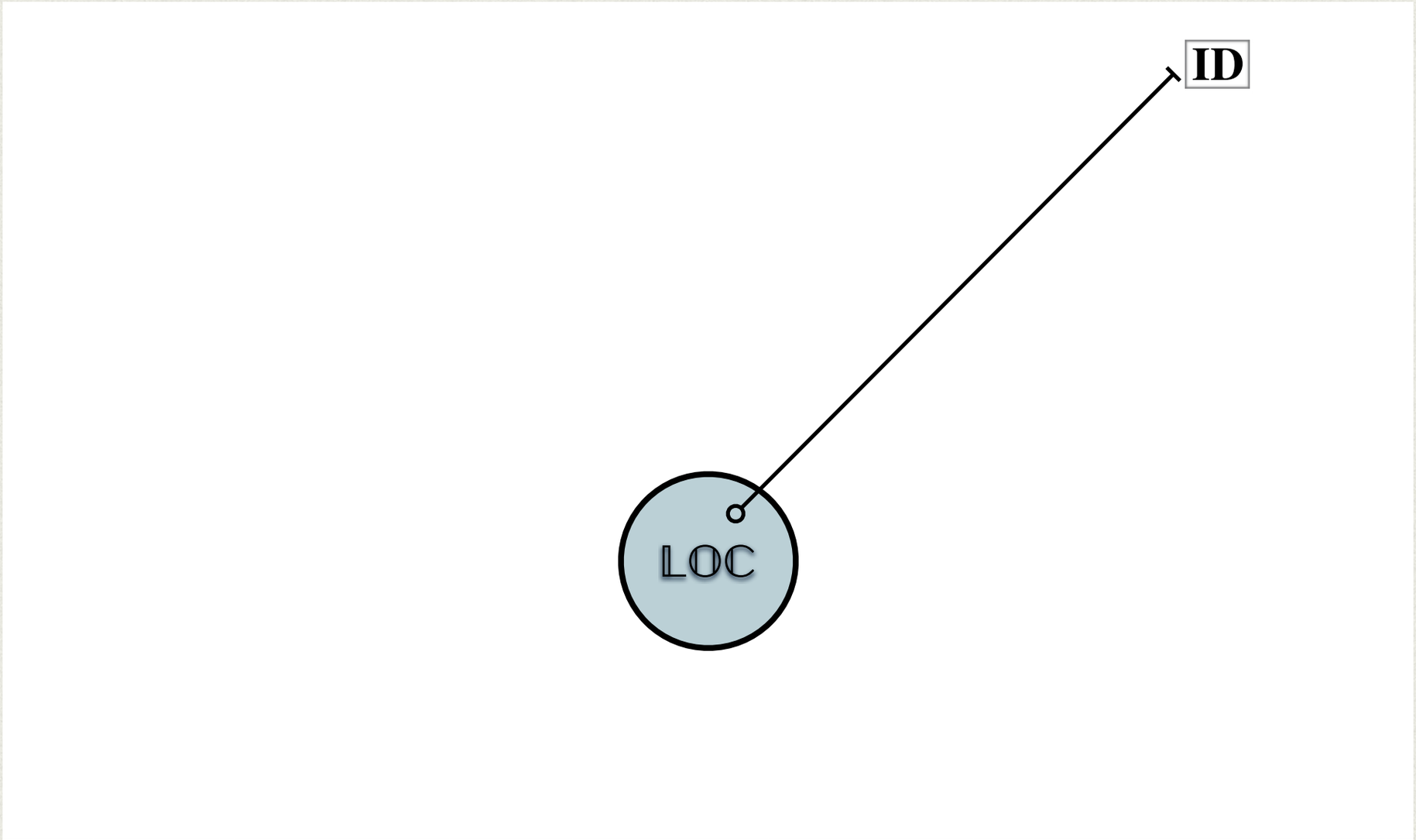

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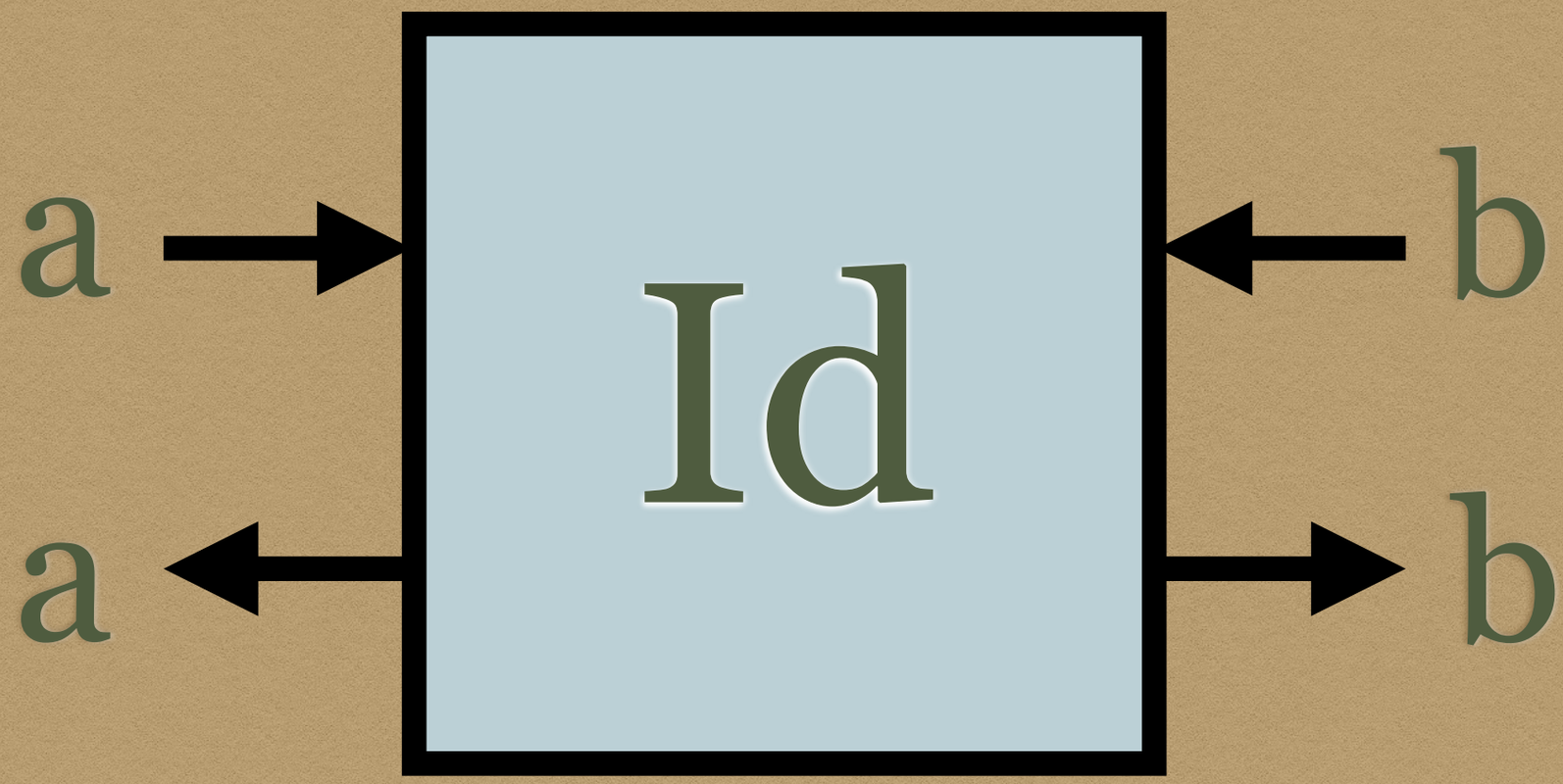

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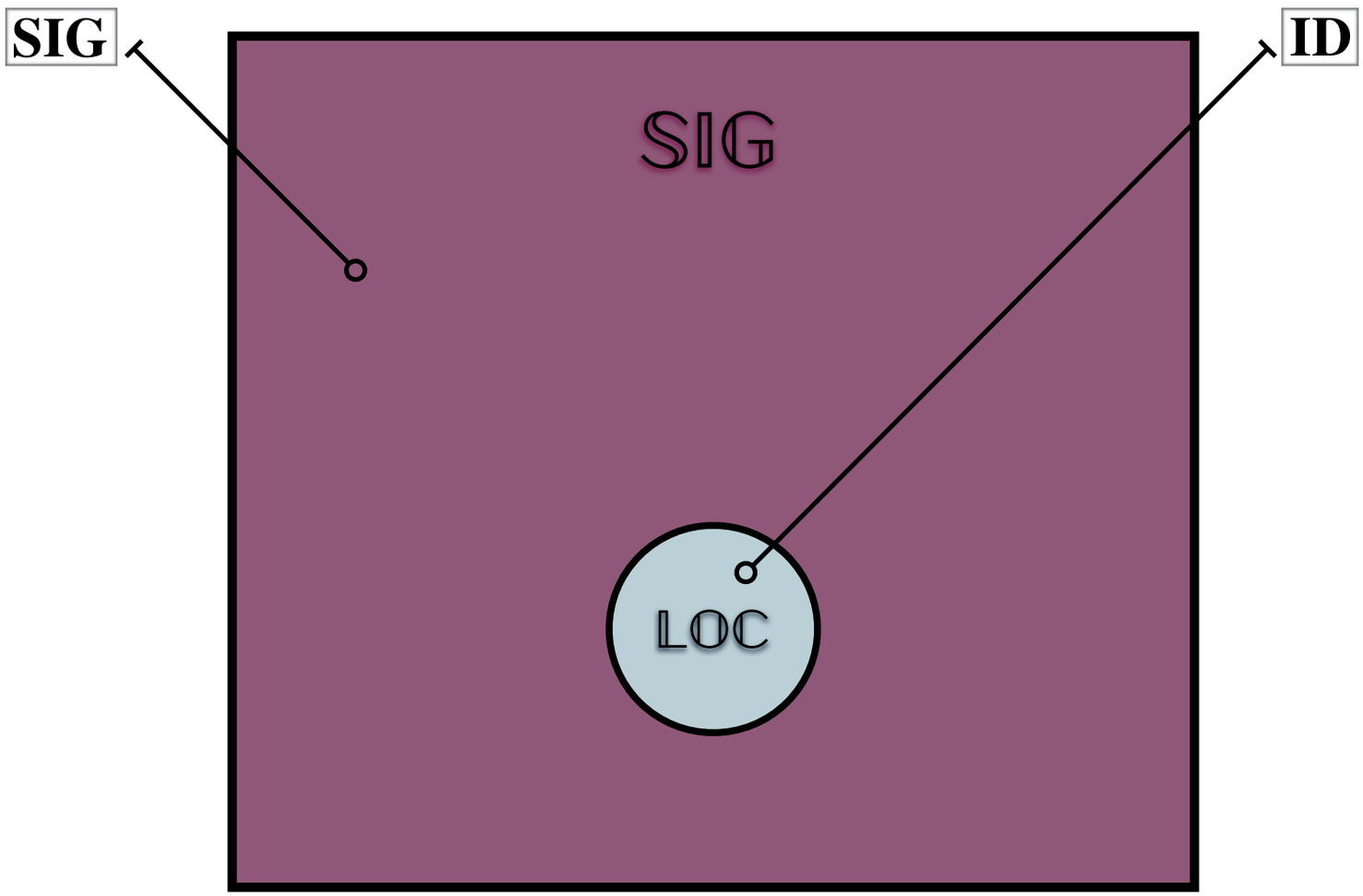

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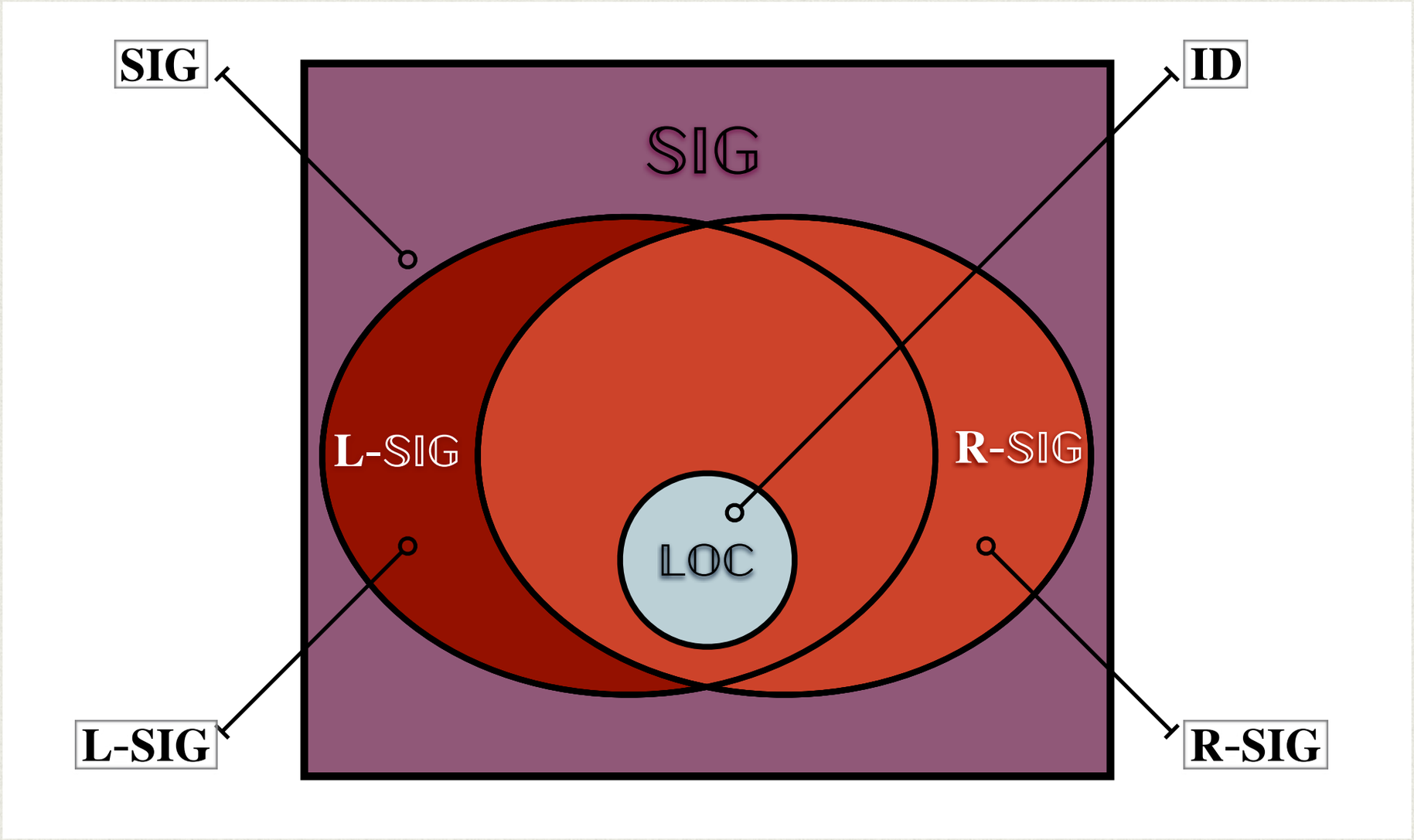

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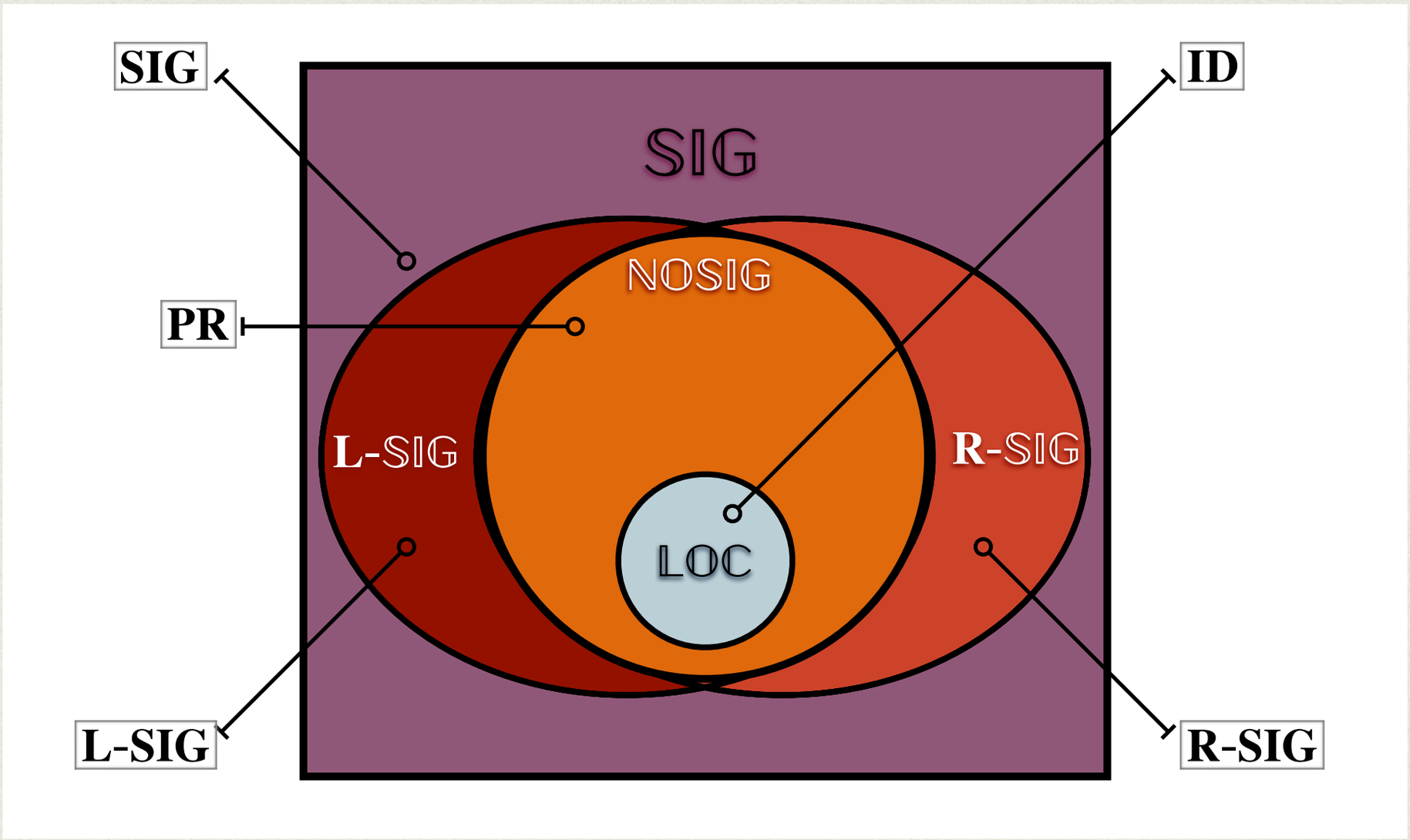
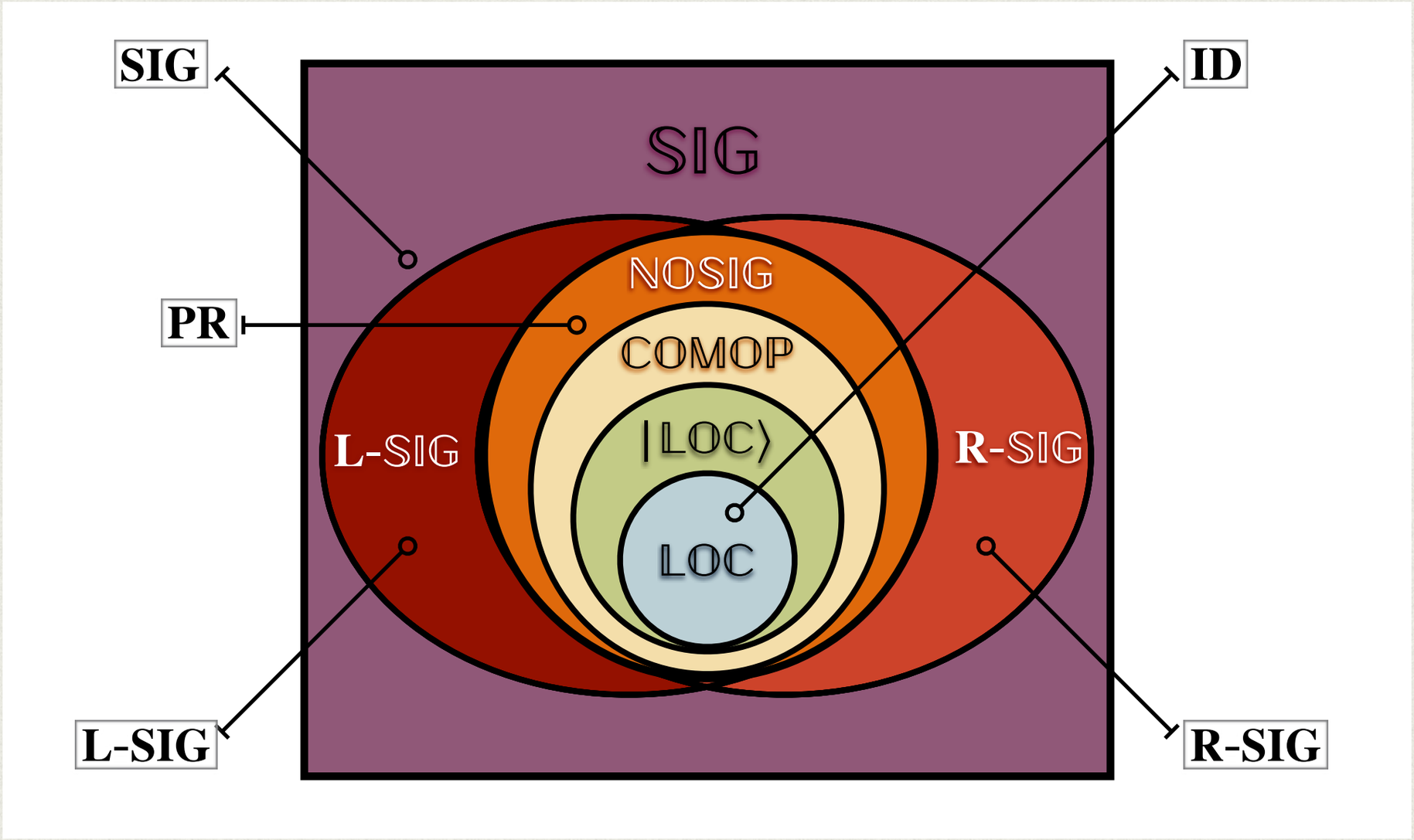


HIERARCHIE DE NON-LOCALITÉ

$x \oplus y = a \cdot b$

x est uniforme

HIERARCHIE DE NON-LOCALITÉ



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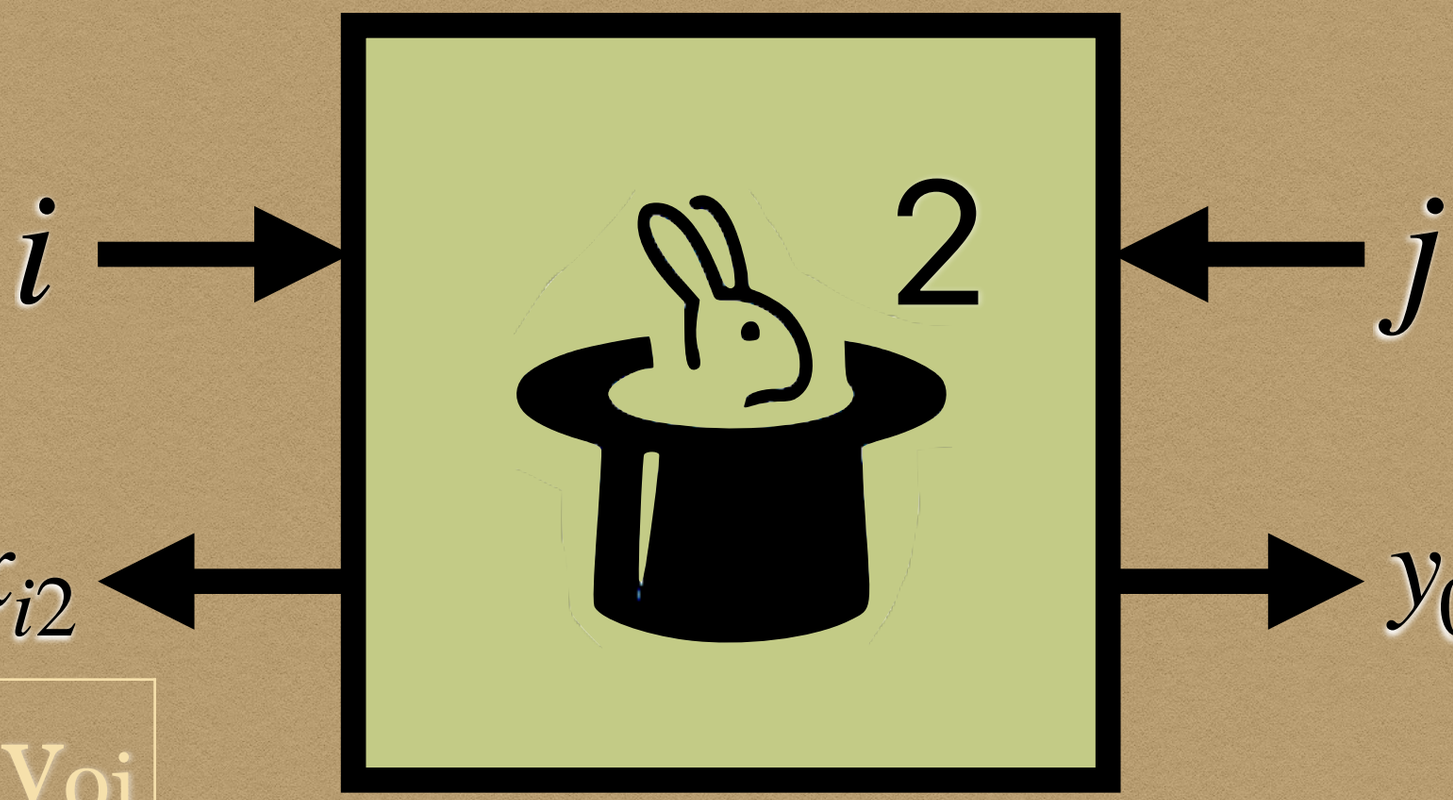


		y_{0j}
x_{i0}	x_{i1}	$x_{i2} = y_{2j}$
		y_{2j}

➡ paire

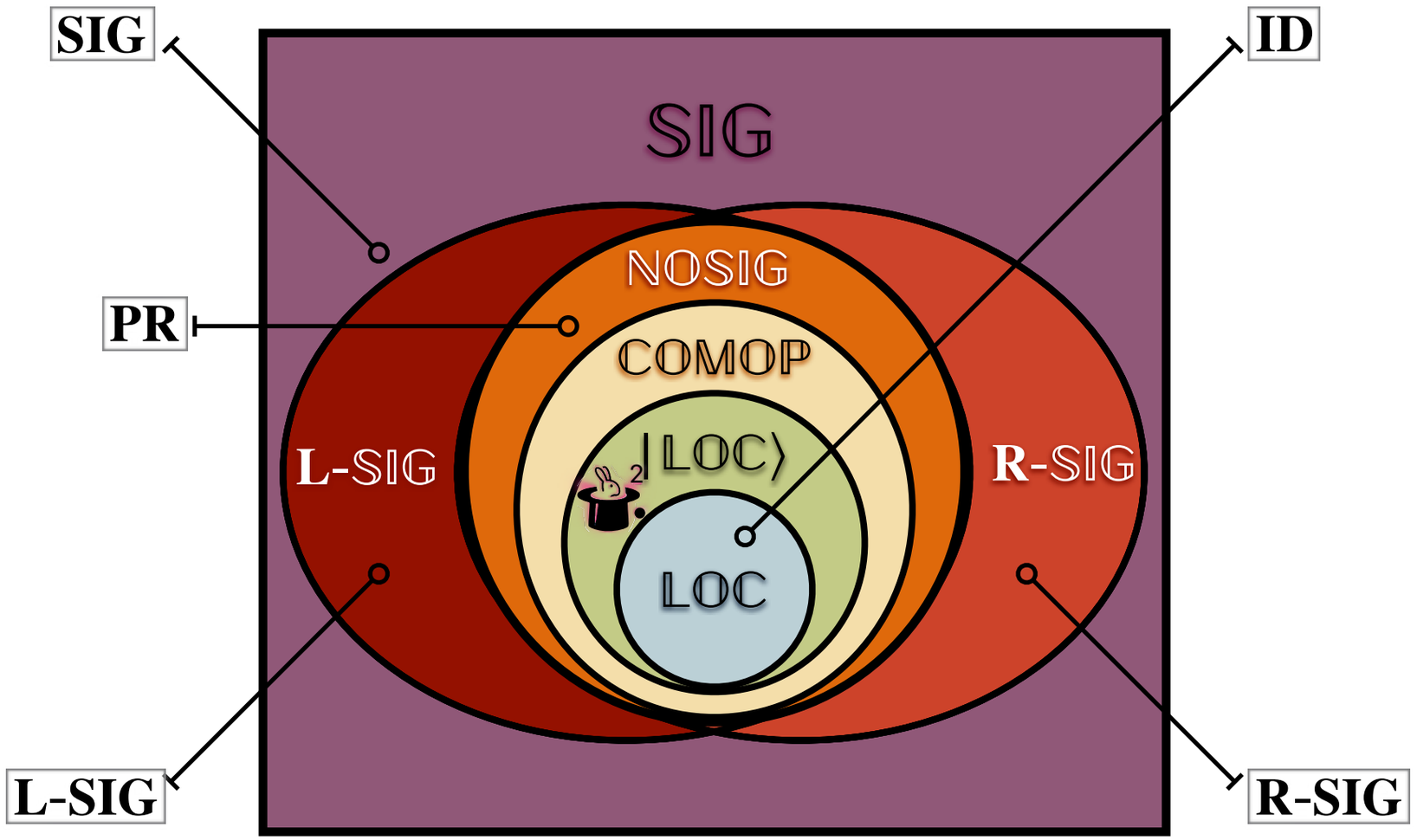
⤷➡ impaire

$$x_{ij} = y_{ij}$$

$$x_{i0} \oplus x_{i1} \oplus x_{i2} = 0$$

$$y_{0j} \oplus y_{1j} \oplus y_{2j} = 1$$

HIERARCHIE DE NON-LOCALITÉ



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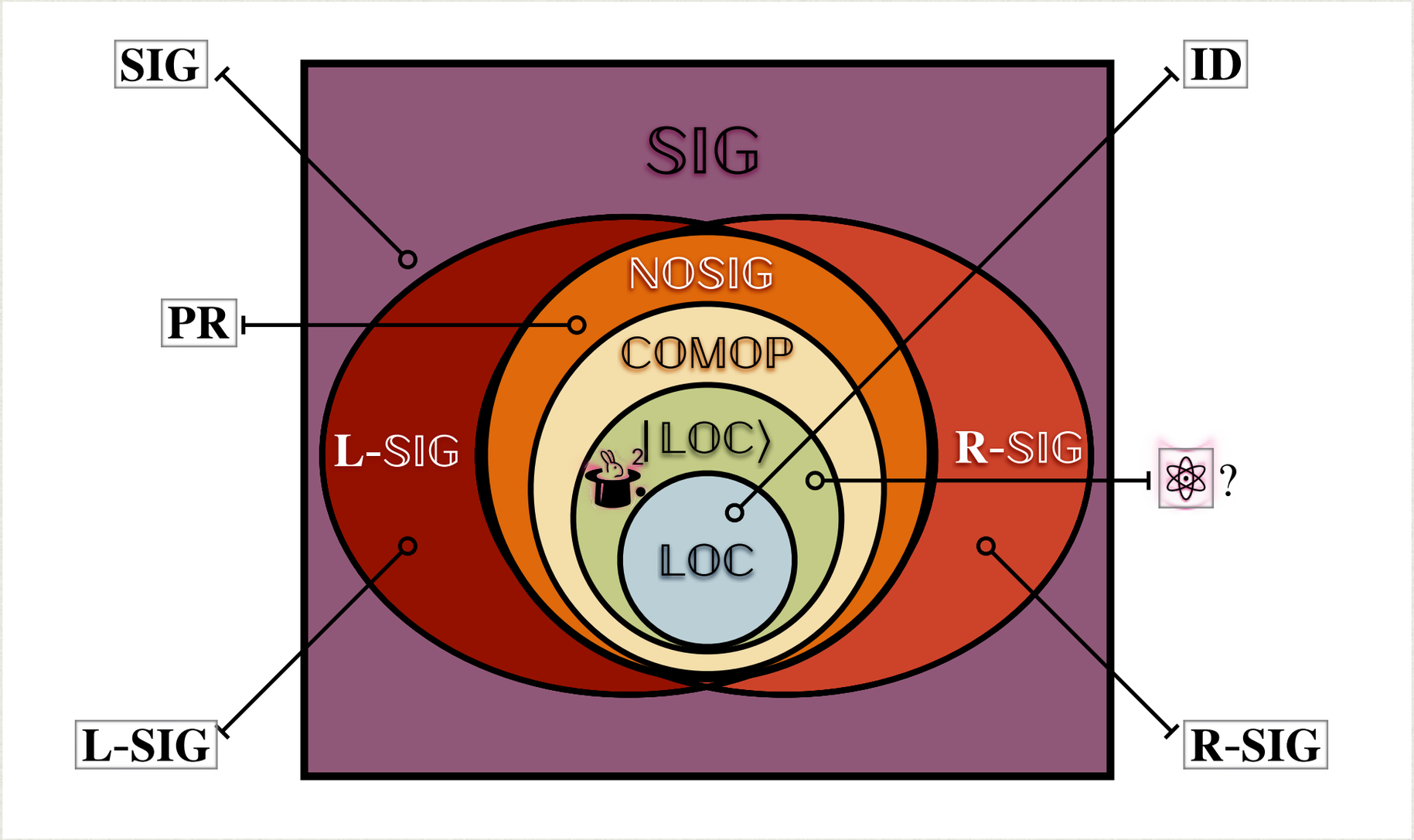

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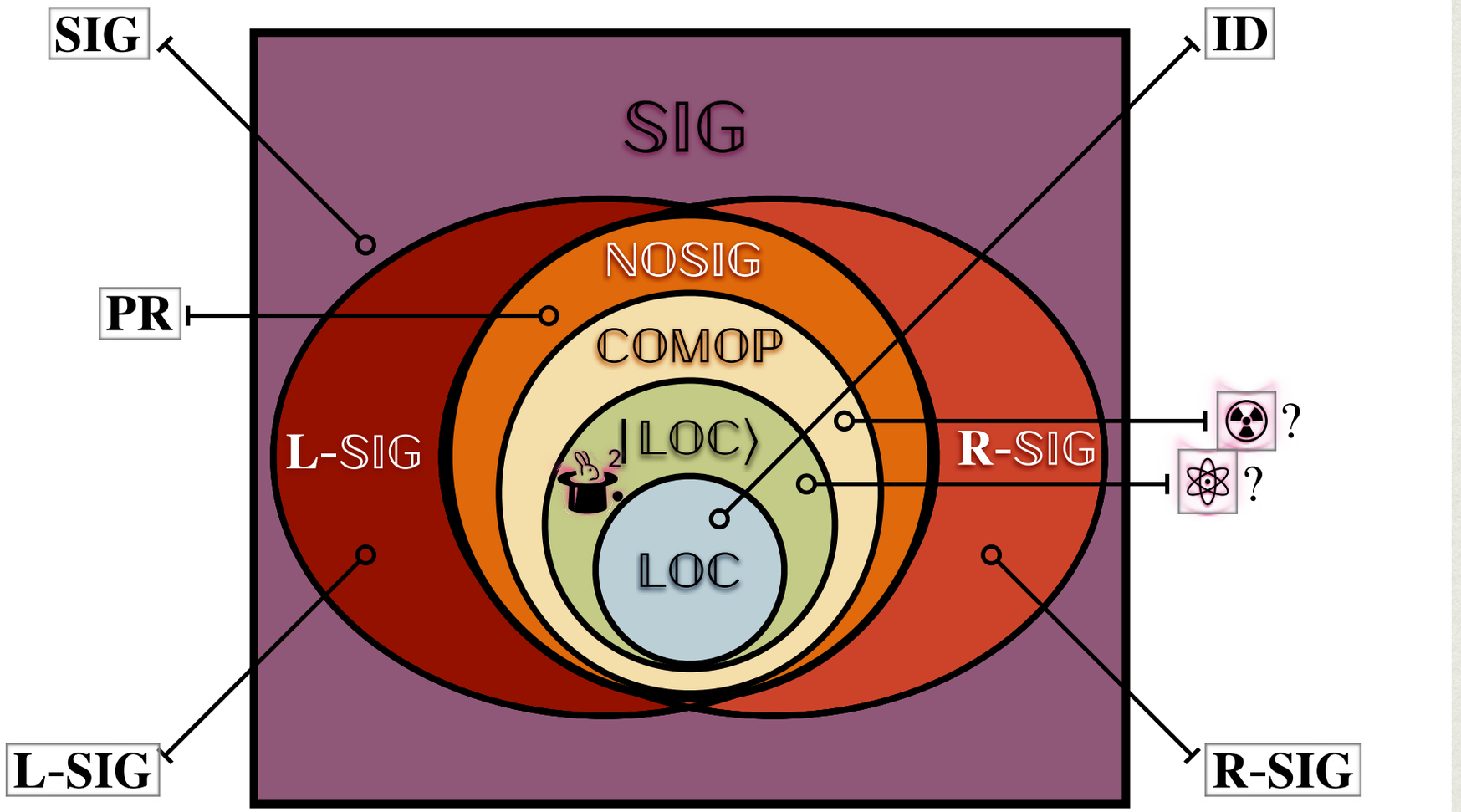
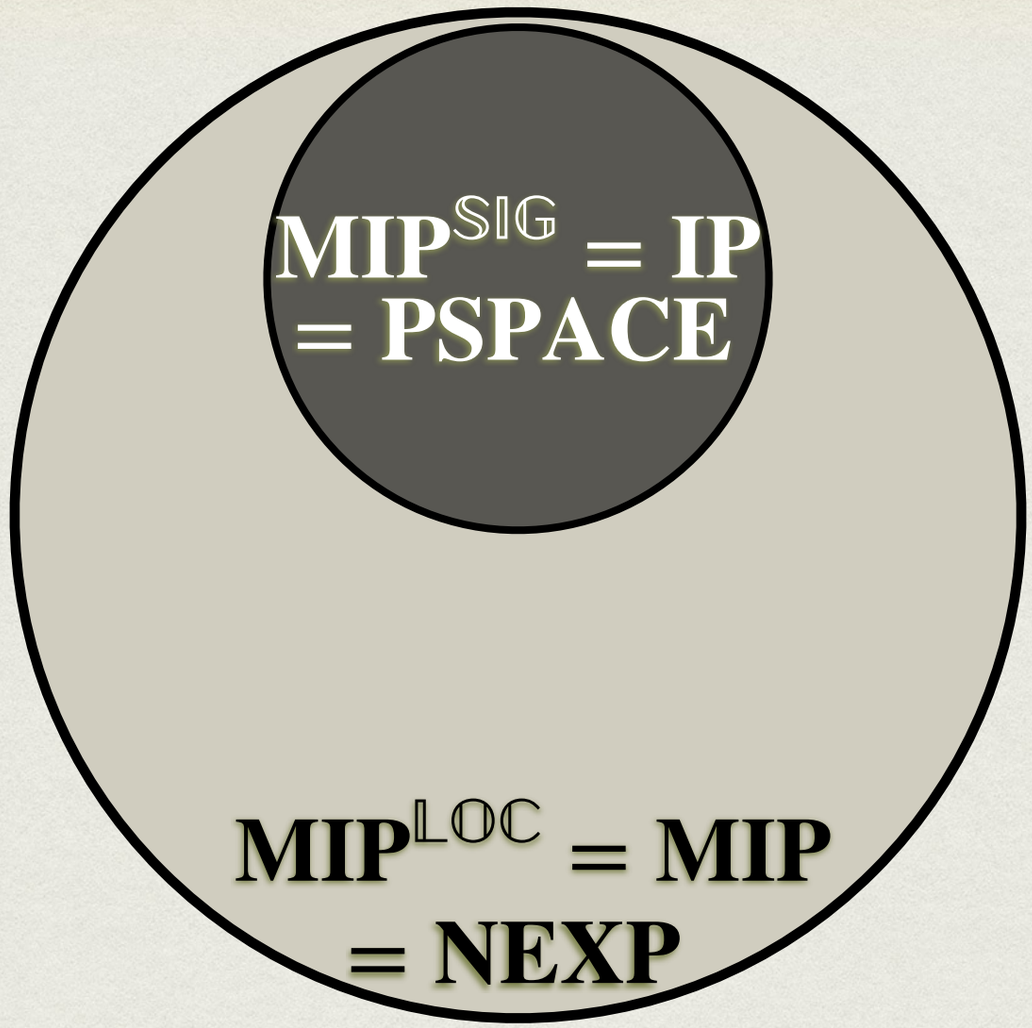


CLASSES DE COMPLEXITÉ

CLASSES DE COMPLEXITÉ



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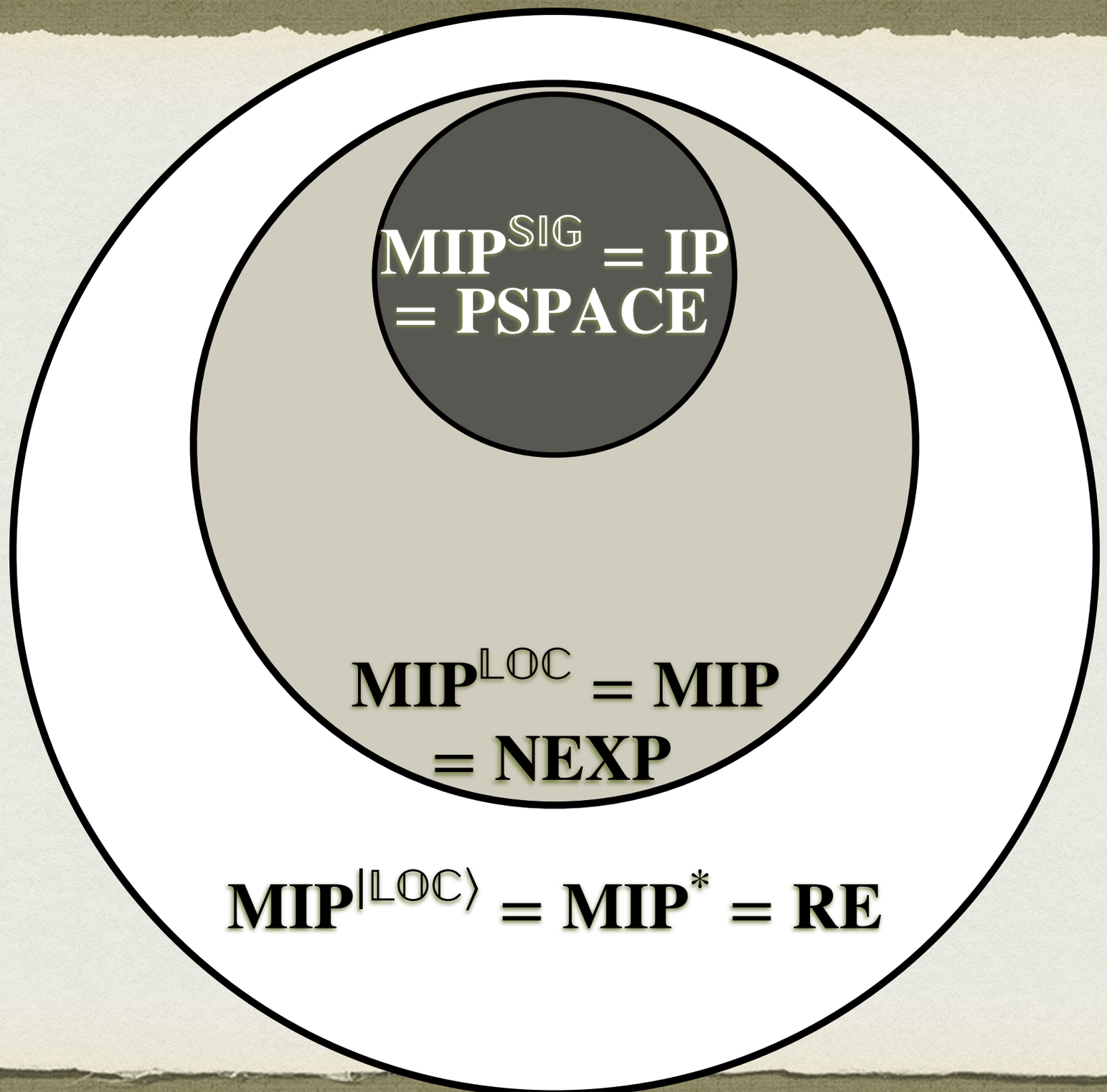

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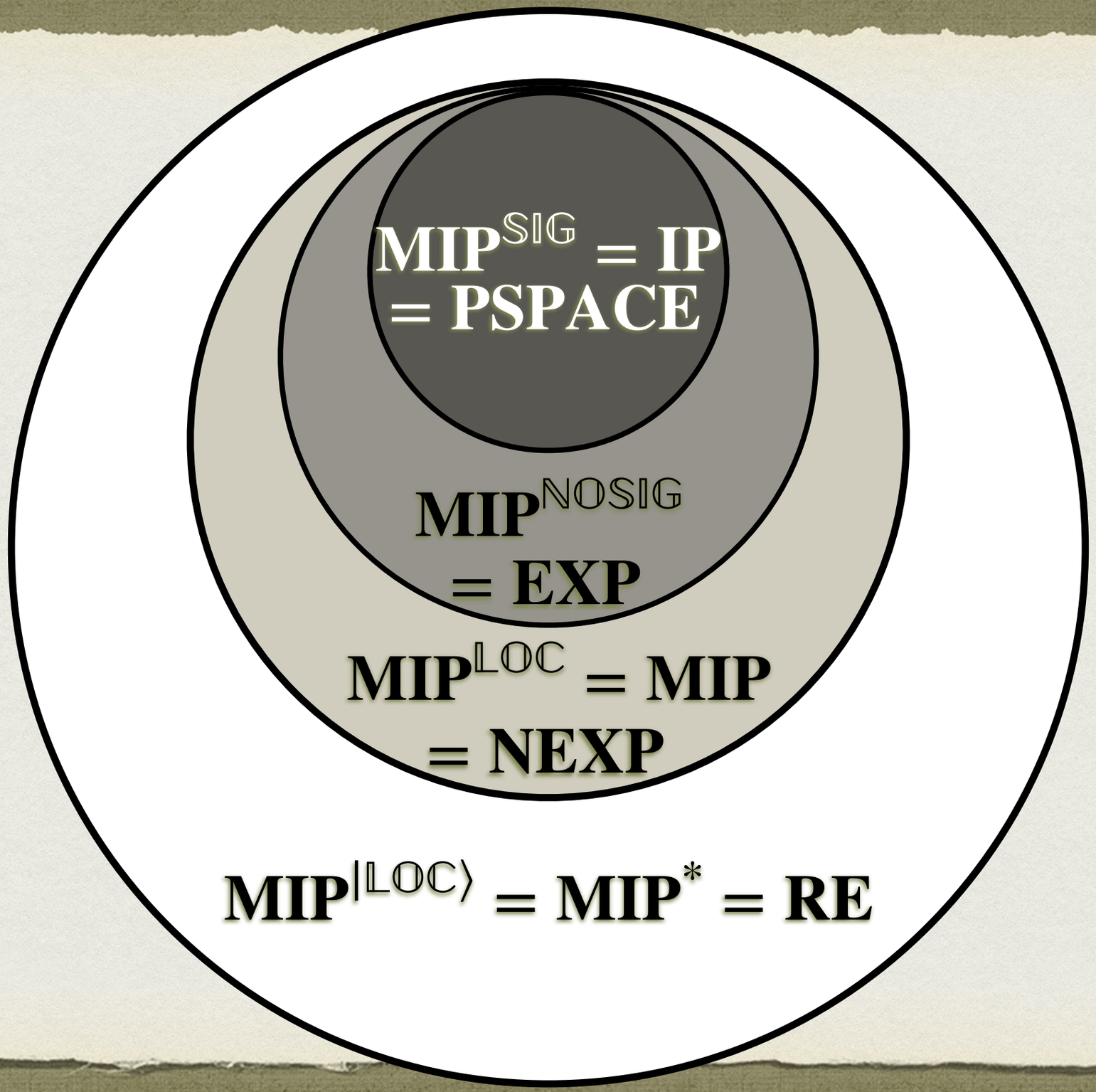

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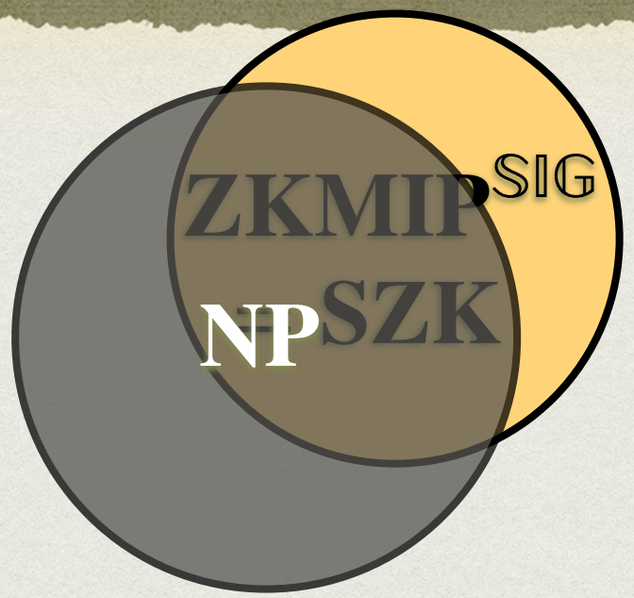
ZKMIP^{SIG} = SZK

CLASSES DE COMPLEXITÉ ZK



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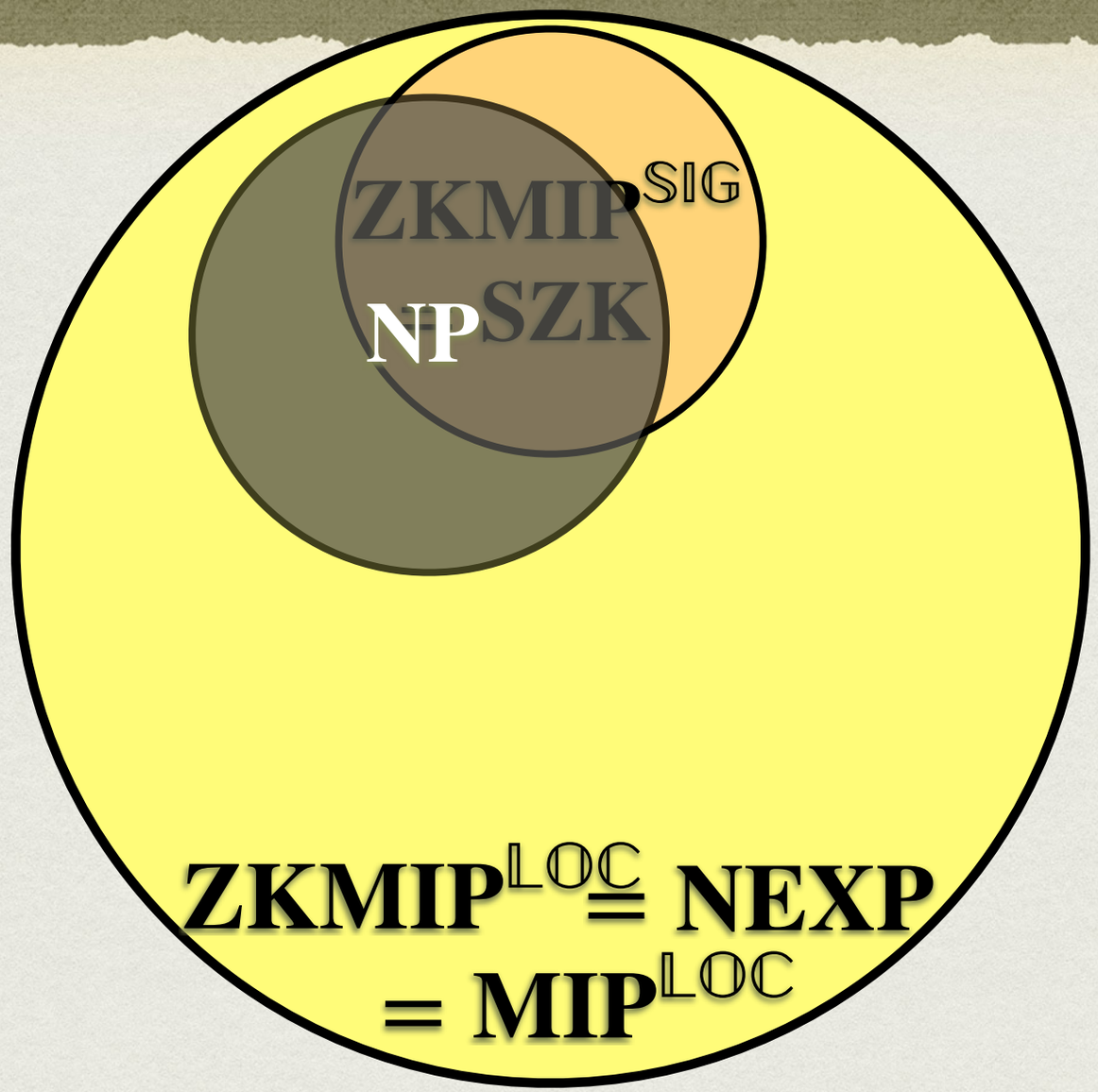

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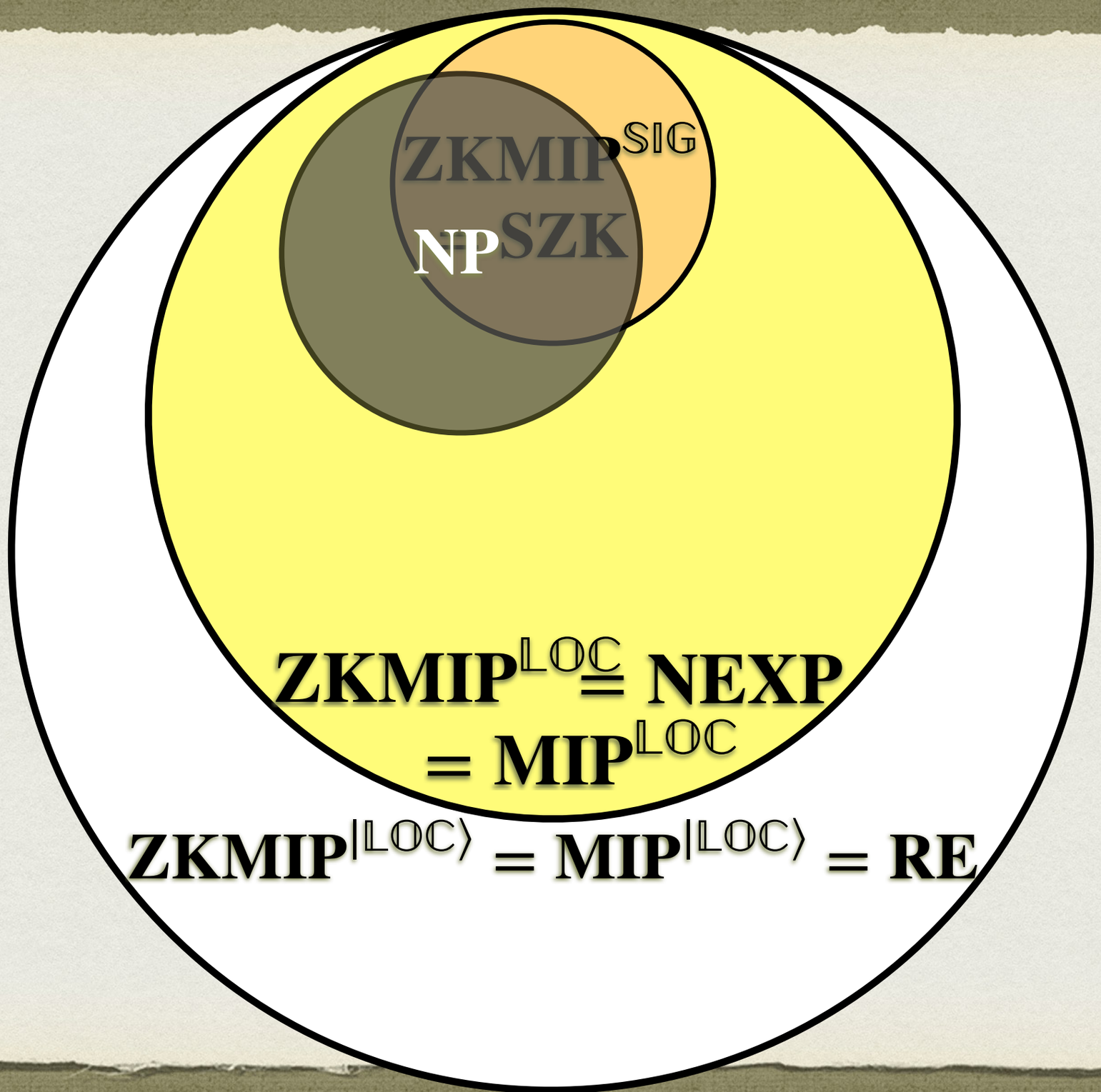

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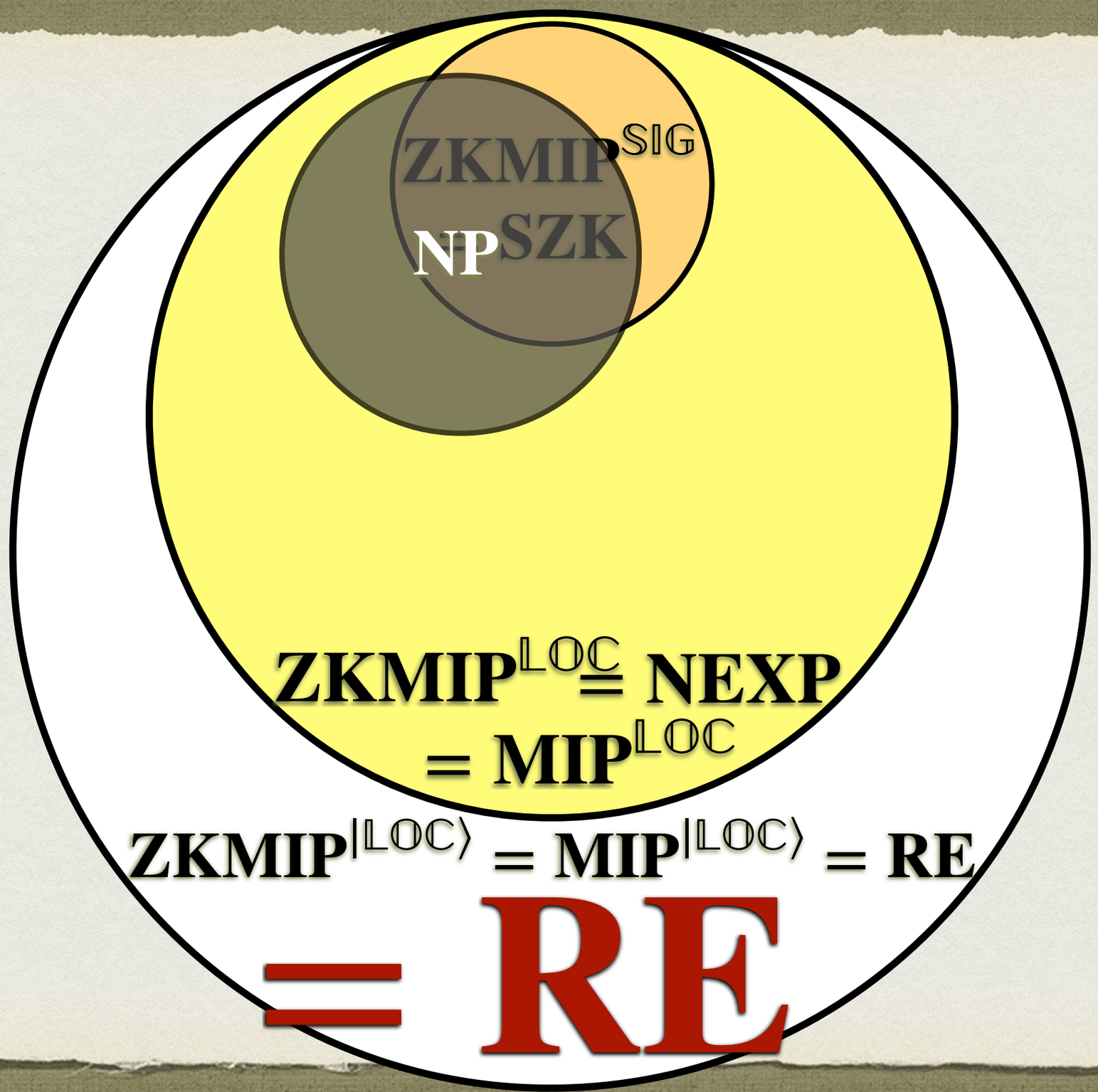

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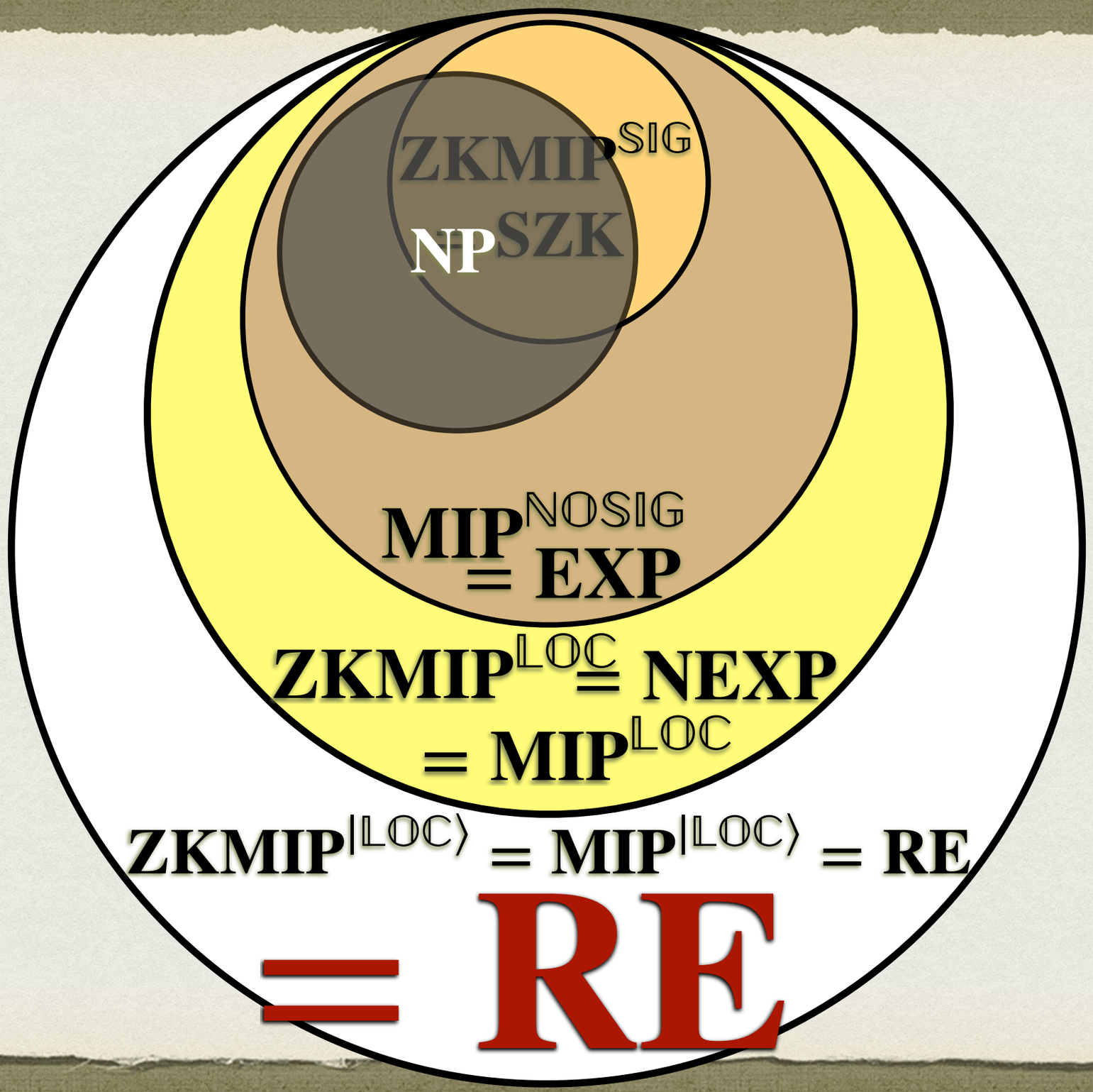

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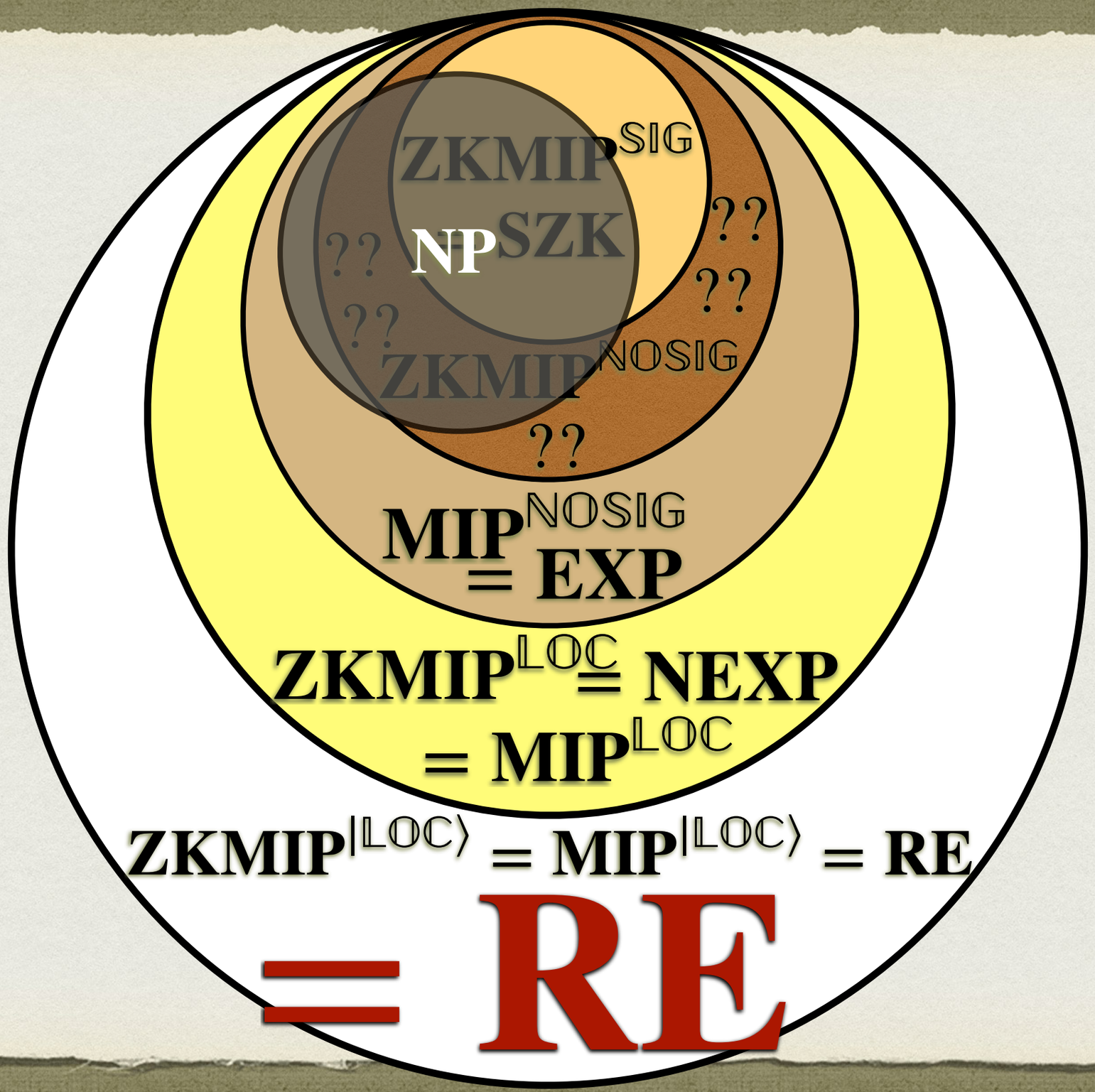

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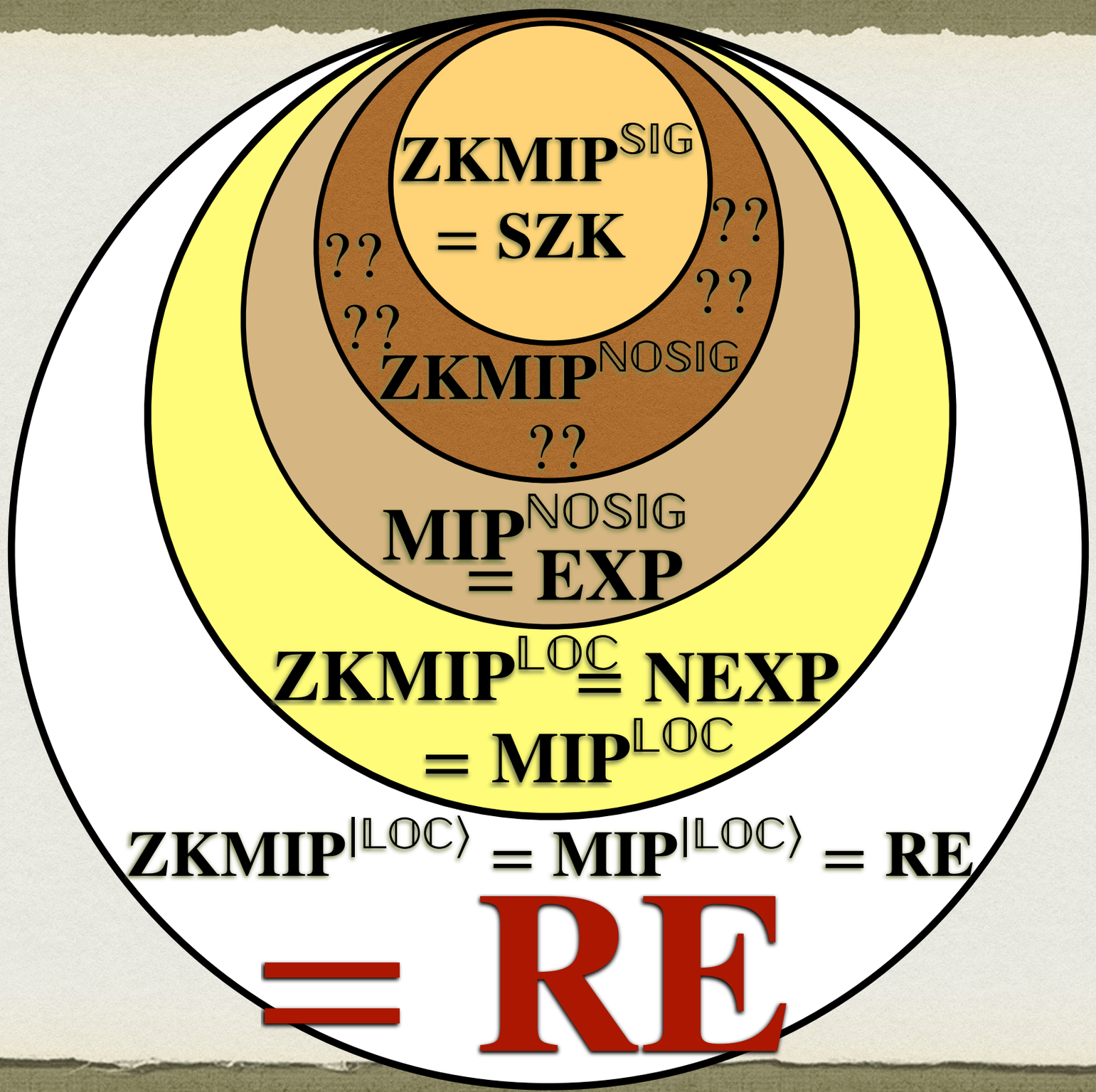

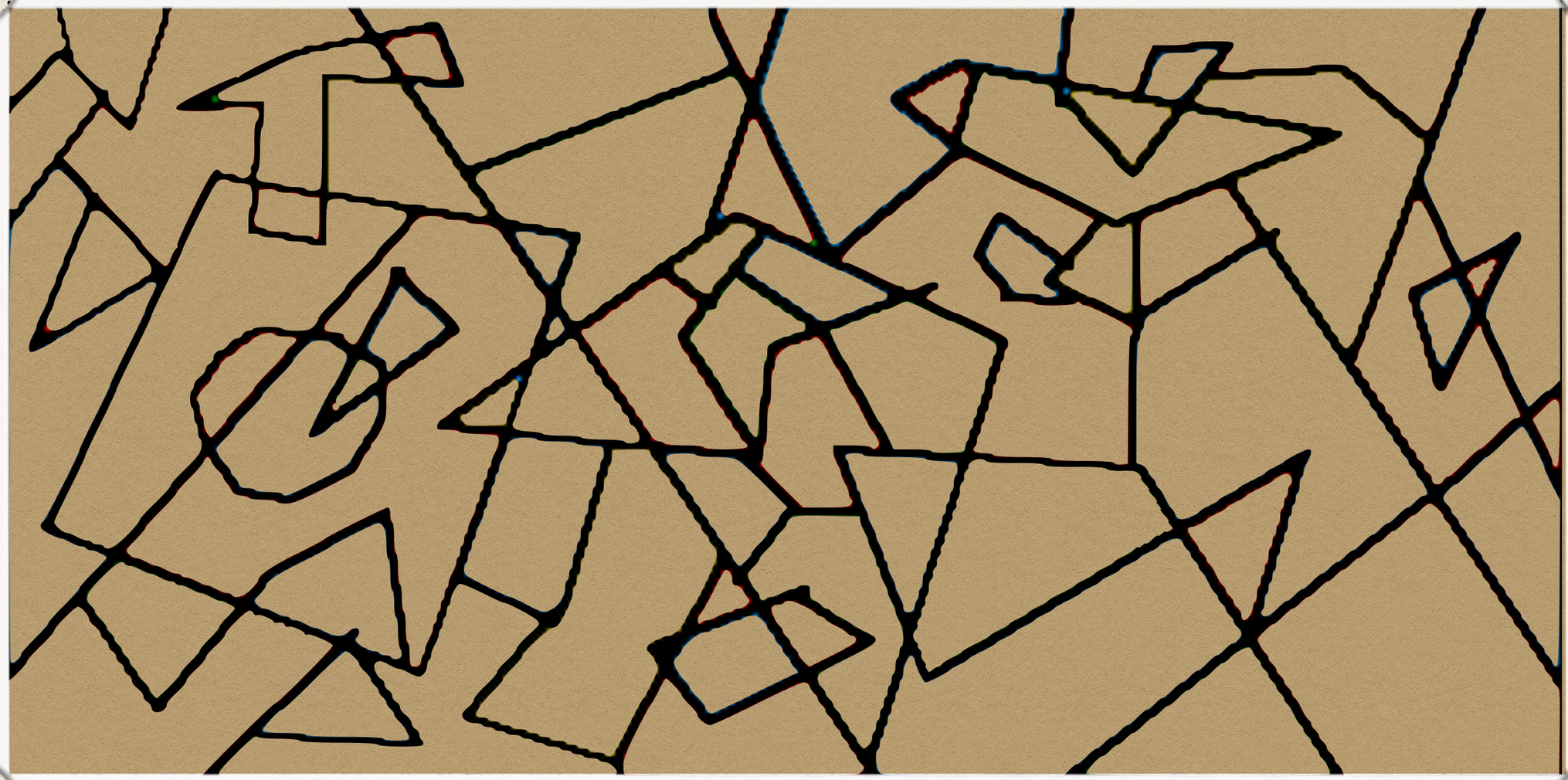

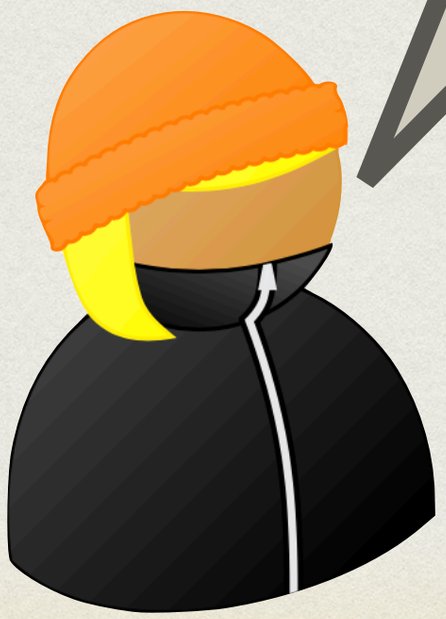

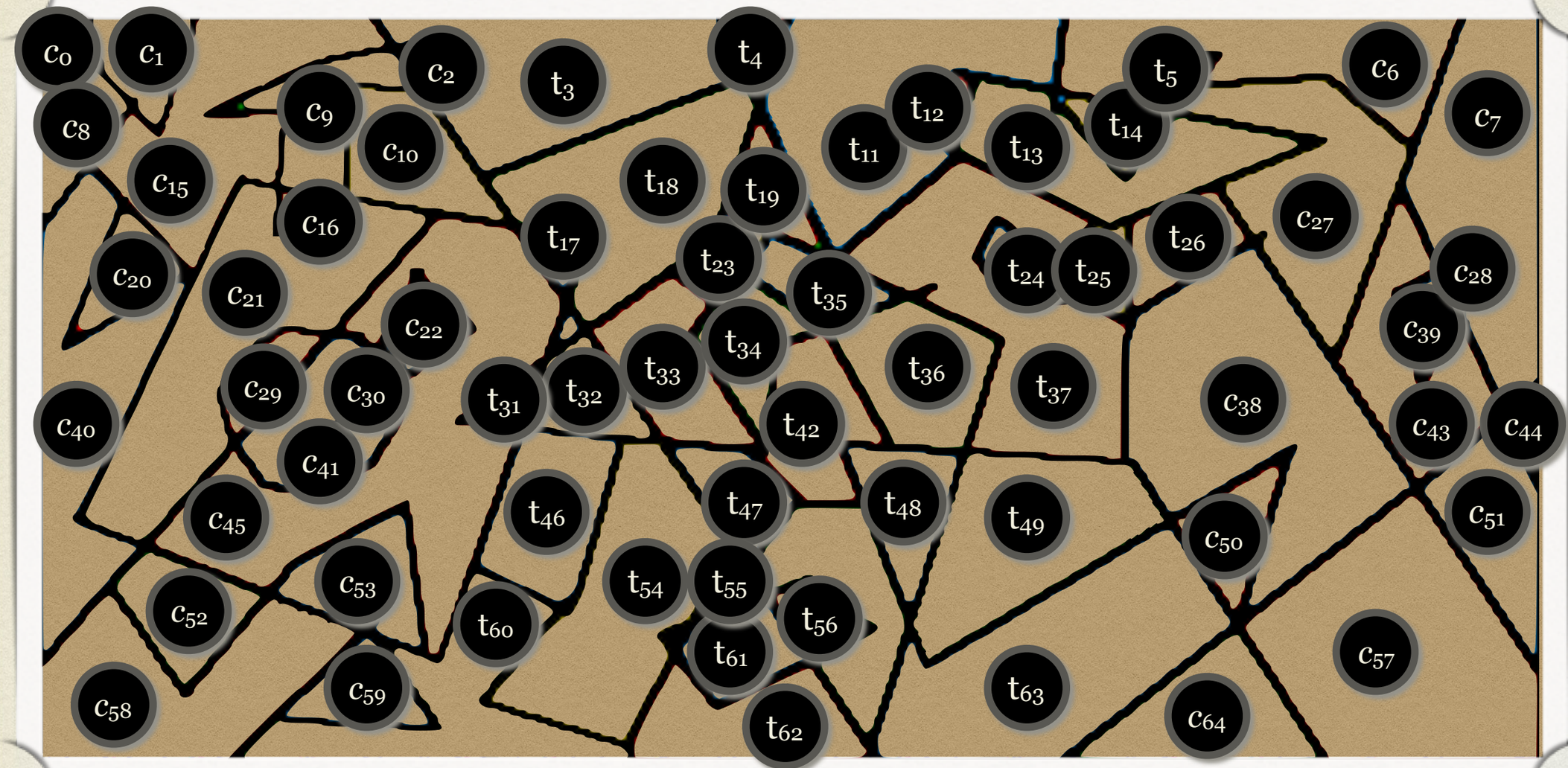
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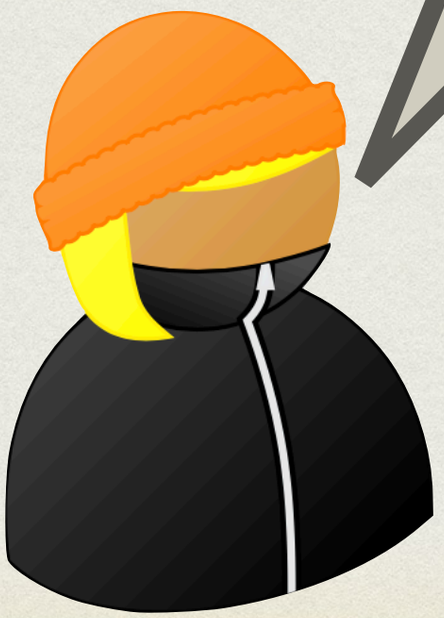

COHÉRENCE INTRIQUÉE ?

SAIS PAS !


C


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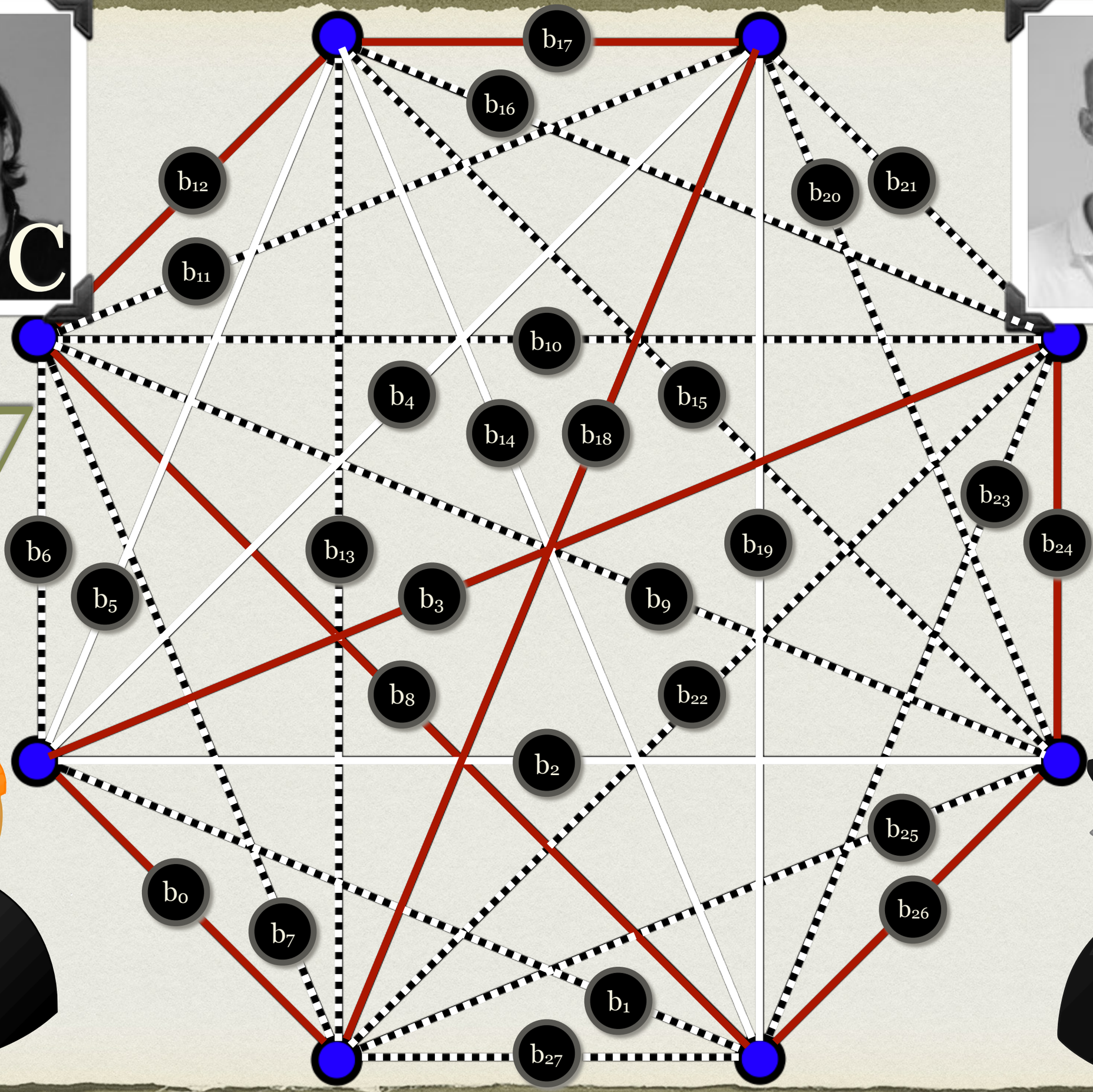
2017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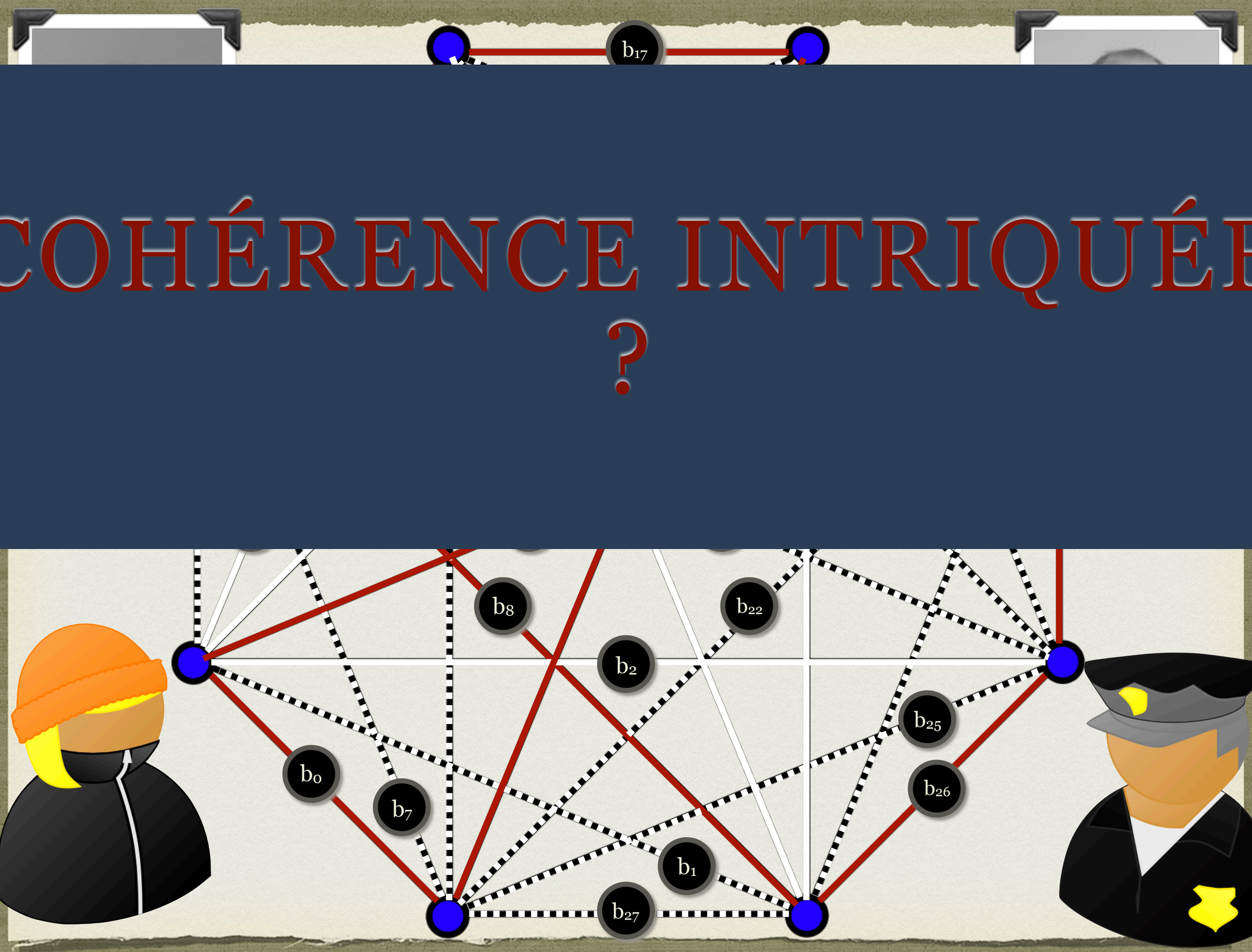
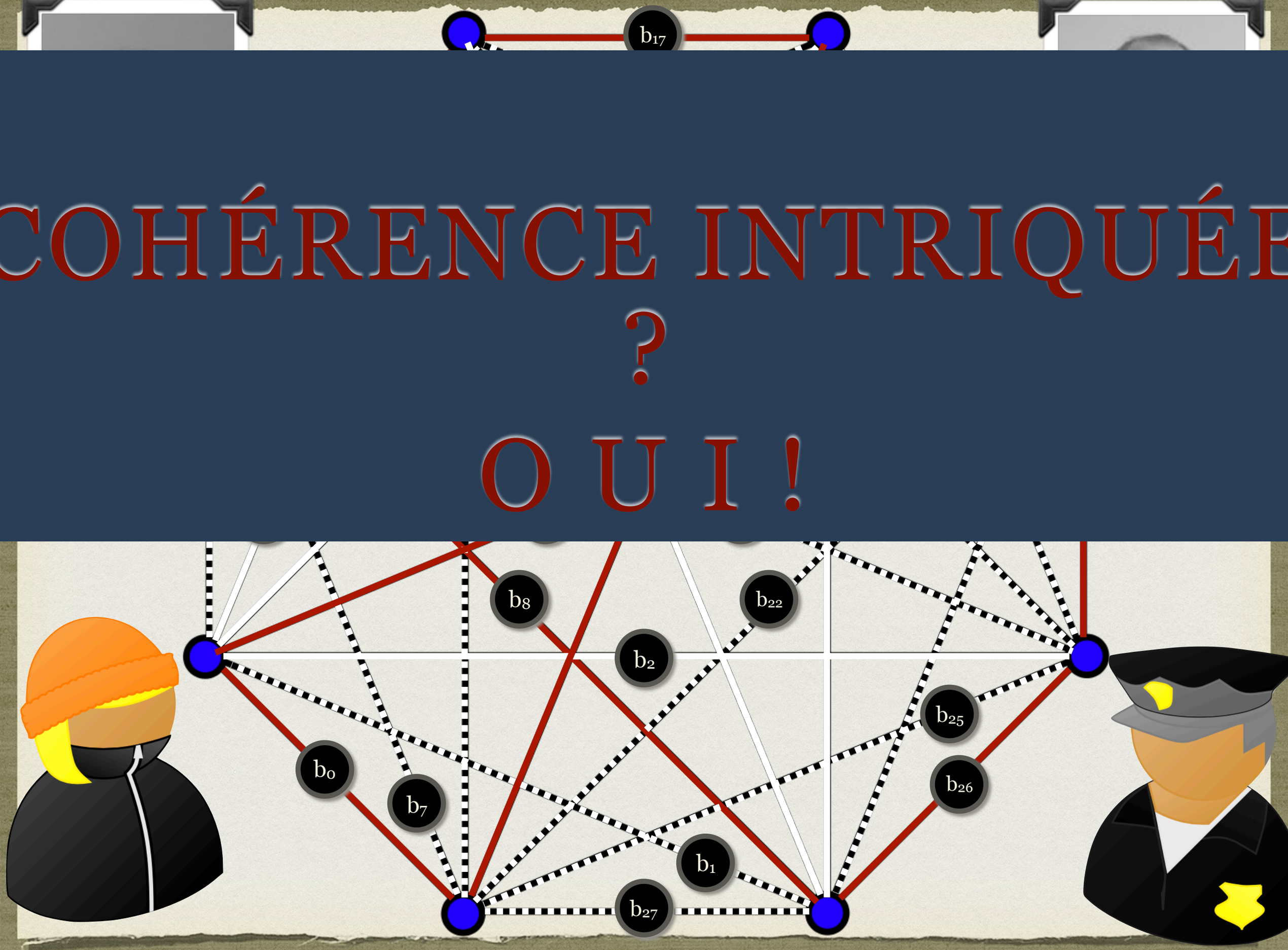
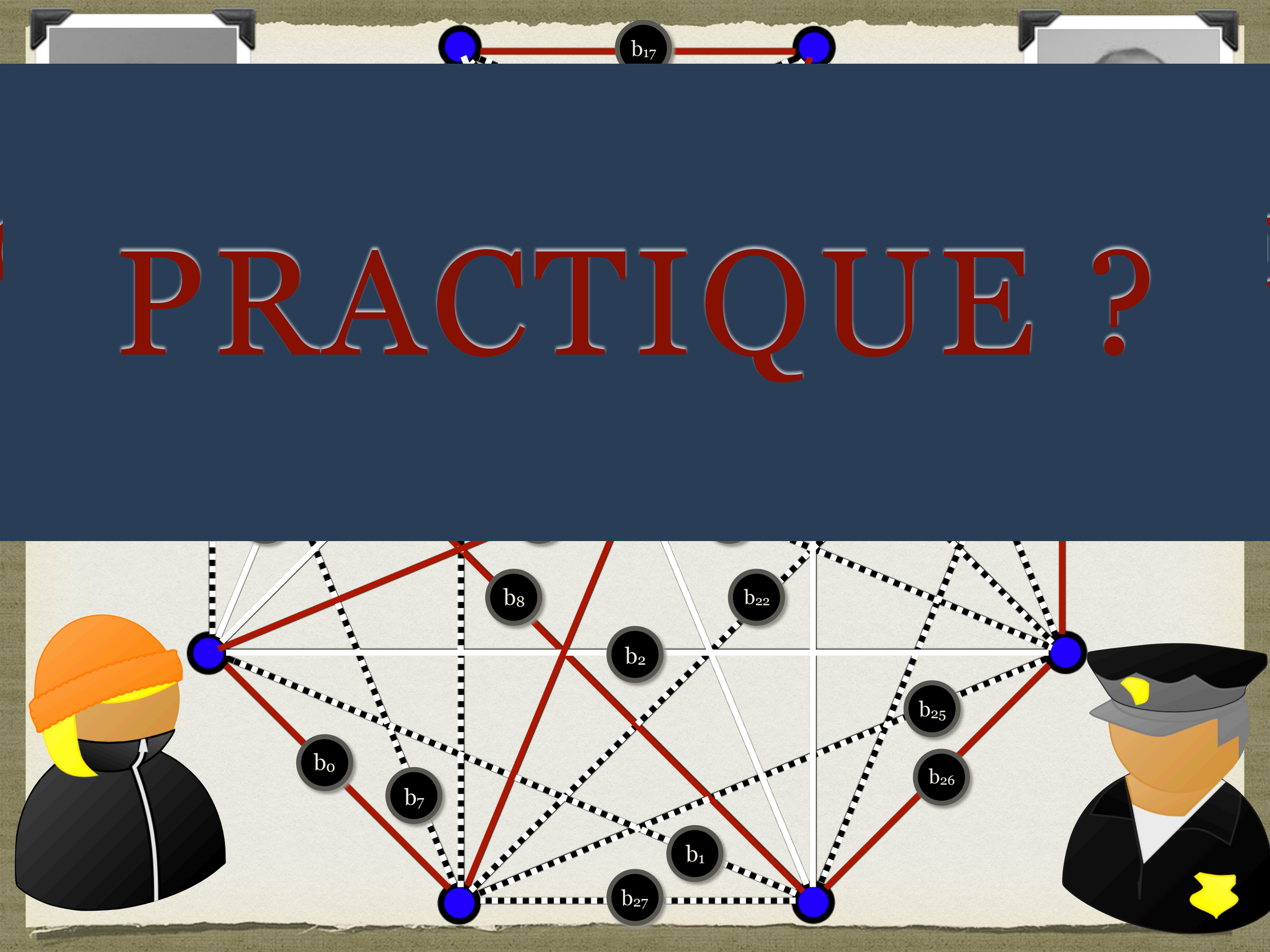


COHÉRENCE INTRIQUÉE ?

COHÉRENCE INTRIQUÉE ?

OUI !

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PRACTIQUE ?
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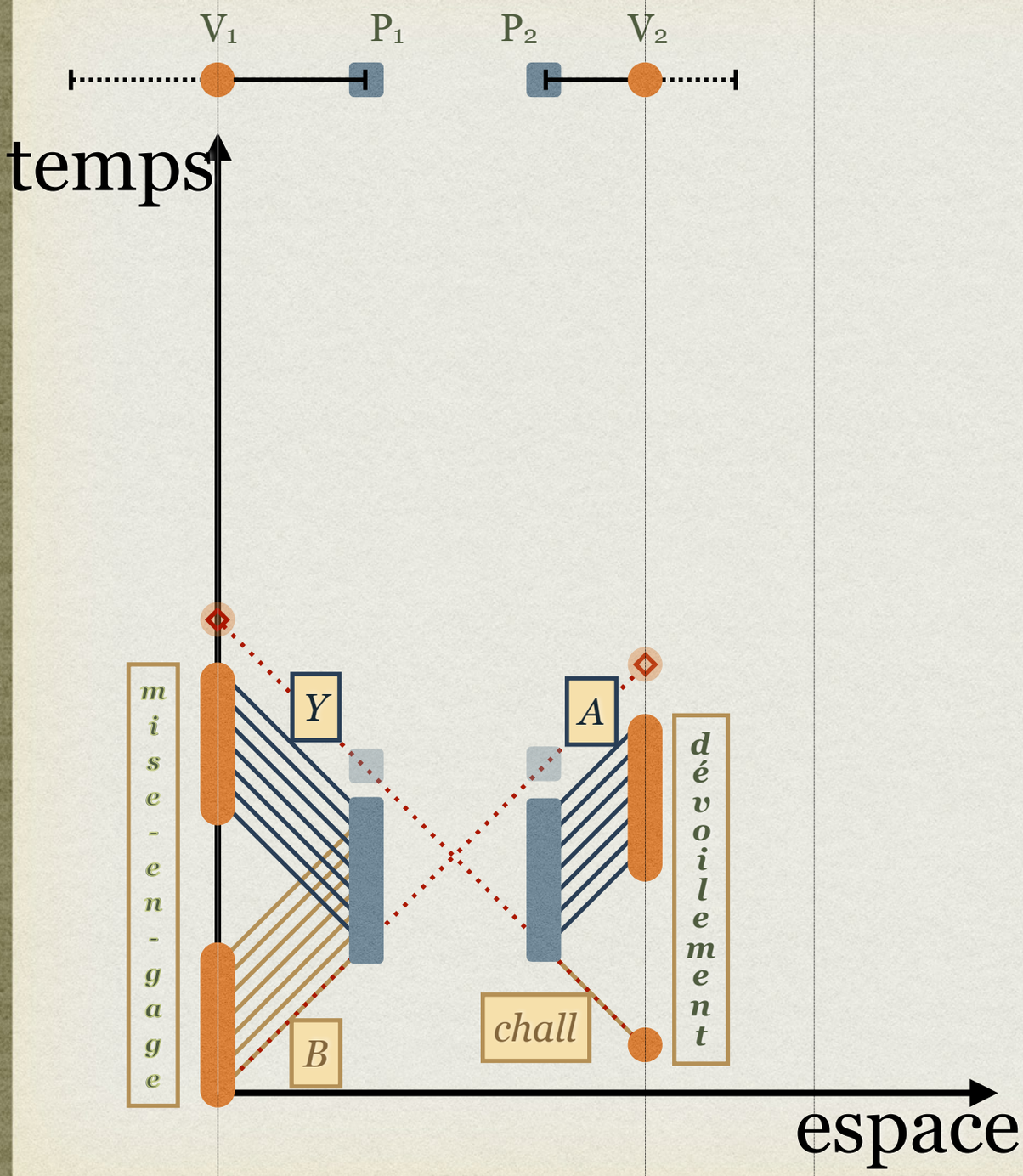
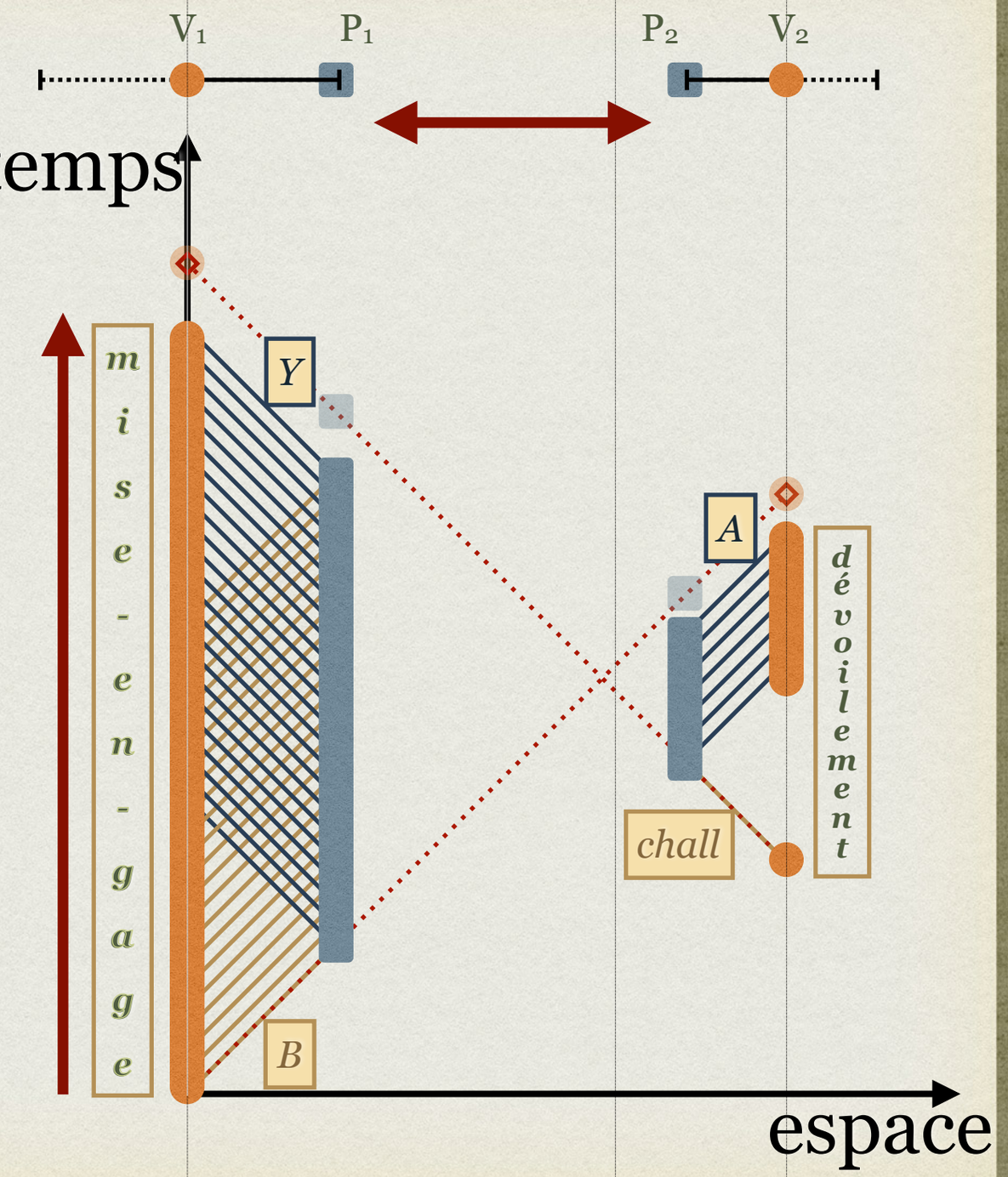
PRACTIQUE ?

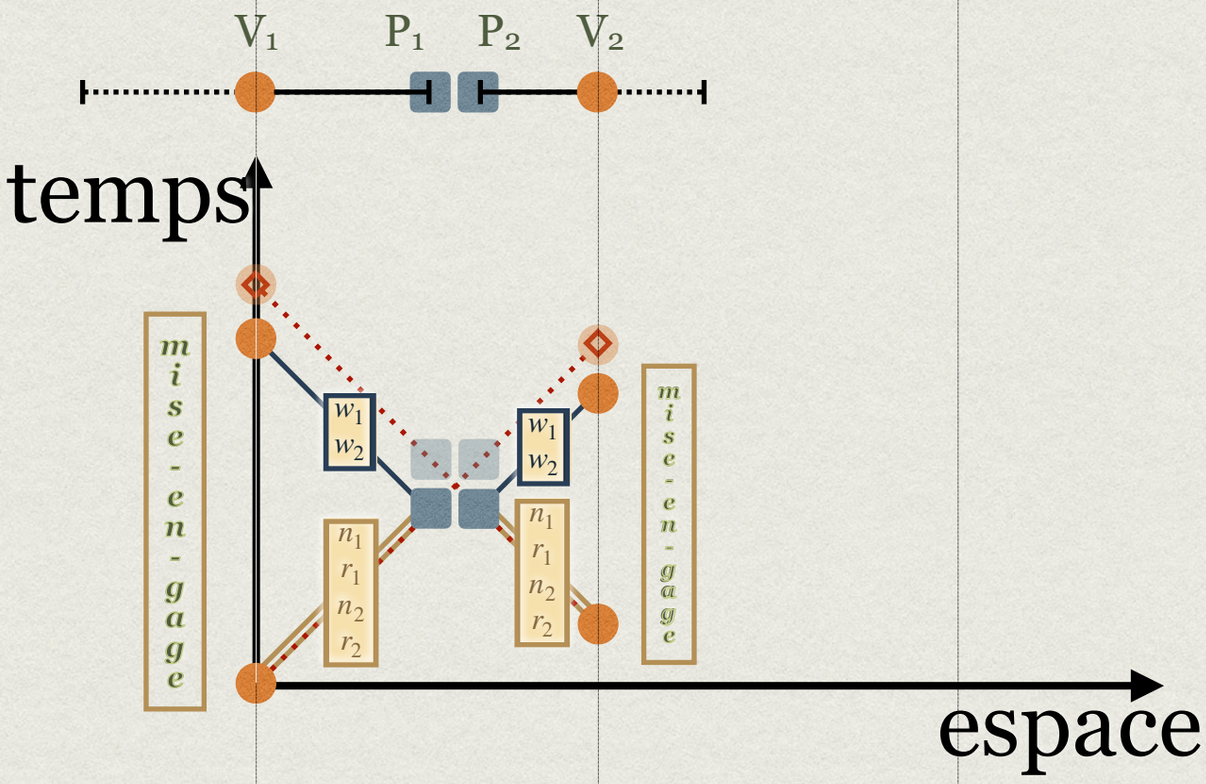
OH QUE NON !

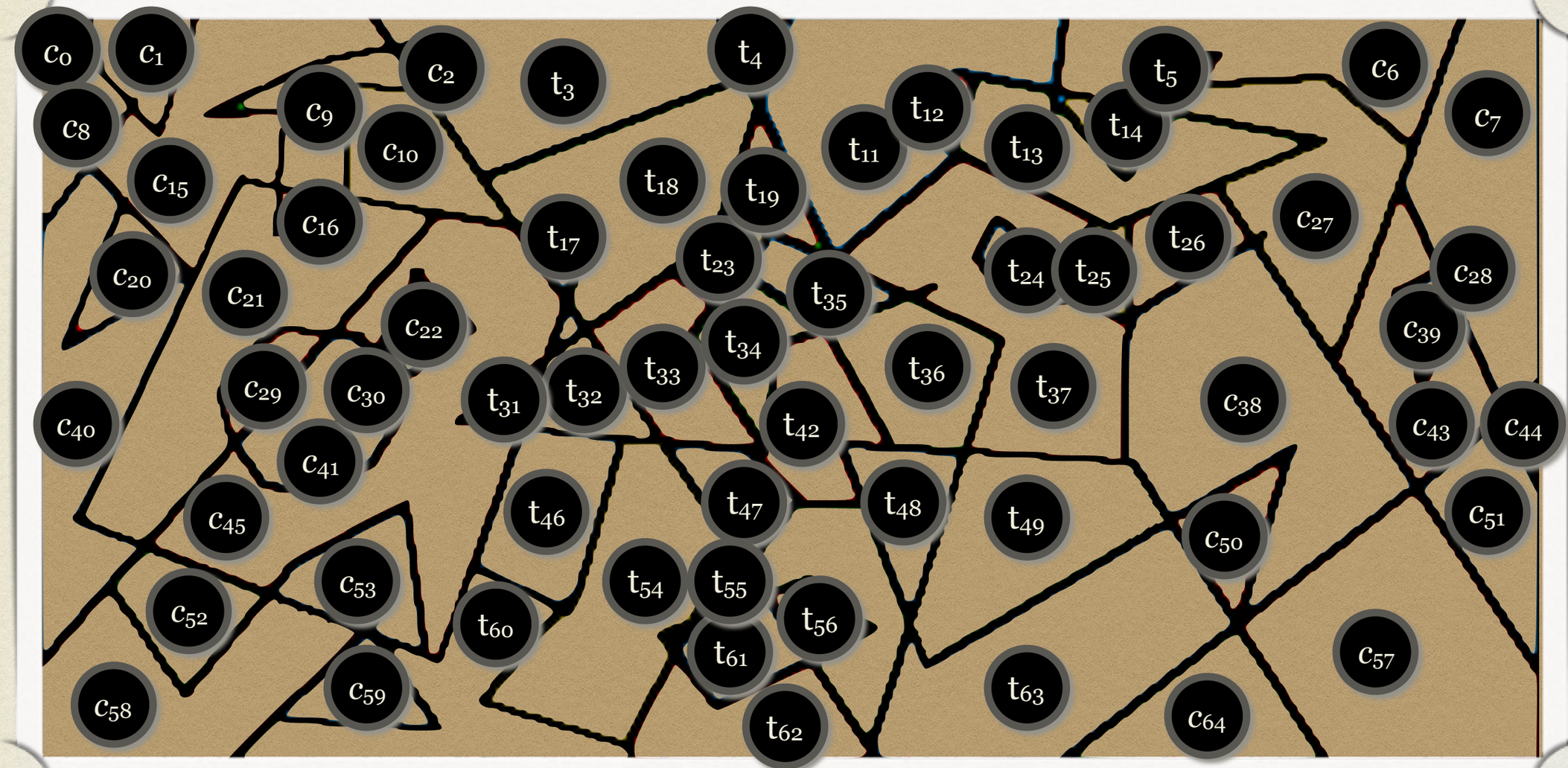
Chailloux-Leverrier





Massenet Salvail Stinchcombe Yang

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NOTRE APPROCHE

(ZK)MIPs





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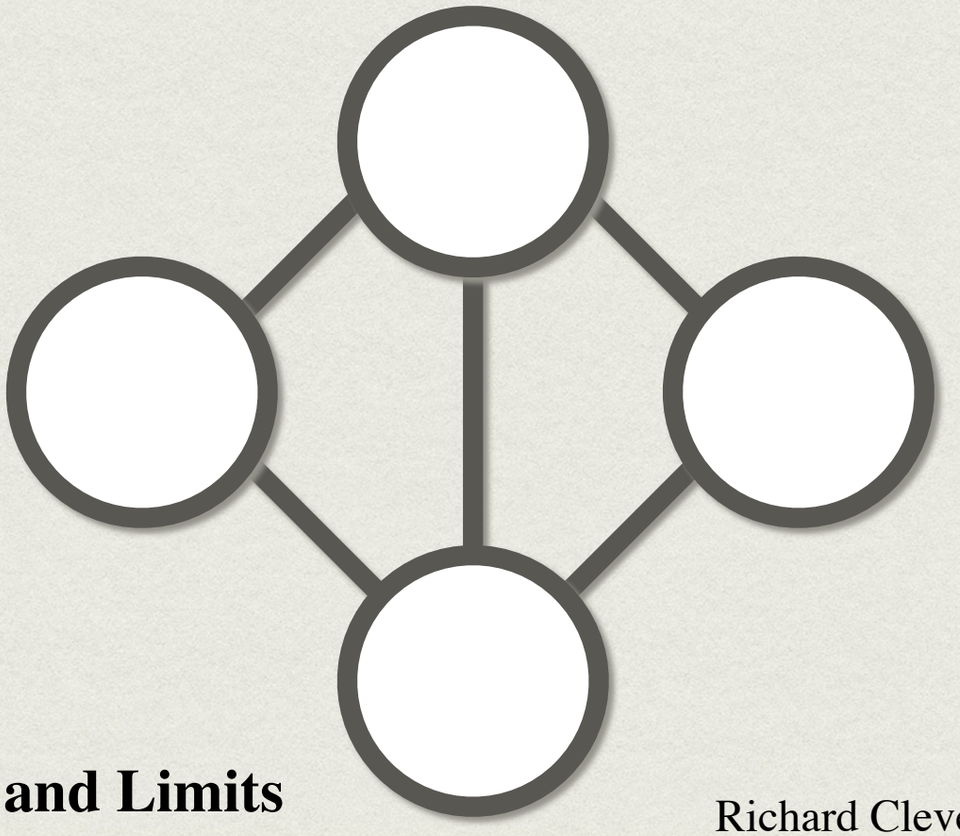

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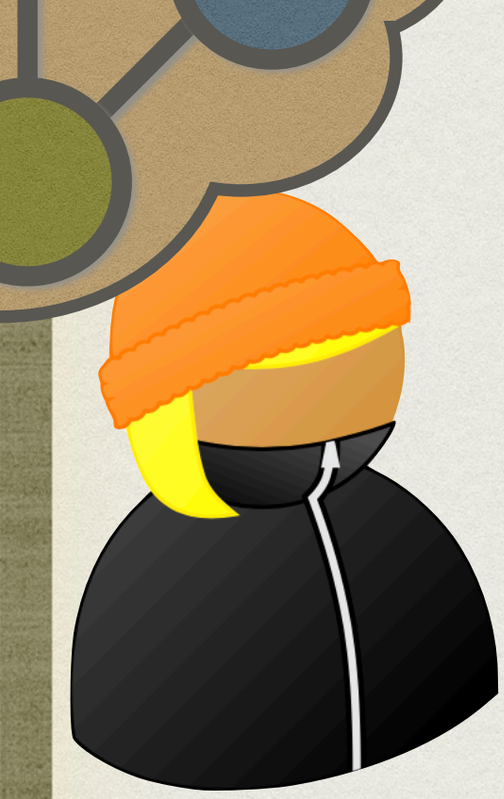
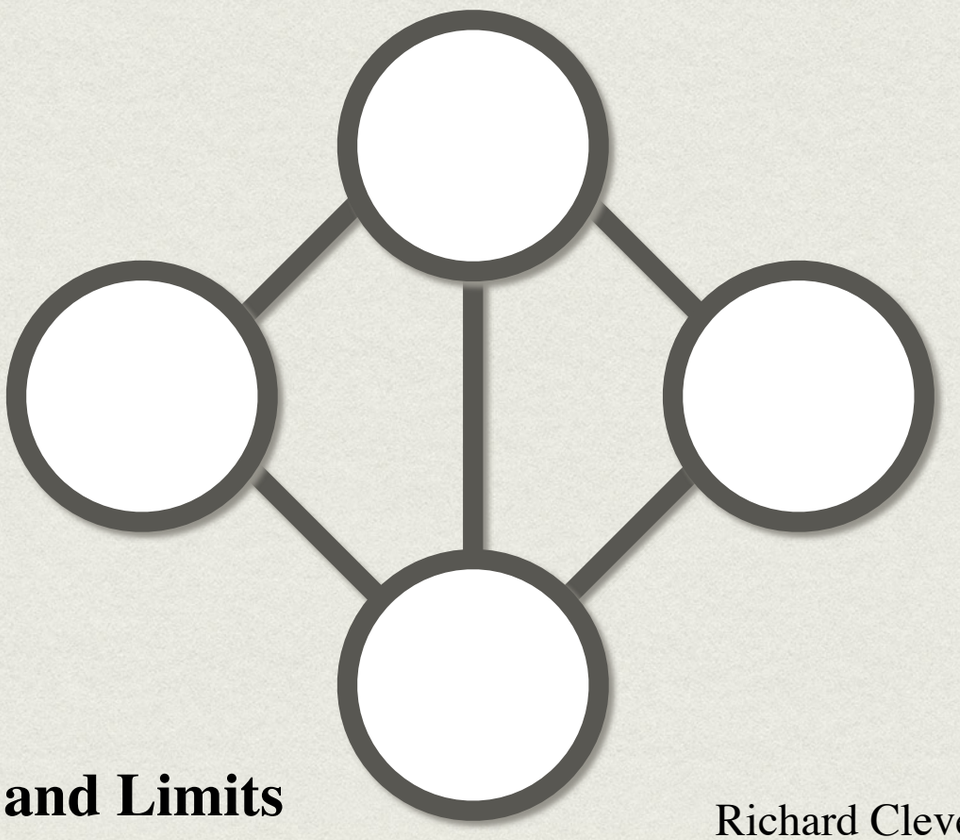
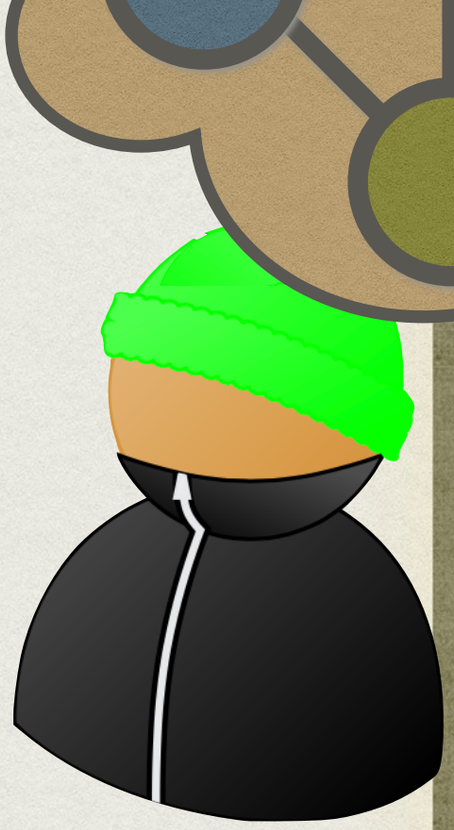

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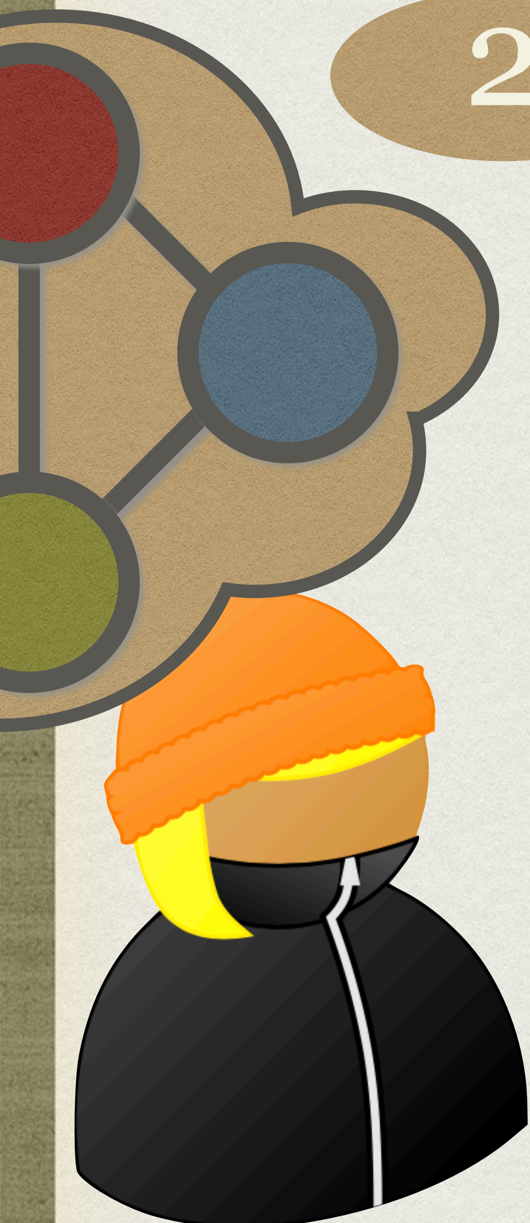

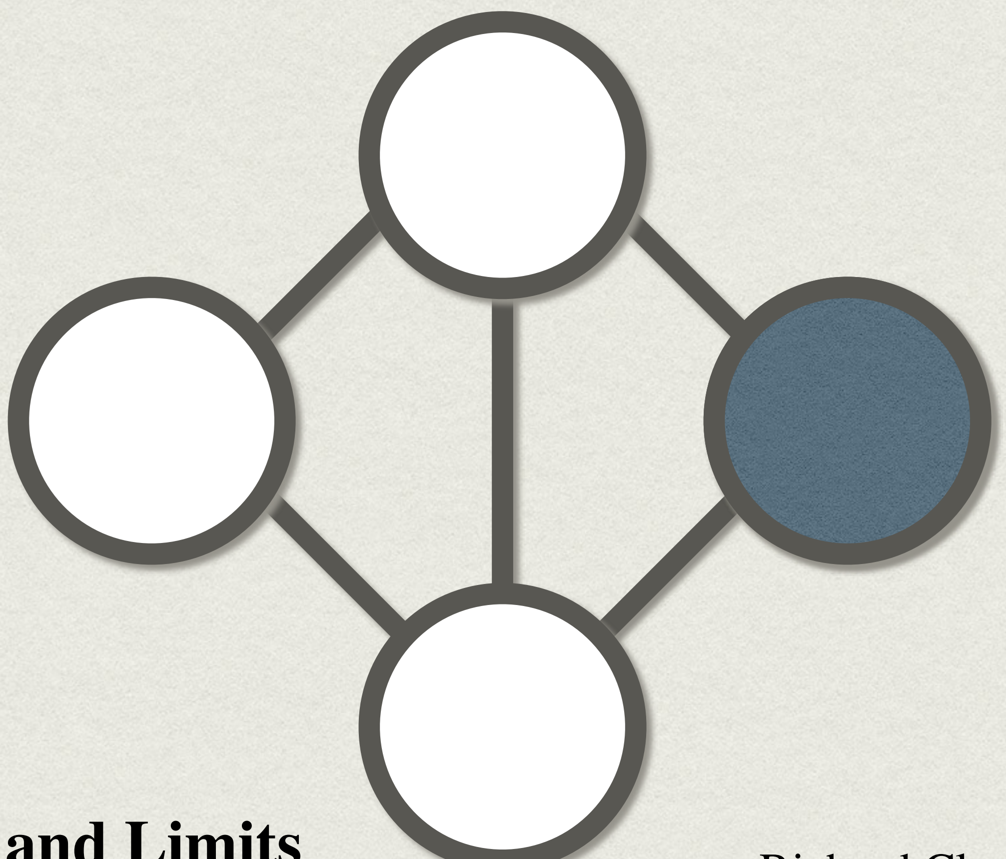

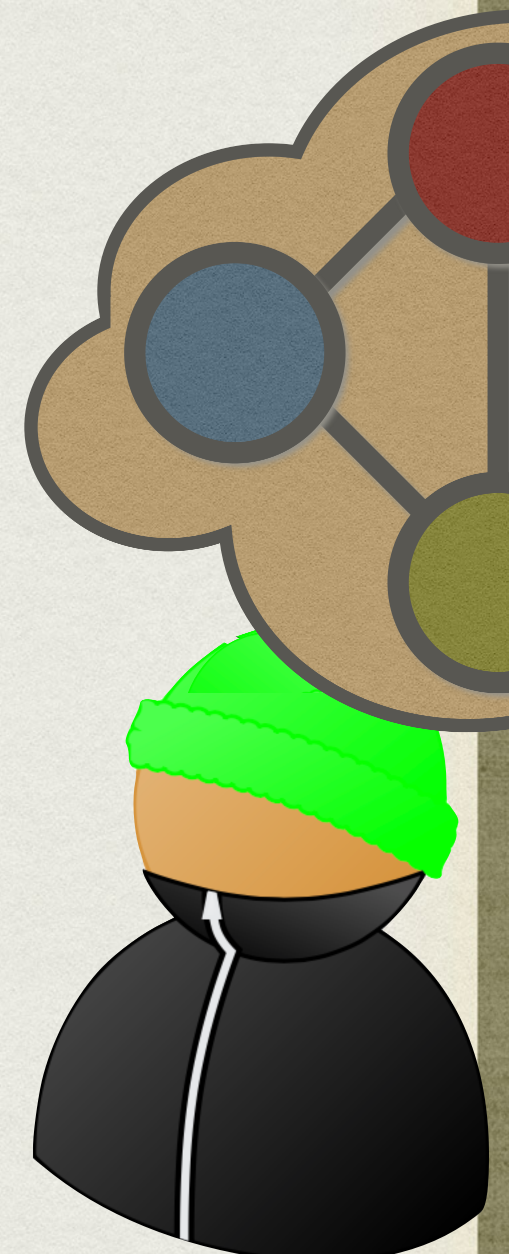

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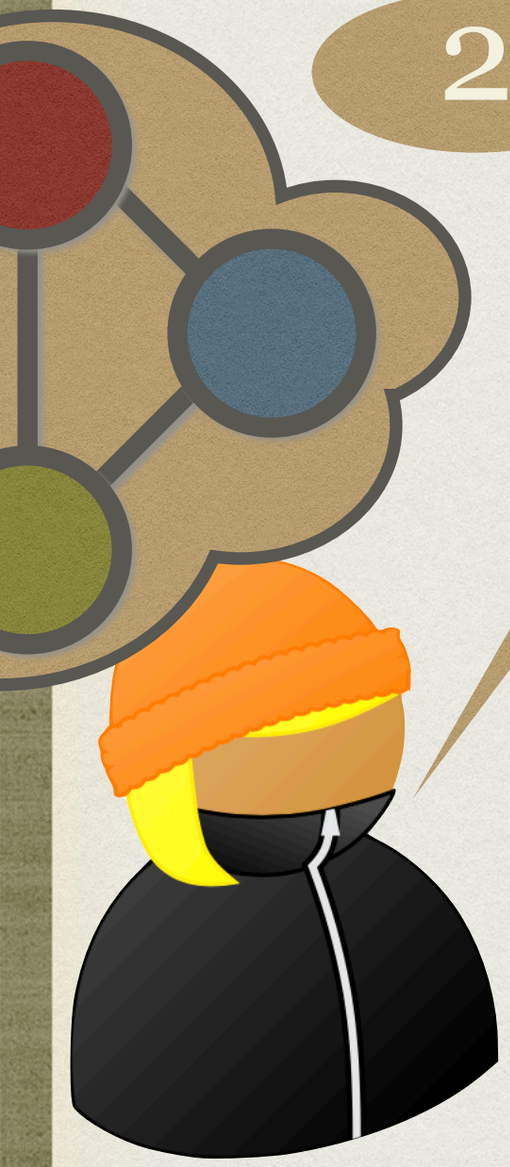

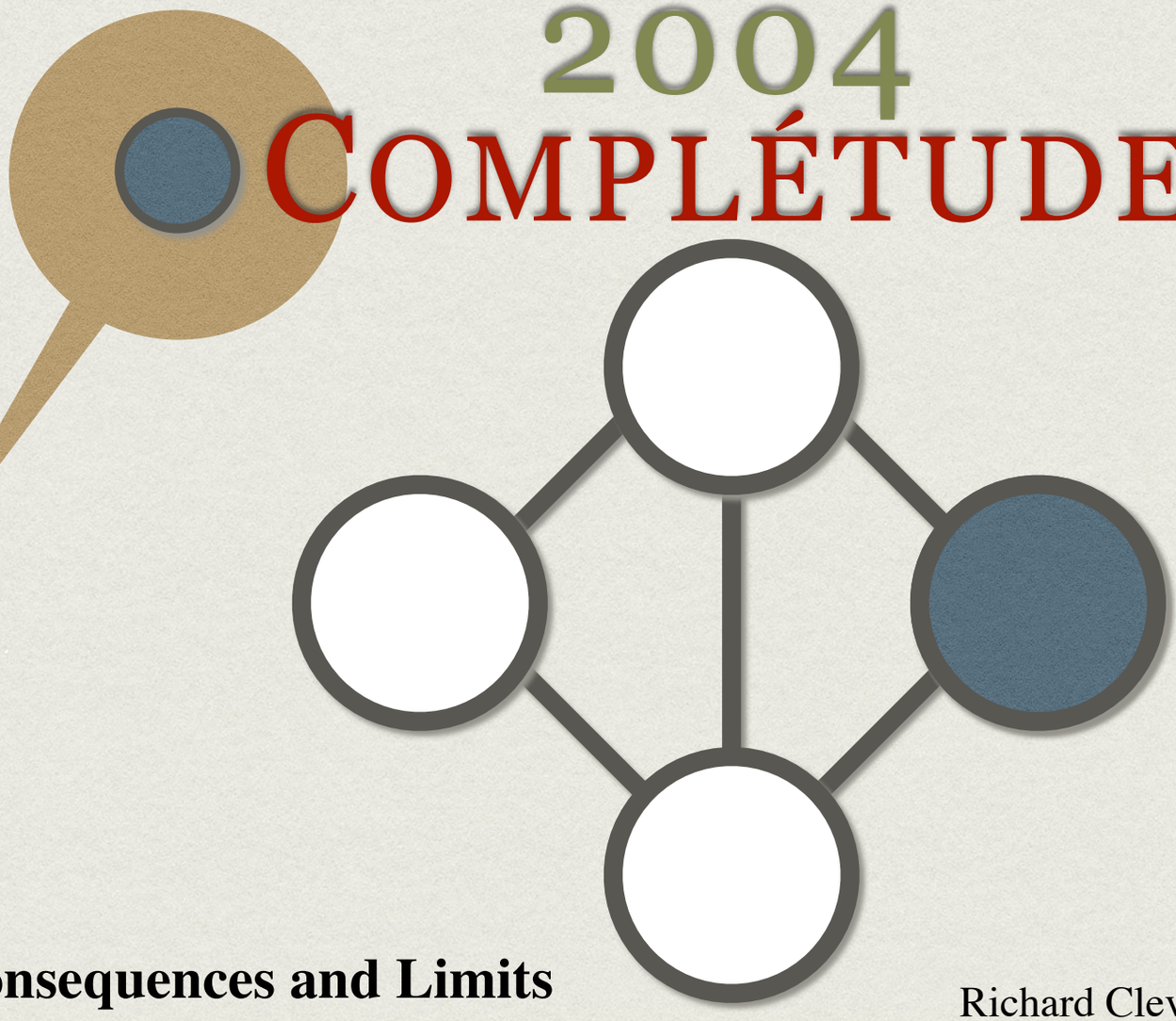

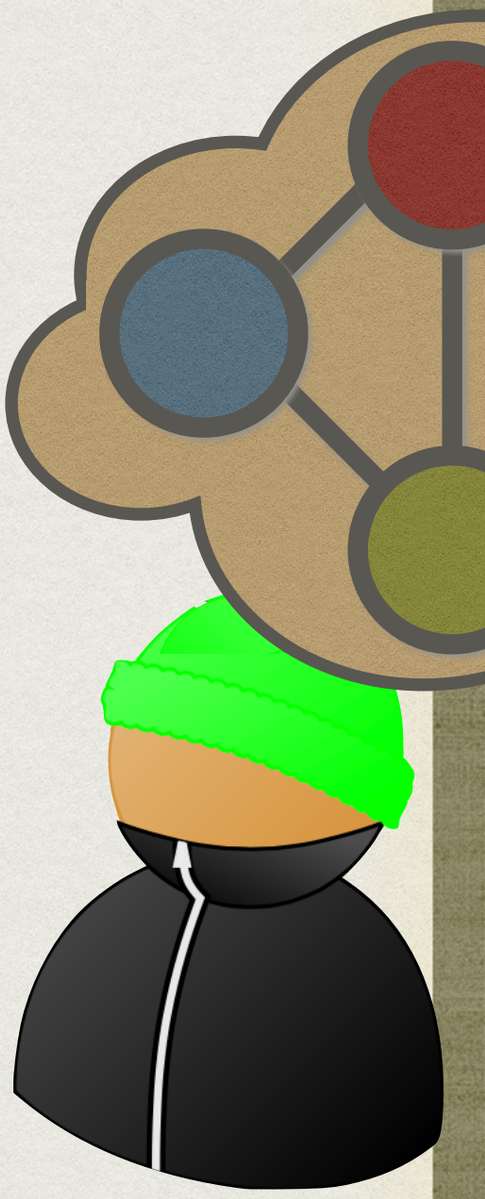

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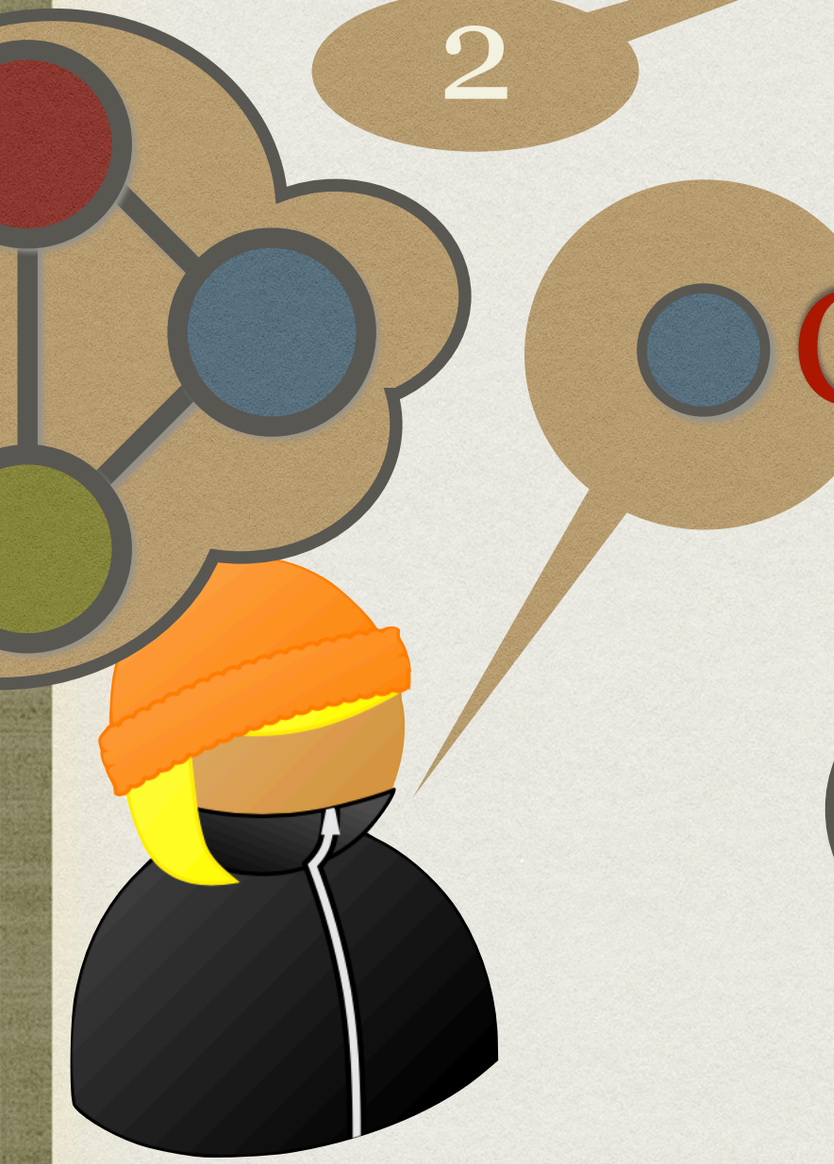

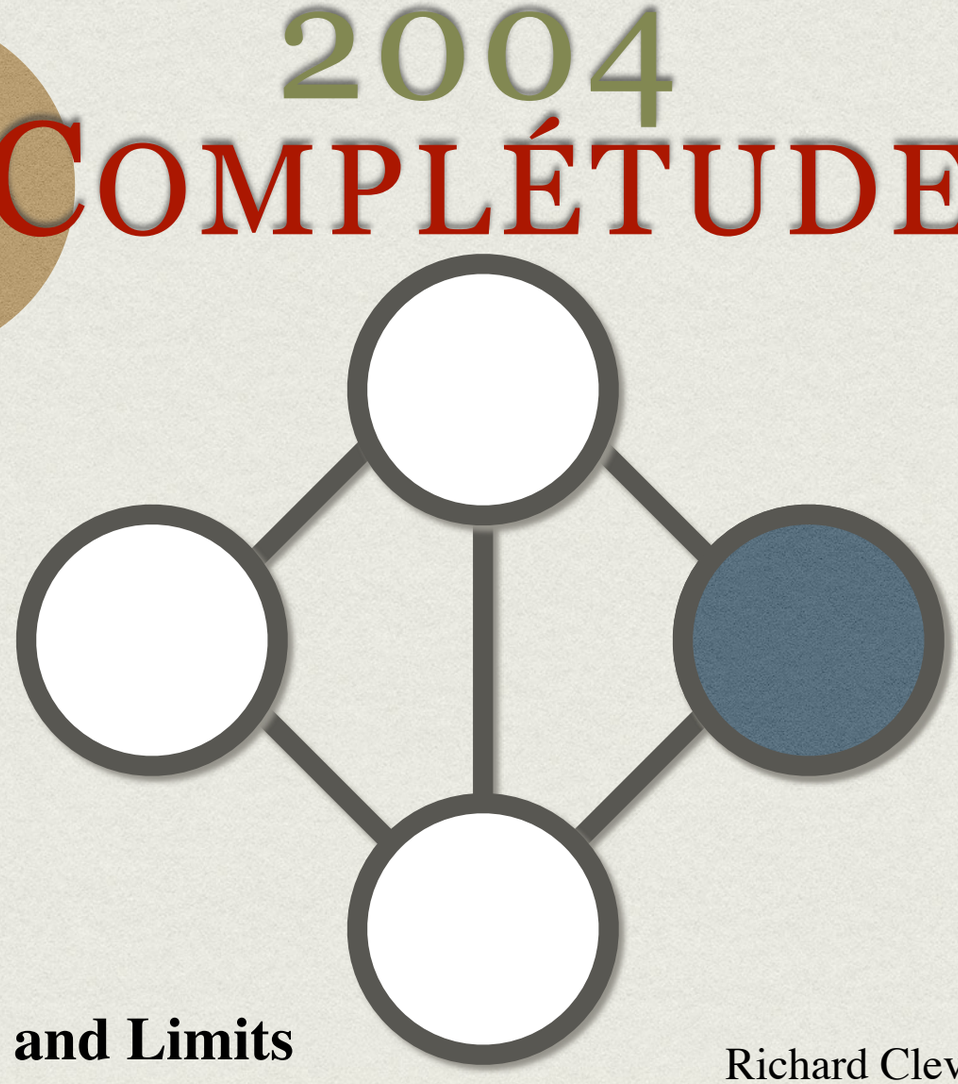

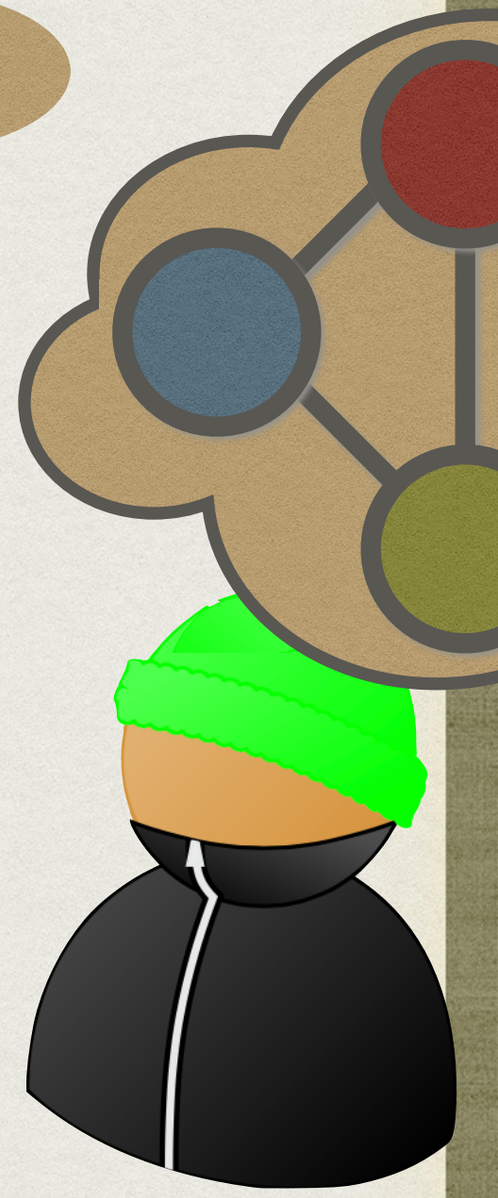

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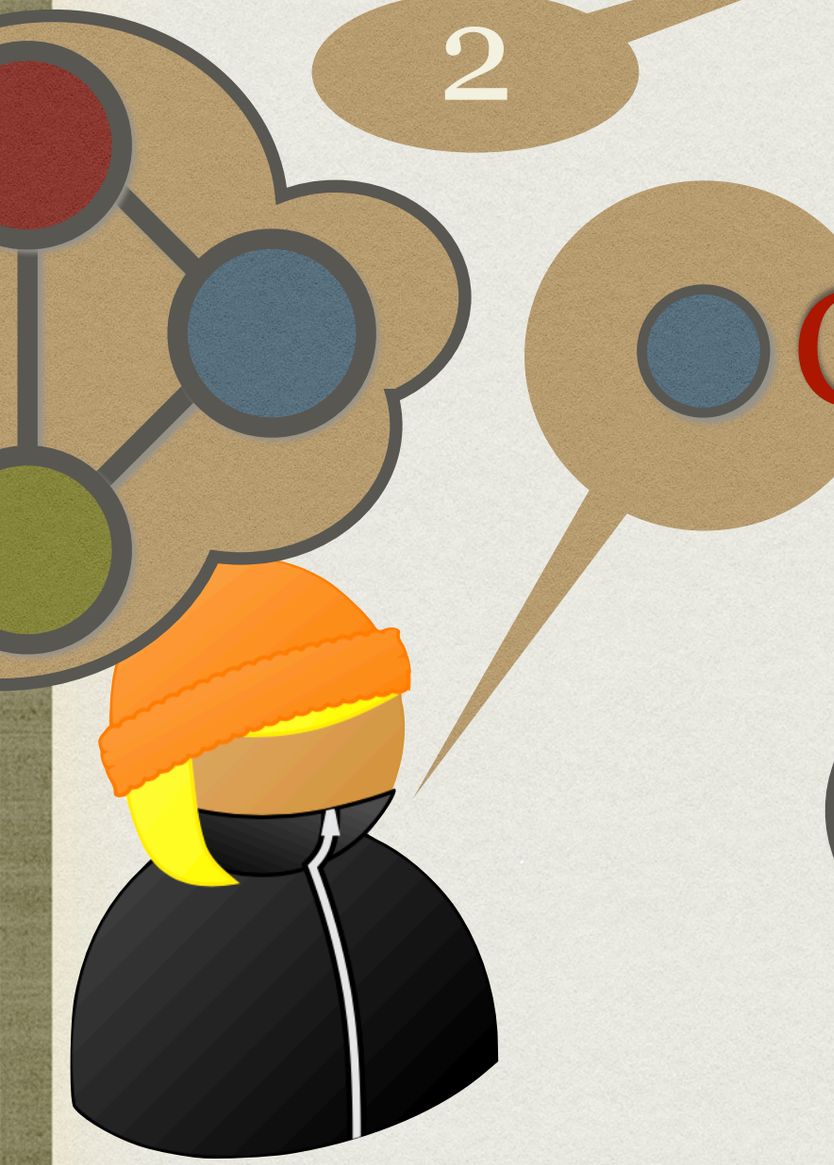

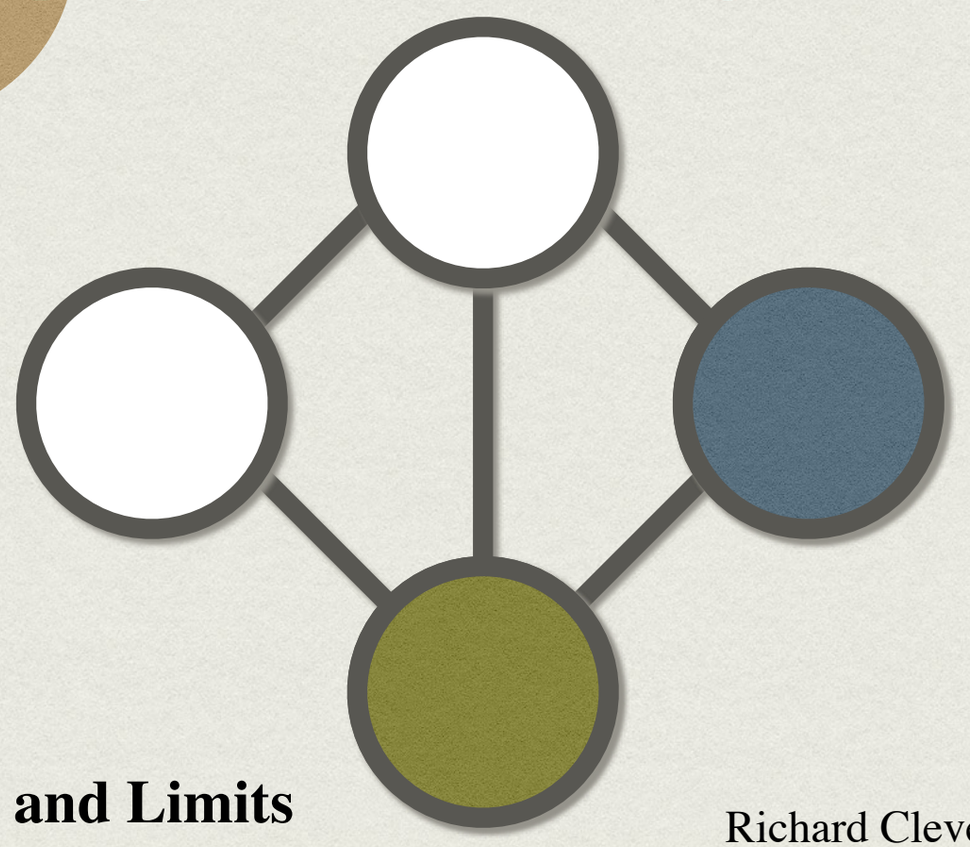

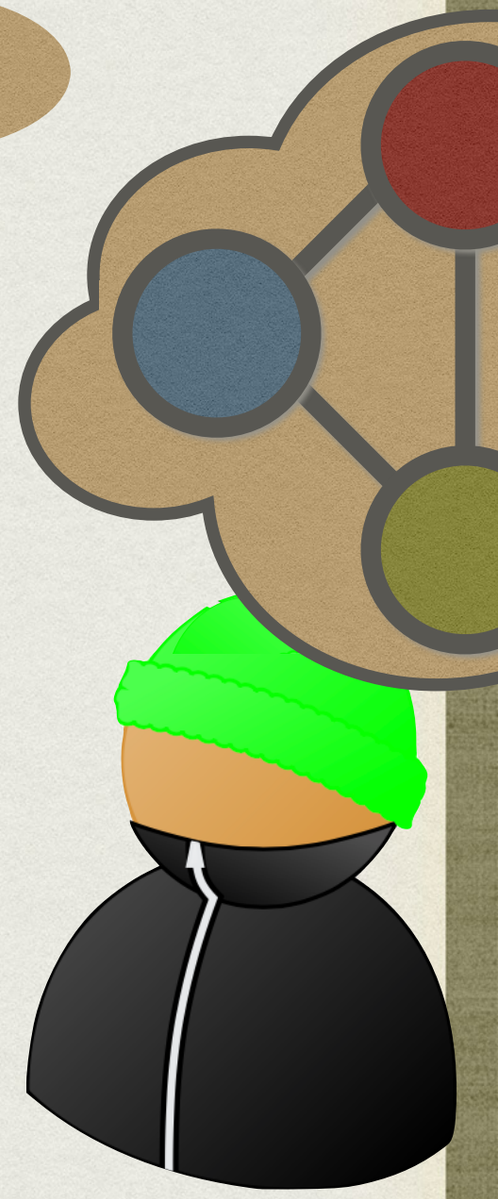

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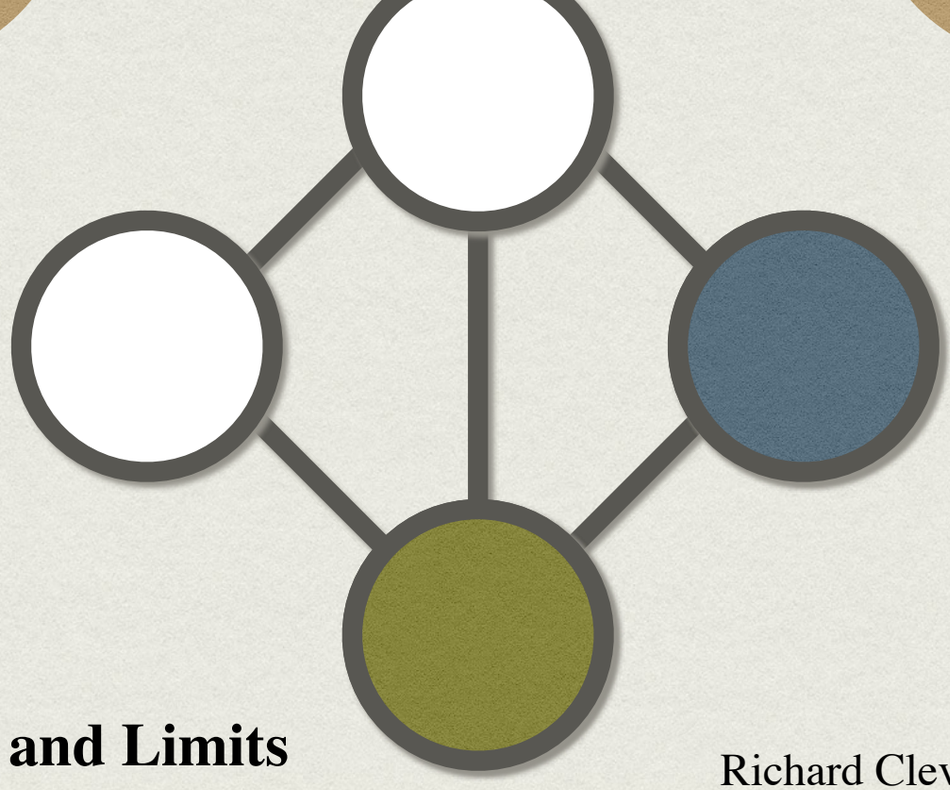

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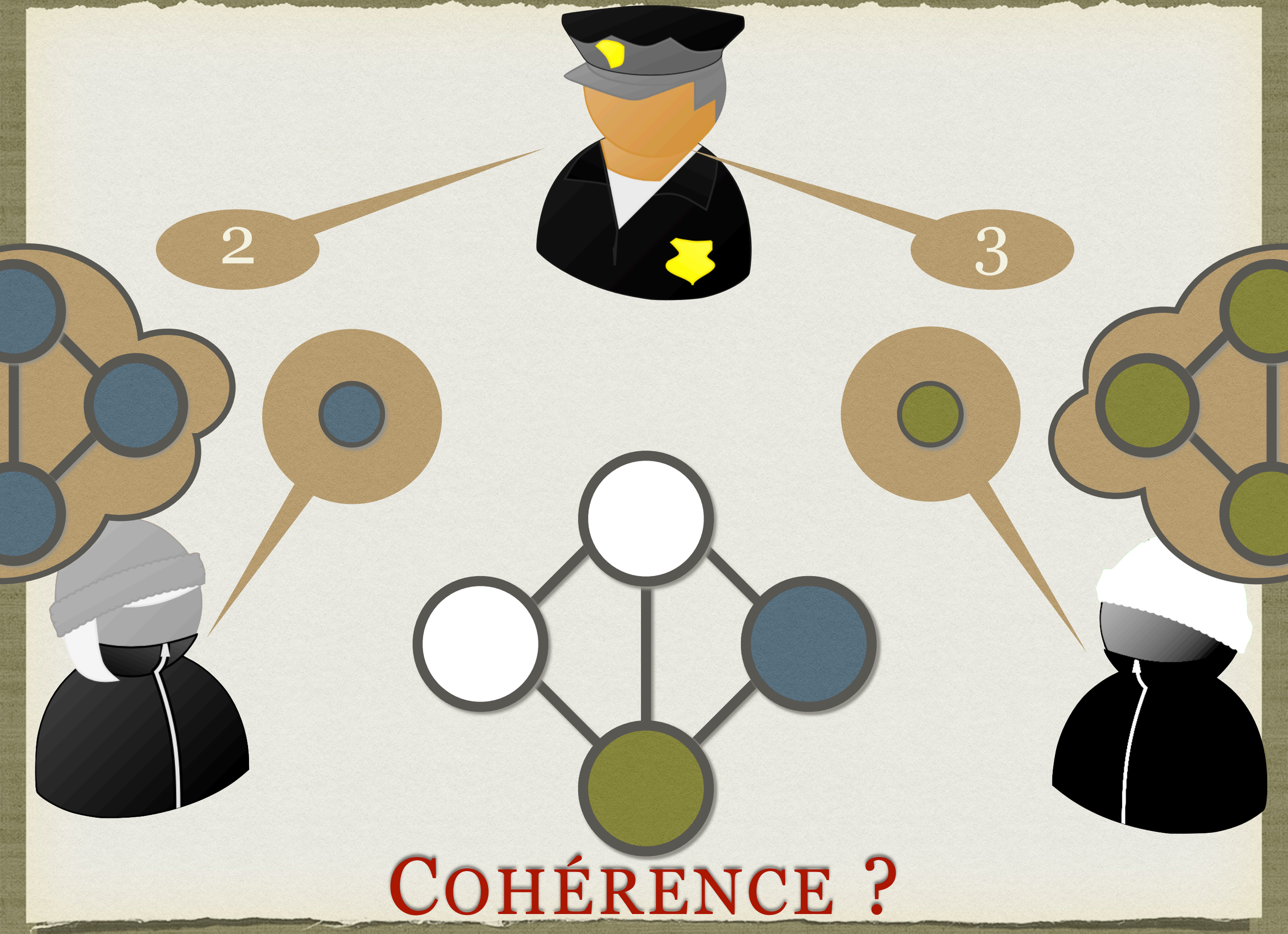

Cohérence ?

2

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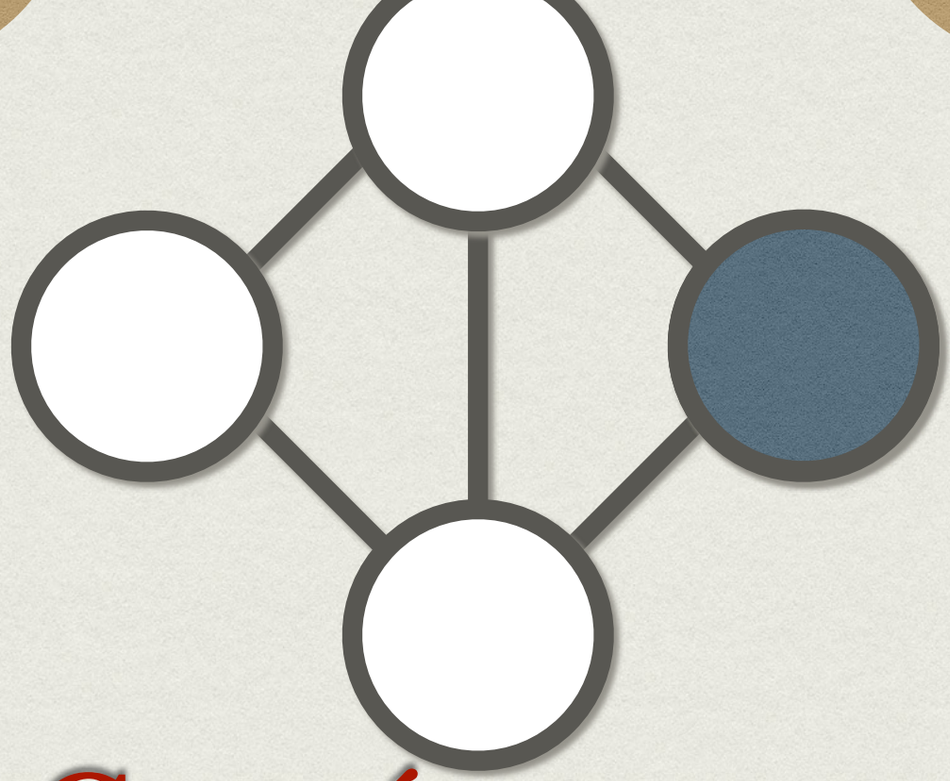
Complétude



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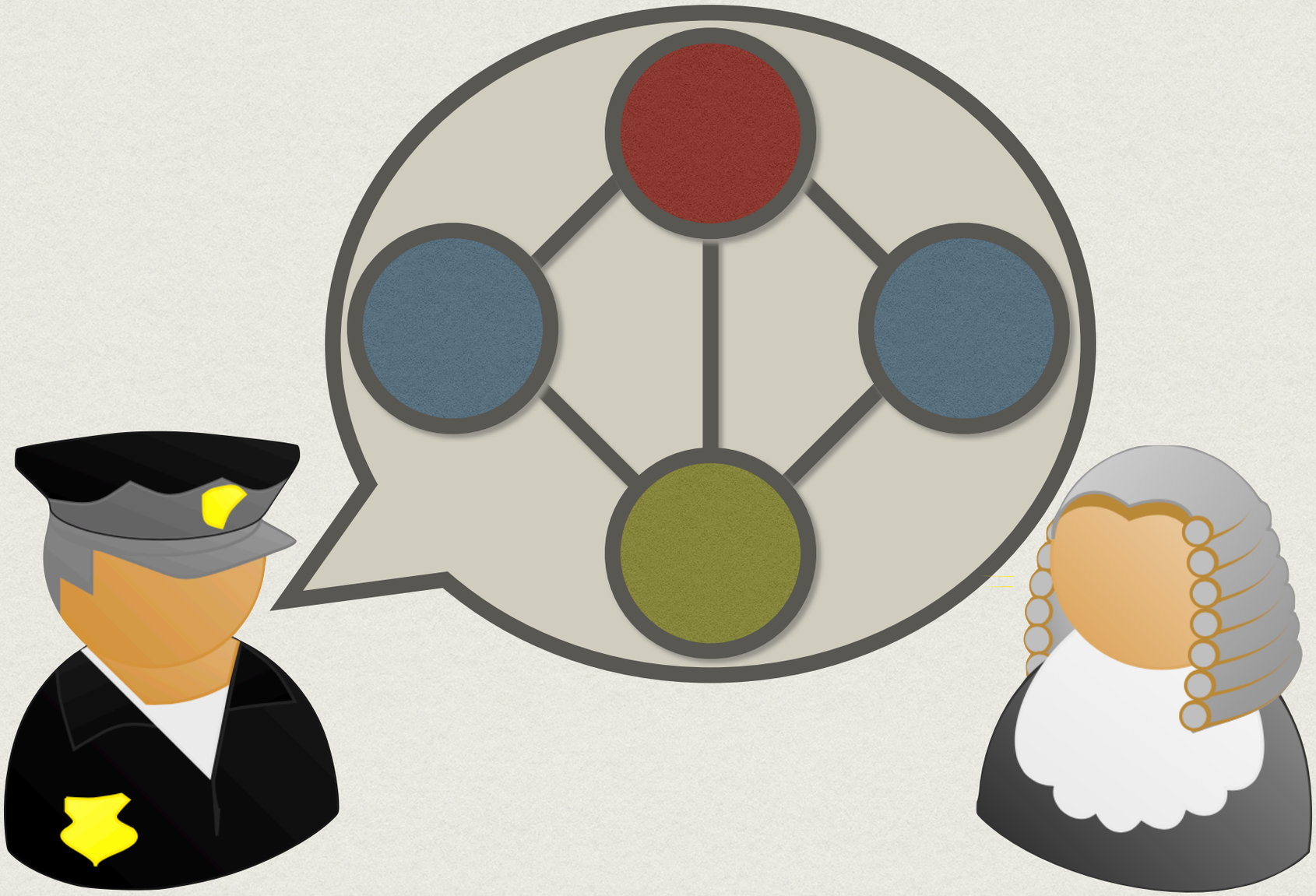

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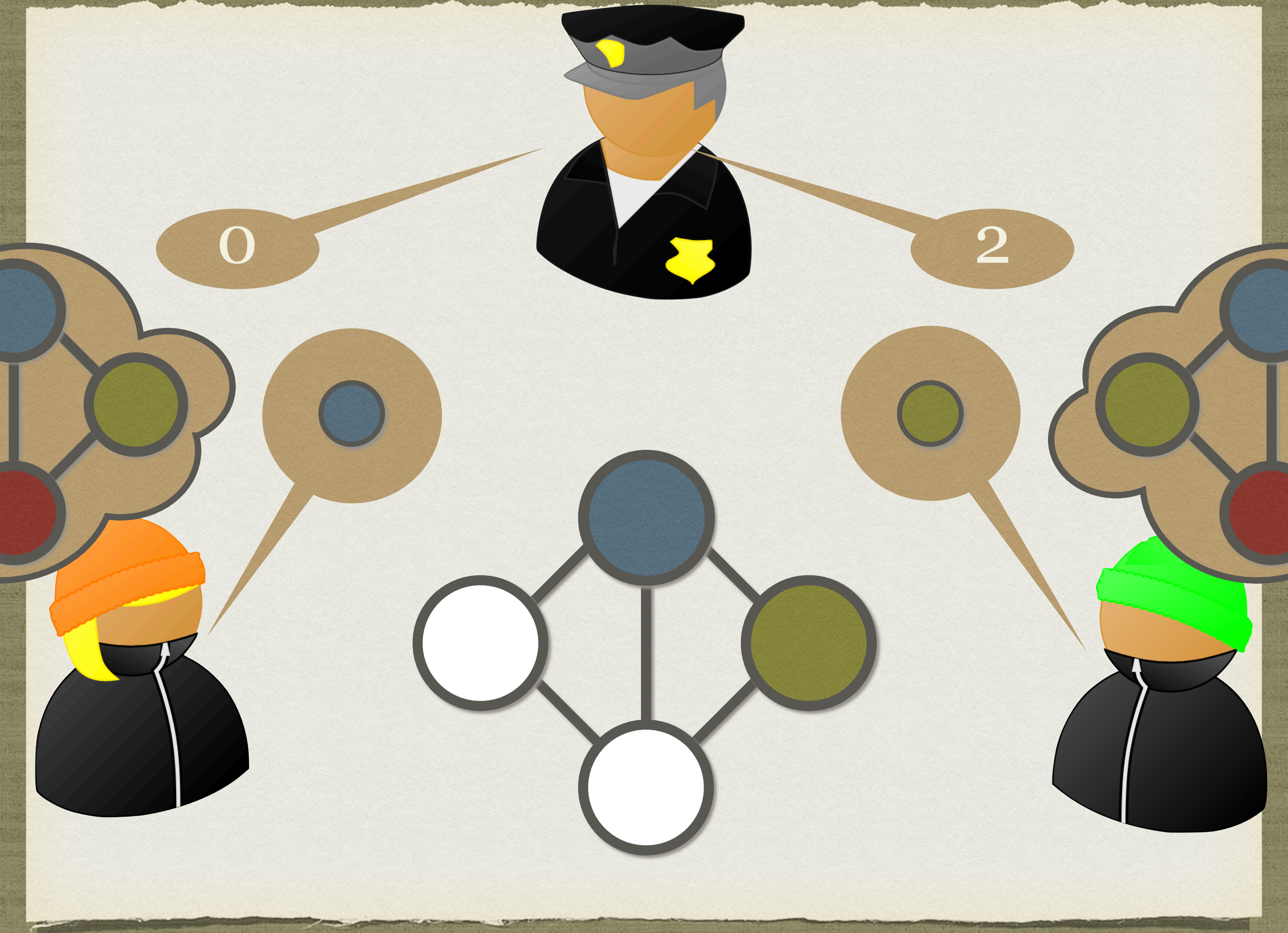
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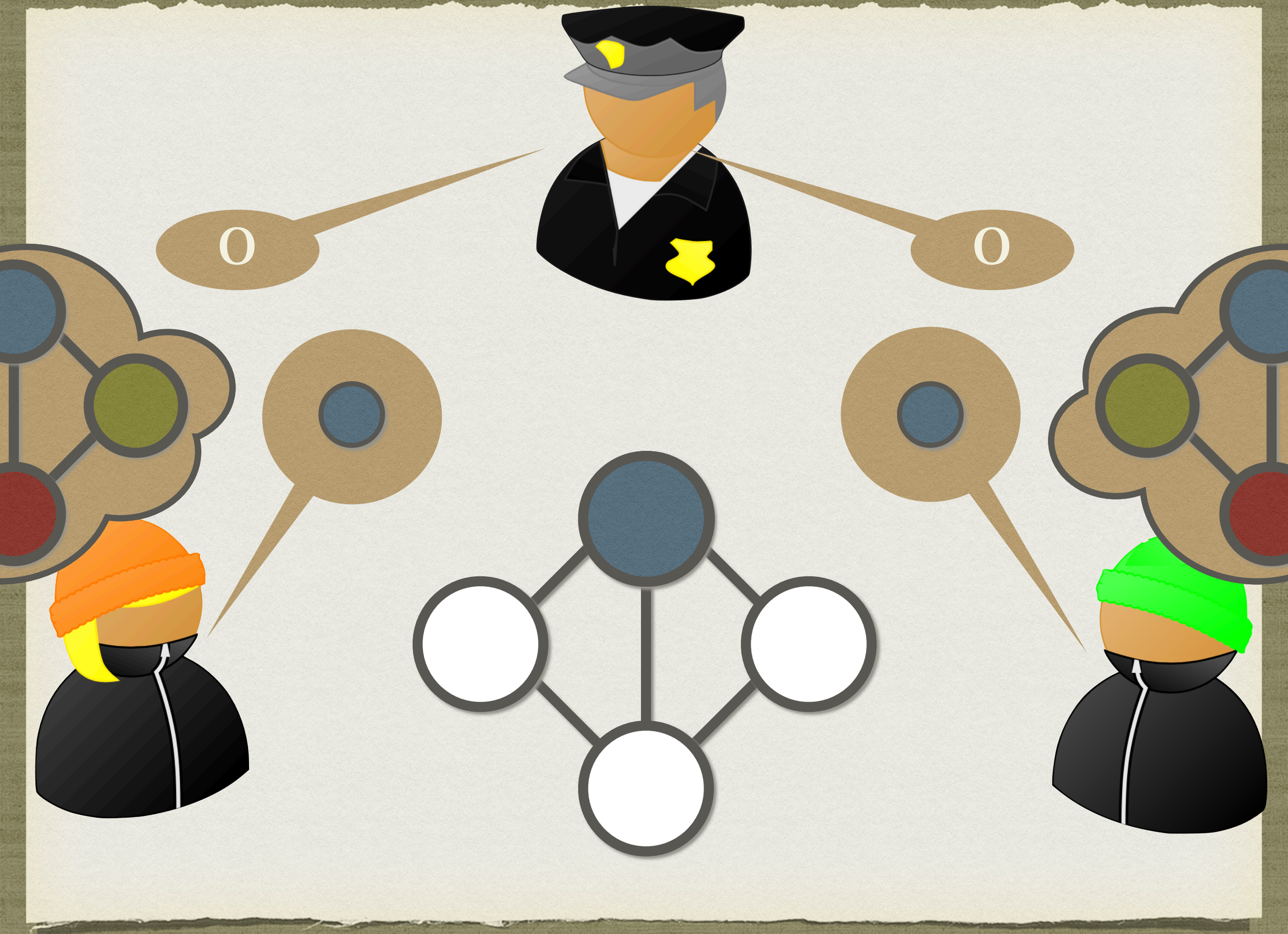
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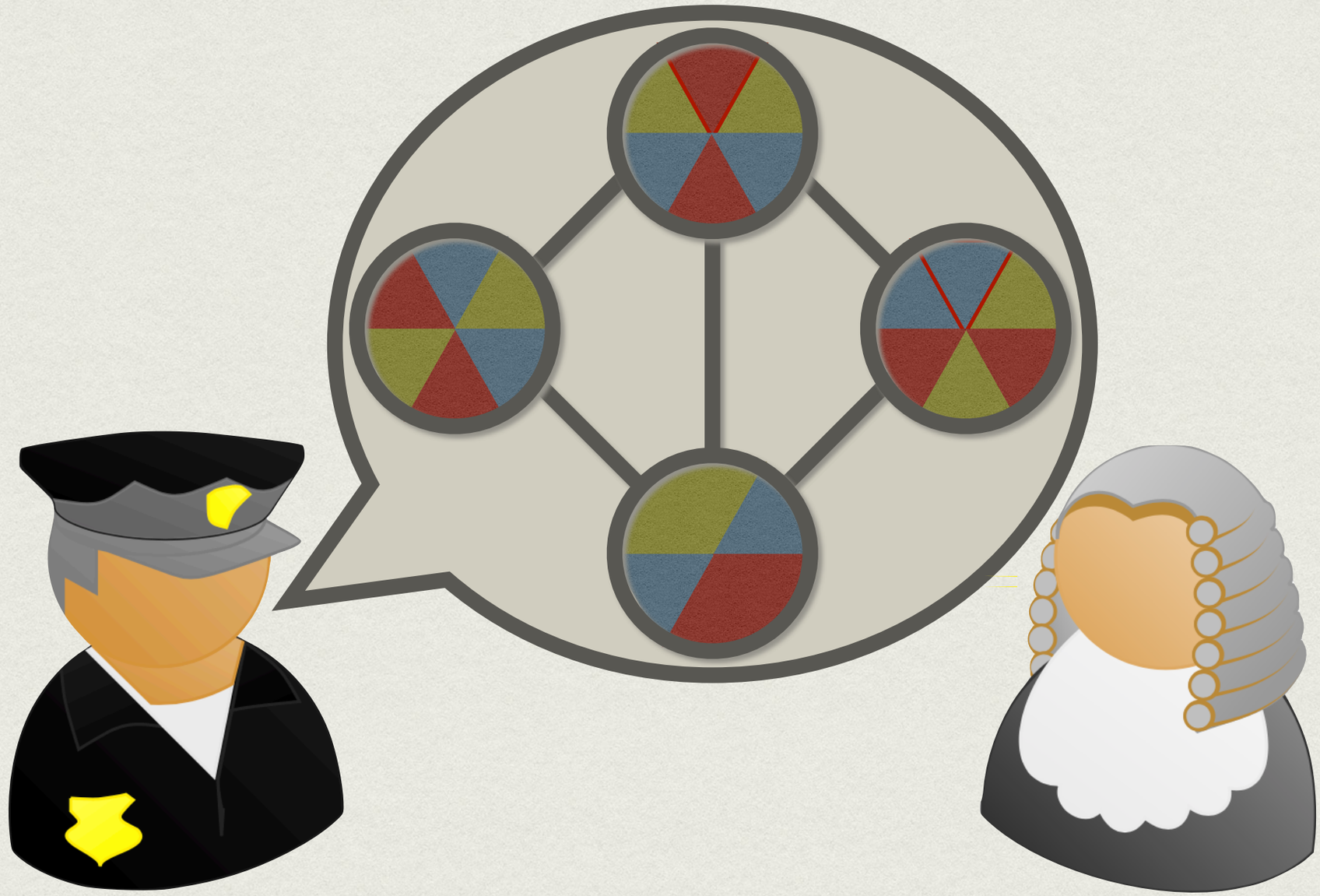

ZK à Vérificateur-honète

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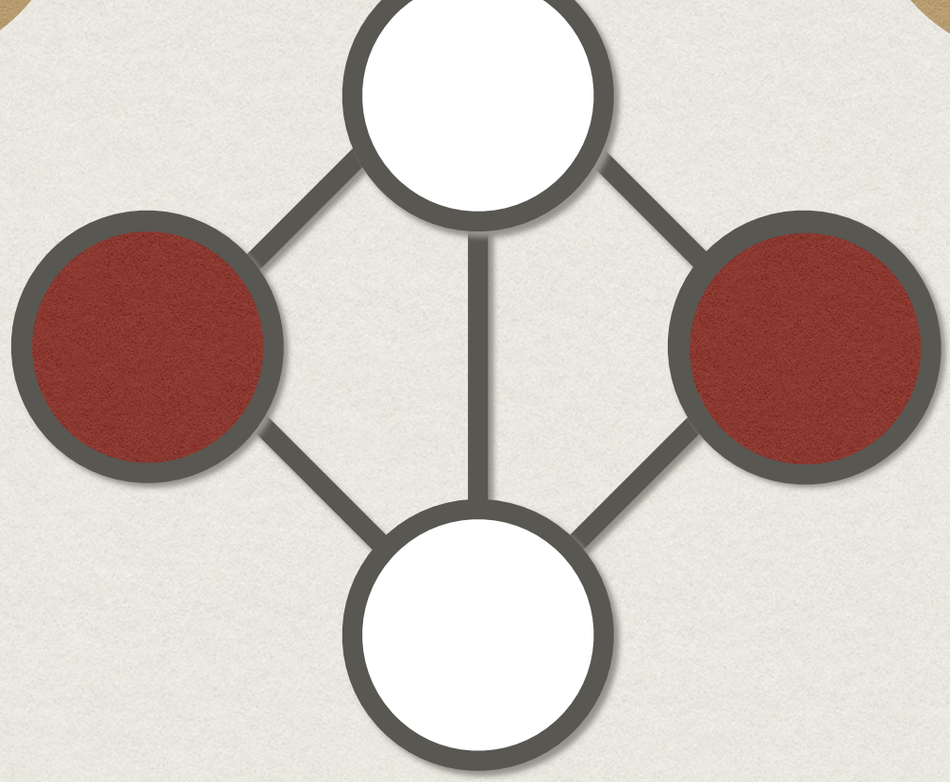
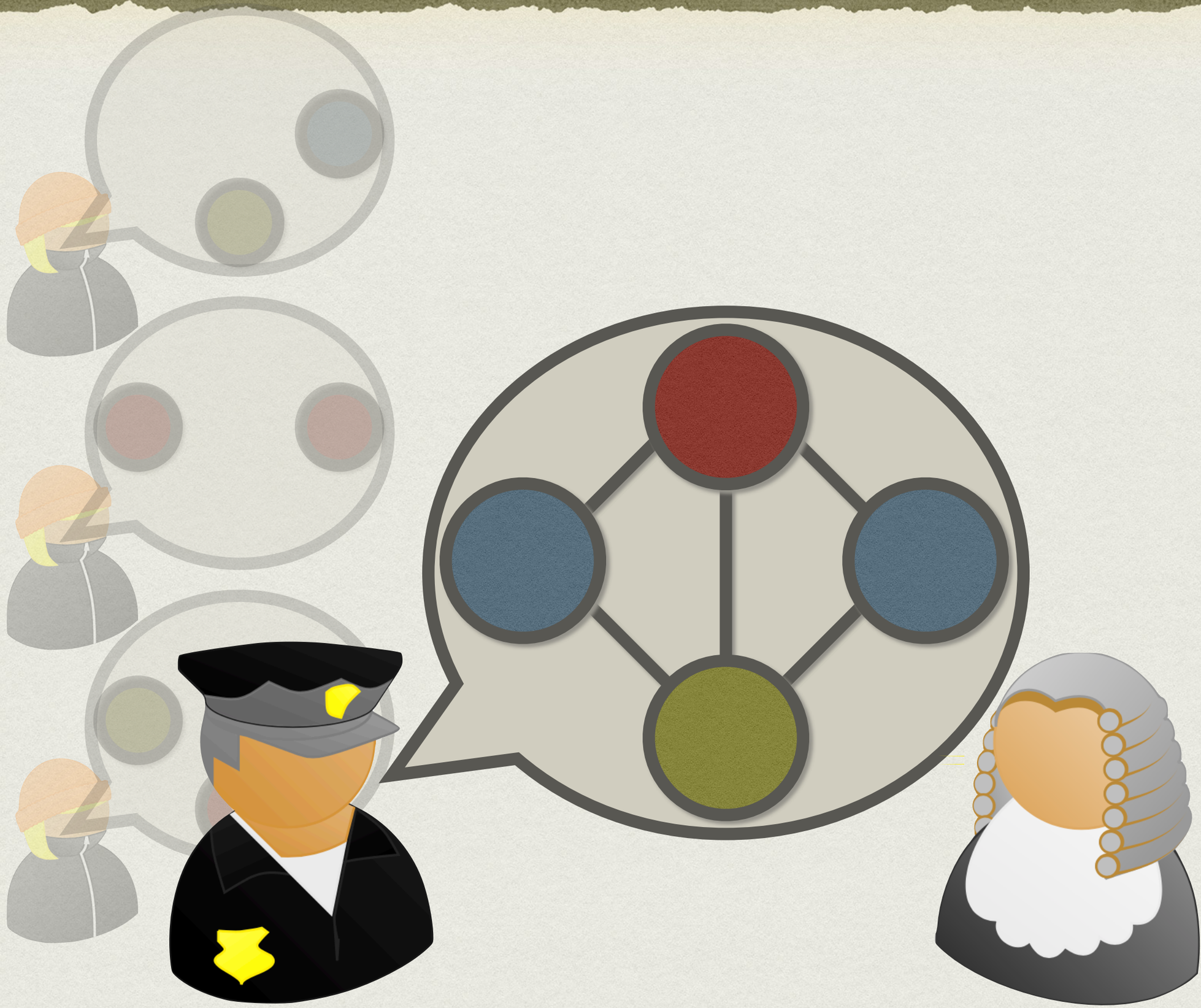
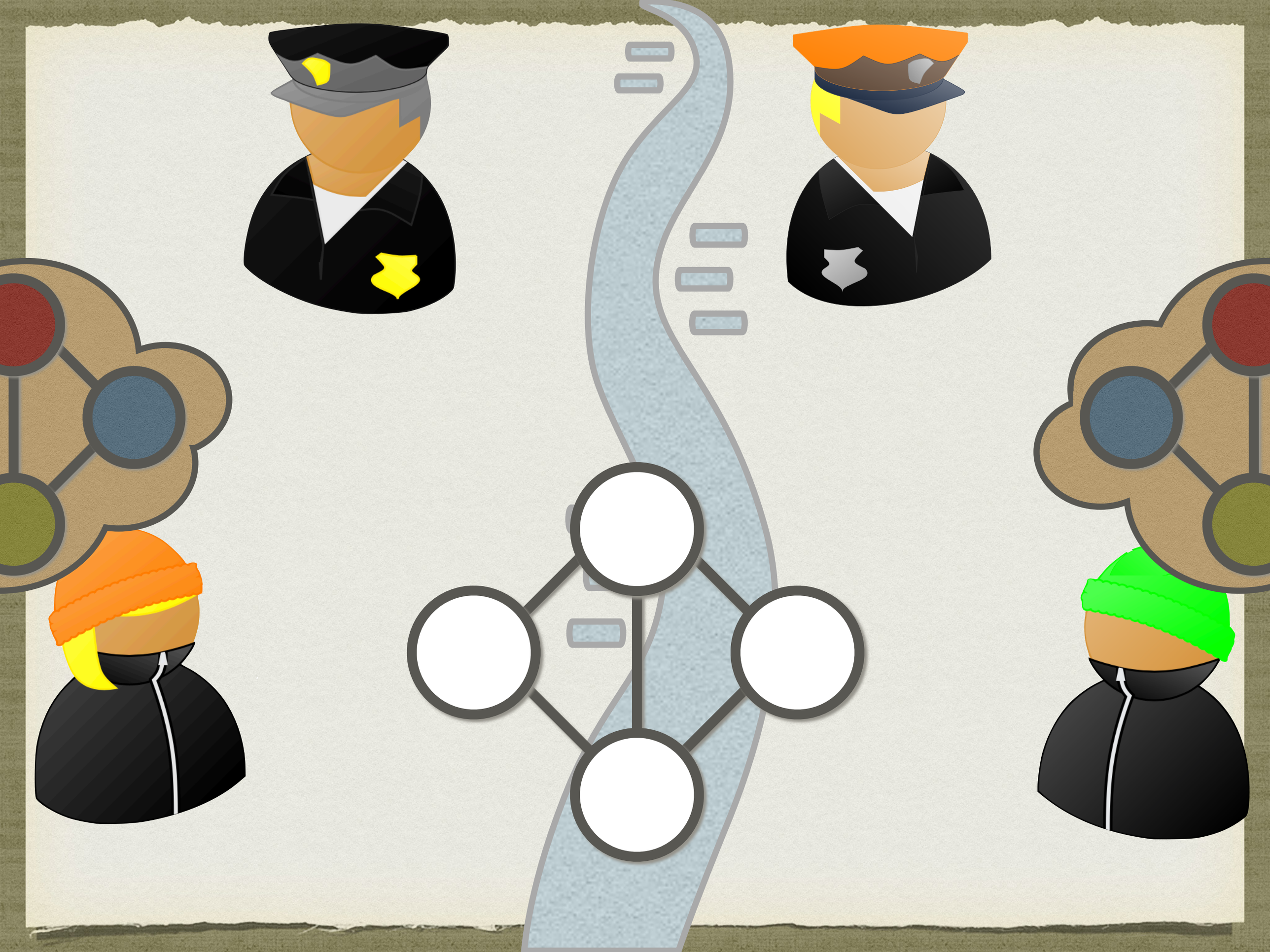




Transférable

IDÉE NOUVELLE

(ZK)MIPs



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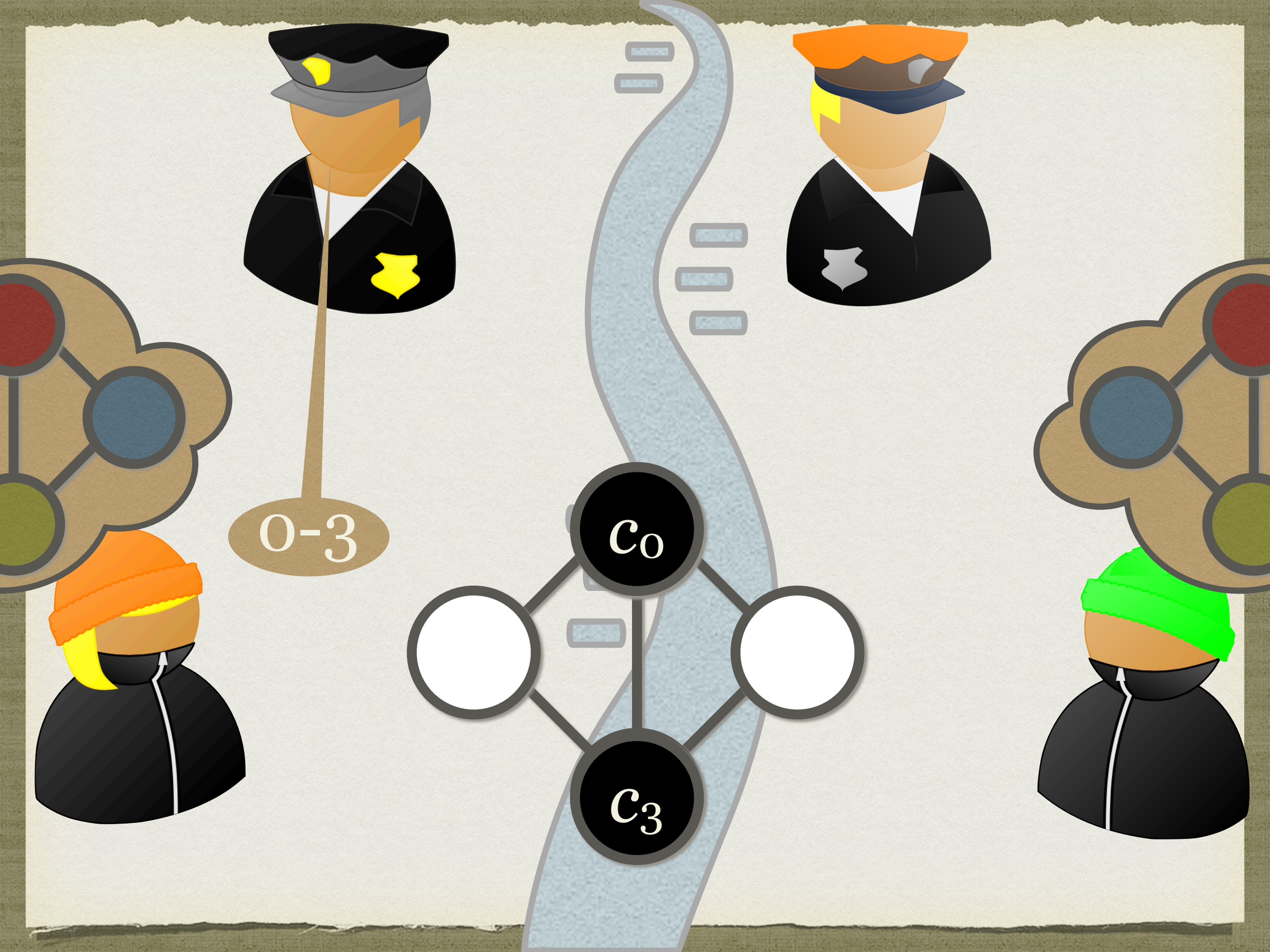
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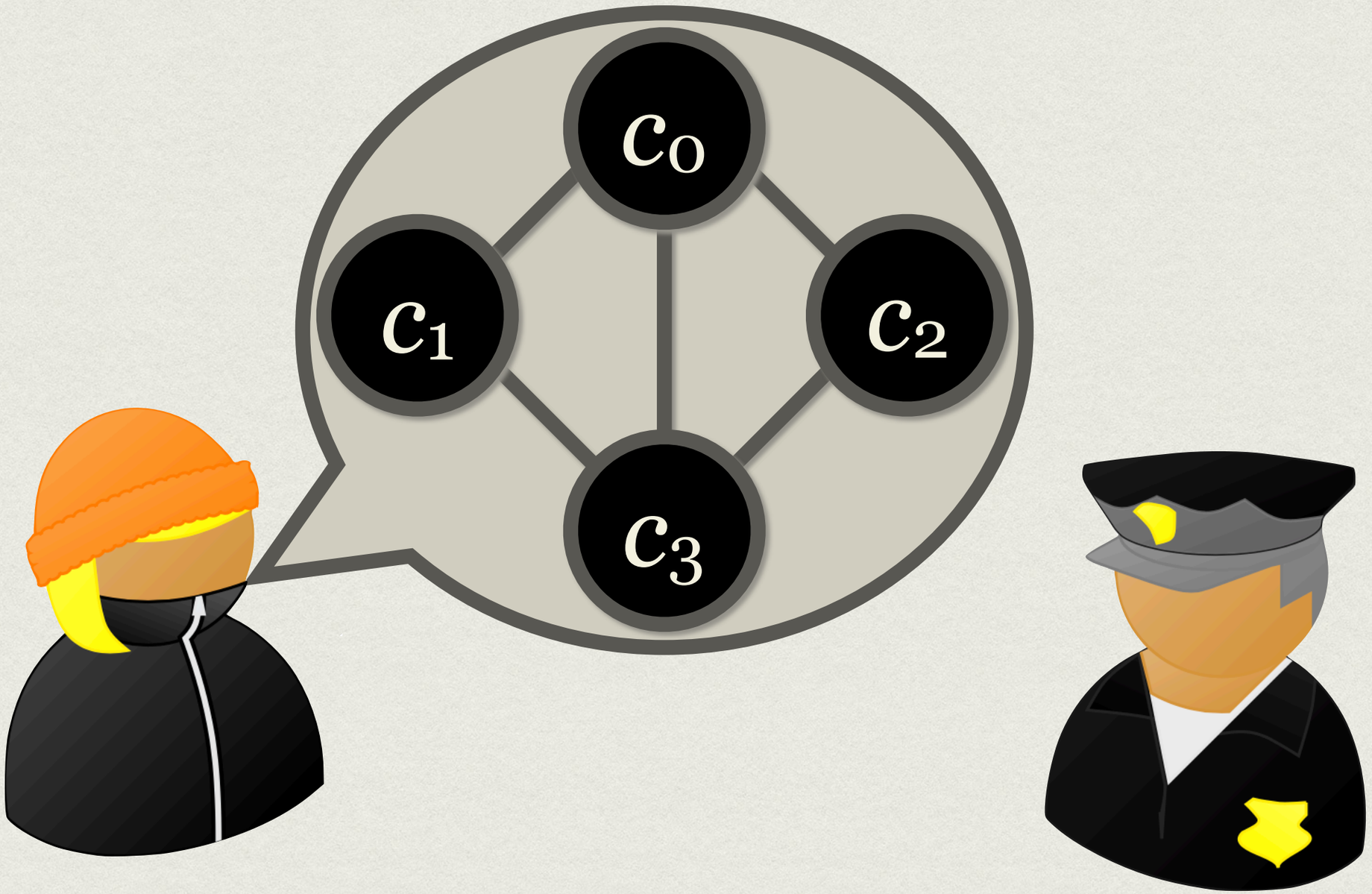
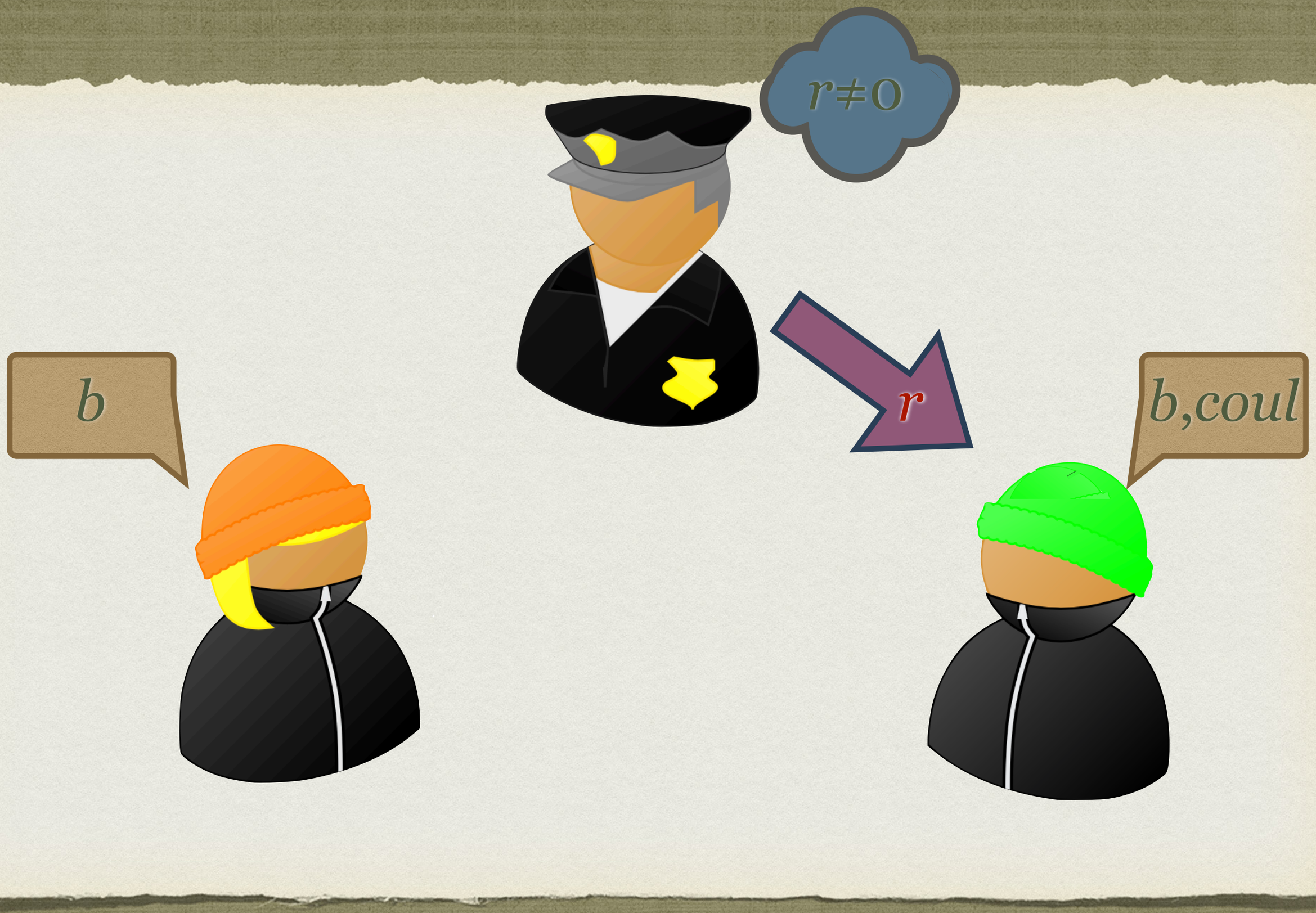
MISE-EN-GAGE ??



MISE-EN-GAGE

MISE-EN-GAGE



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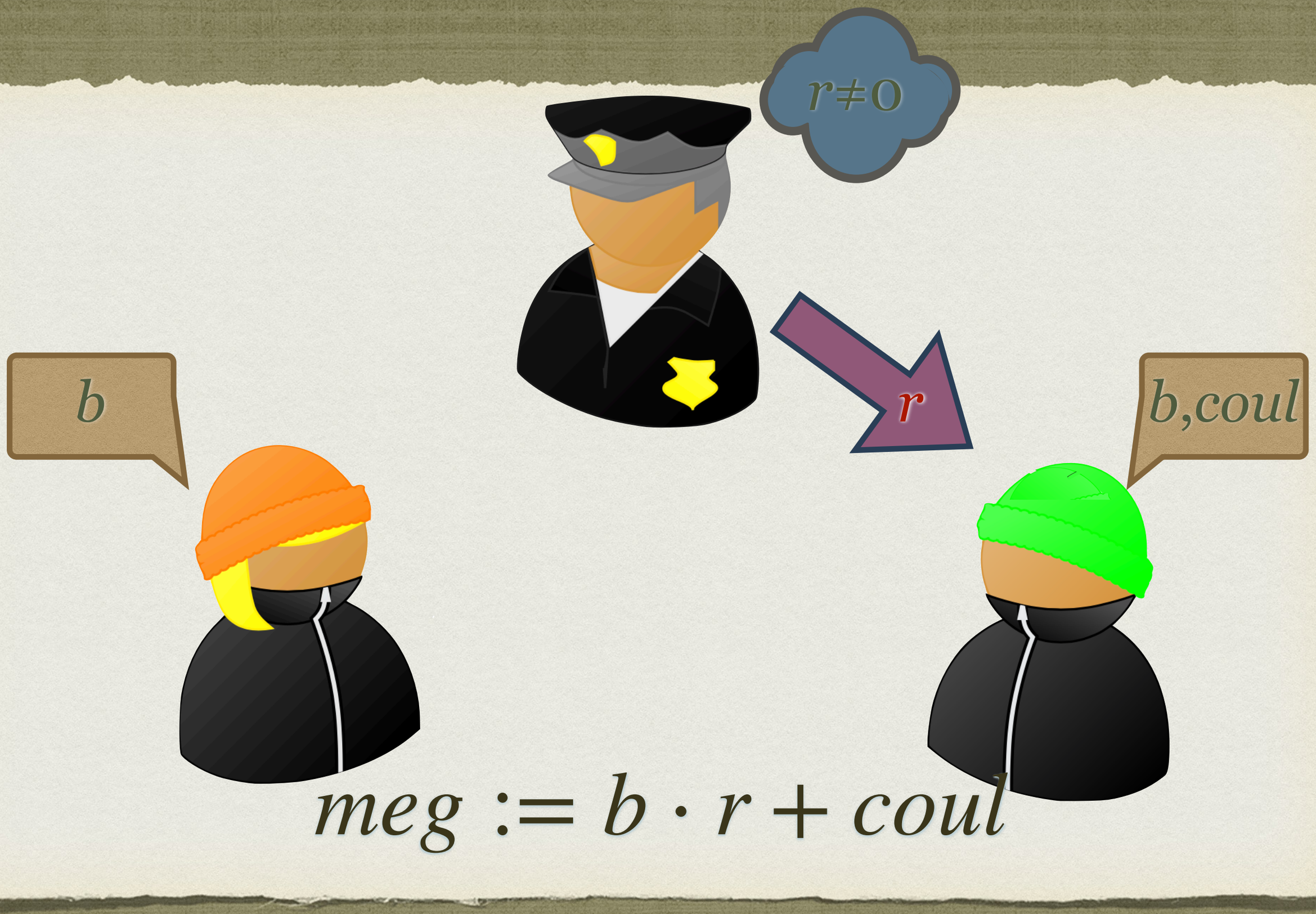
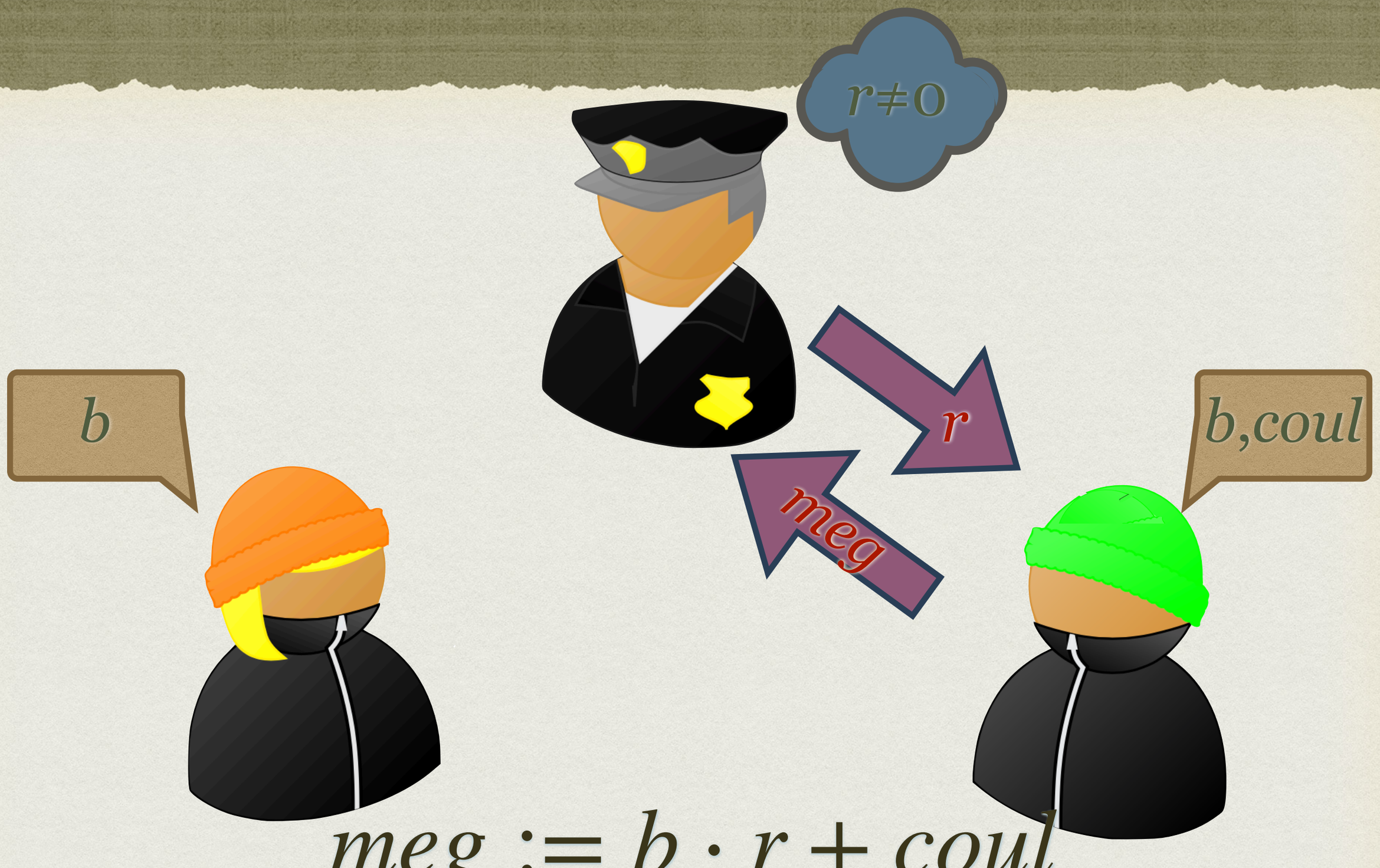


$$meg := b \cdot r + coul$$

MISE-EN-GAGE



$$meg := b \cdot r + coul$$

MISE-EN-GAGE

$$meg := b \cdot r + coul$$

MISE-EN-GAGE

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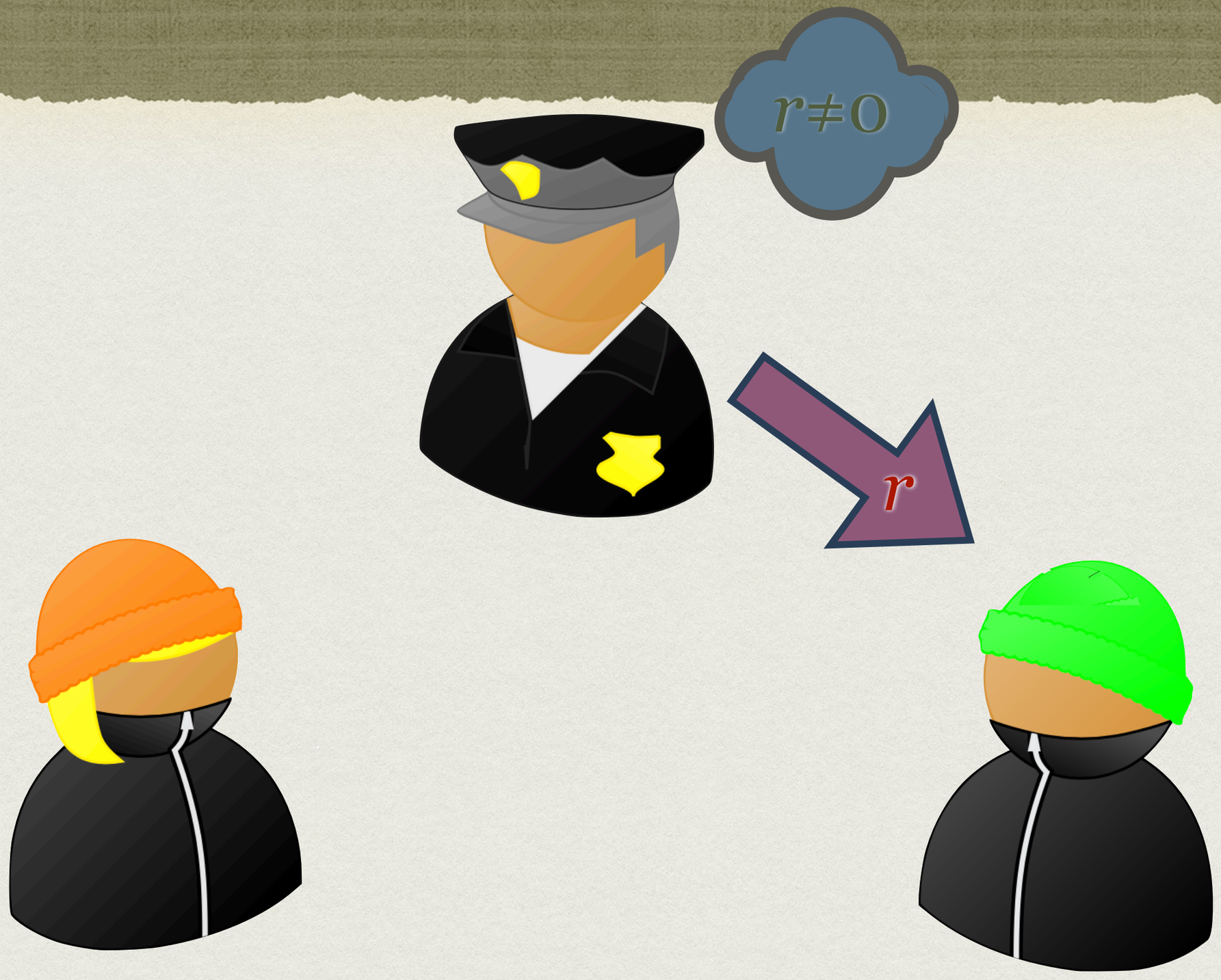
MISE-EN-GAGE

MISE-EN-GAGE



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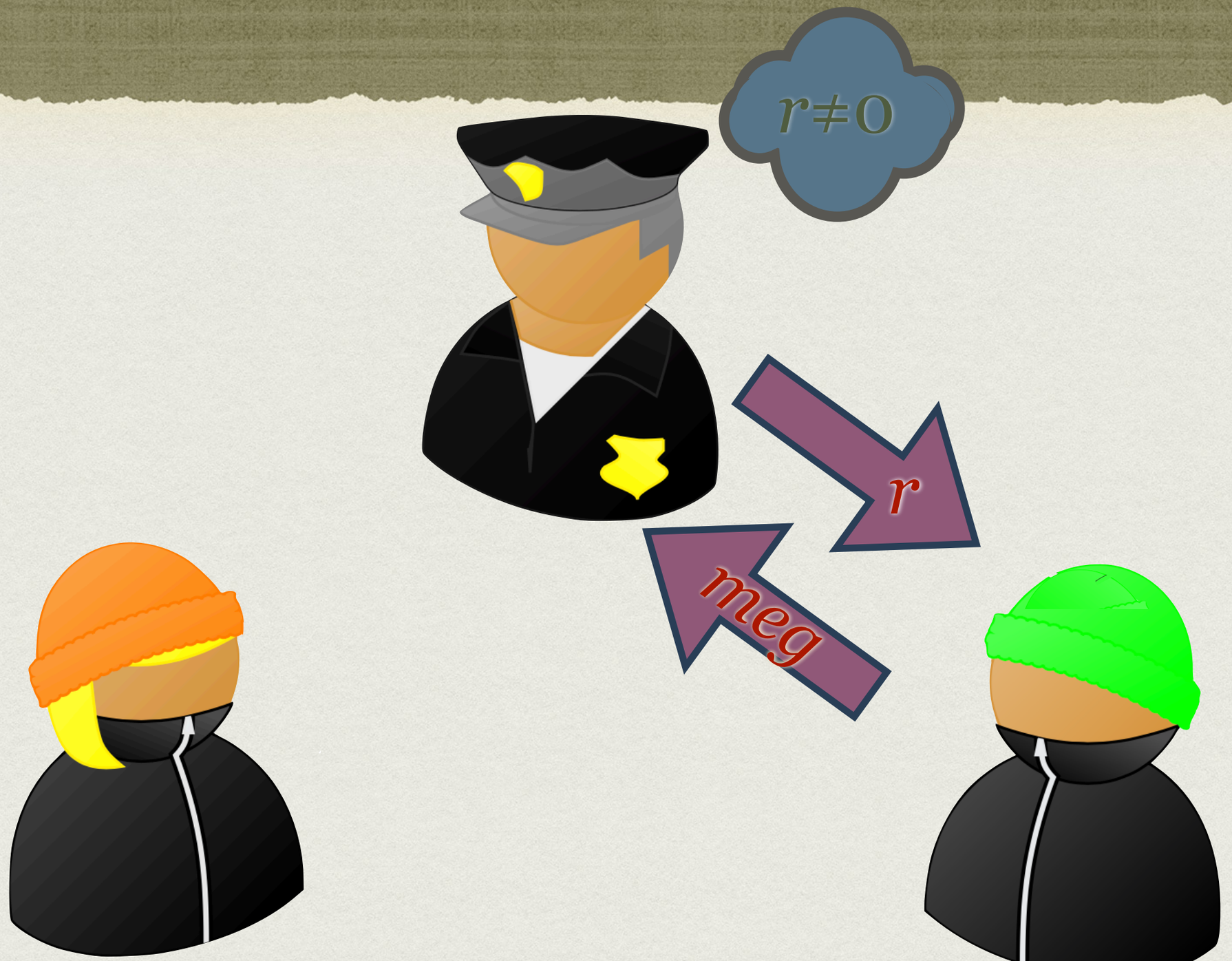

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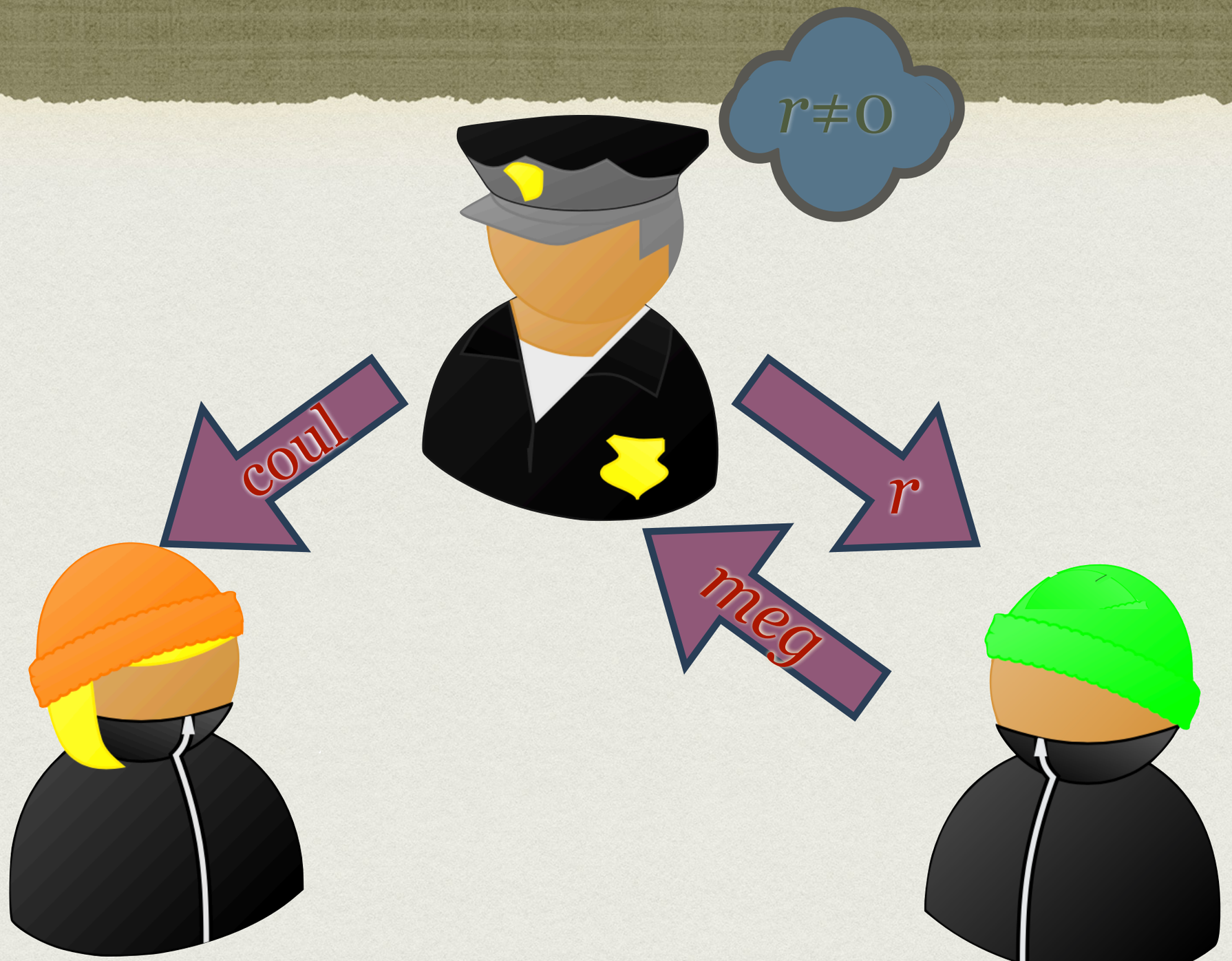

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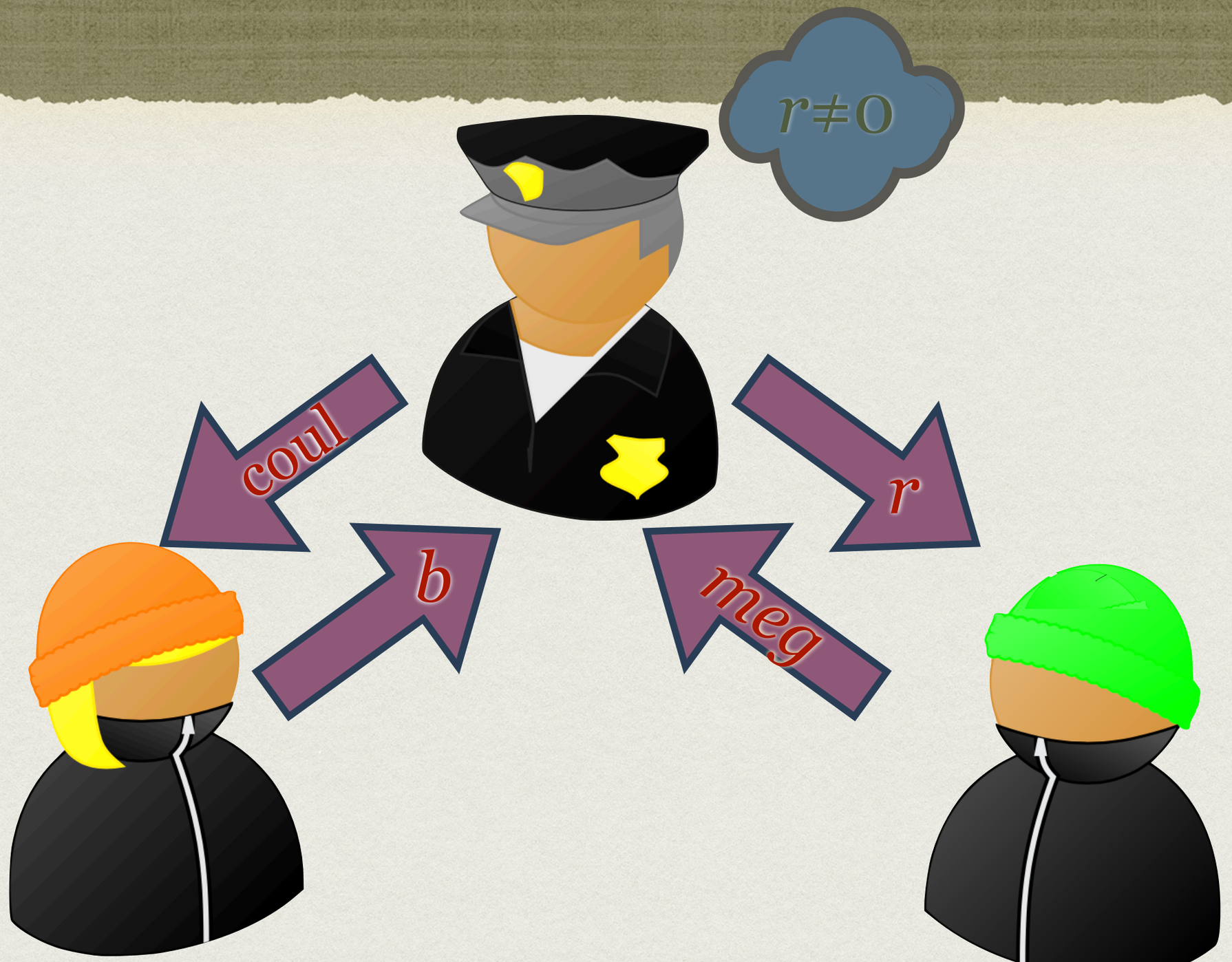

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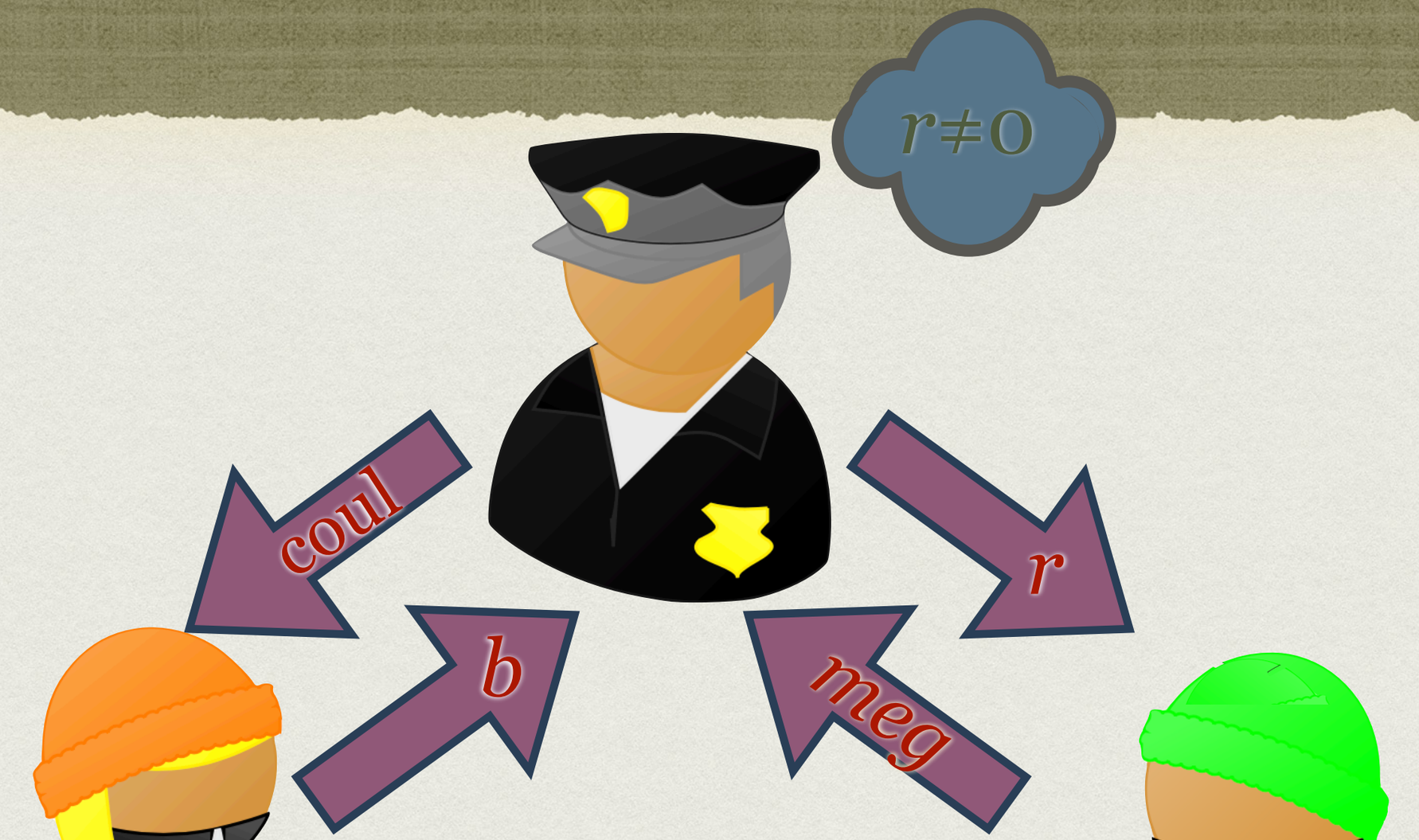
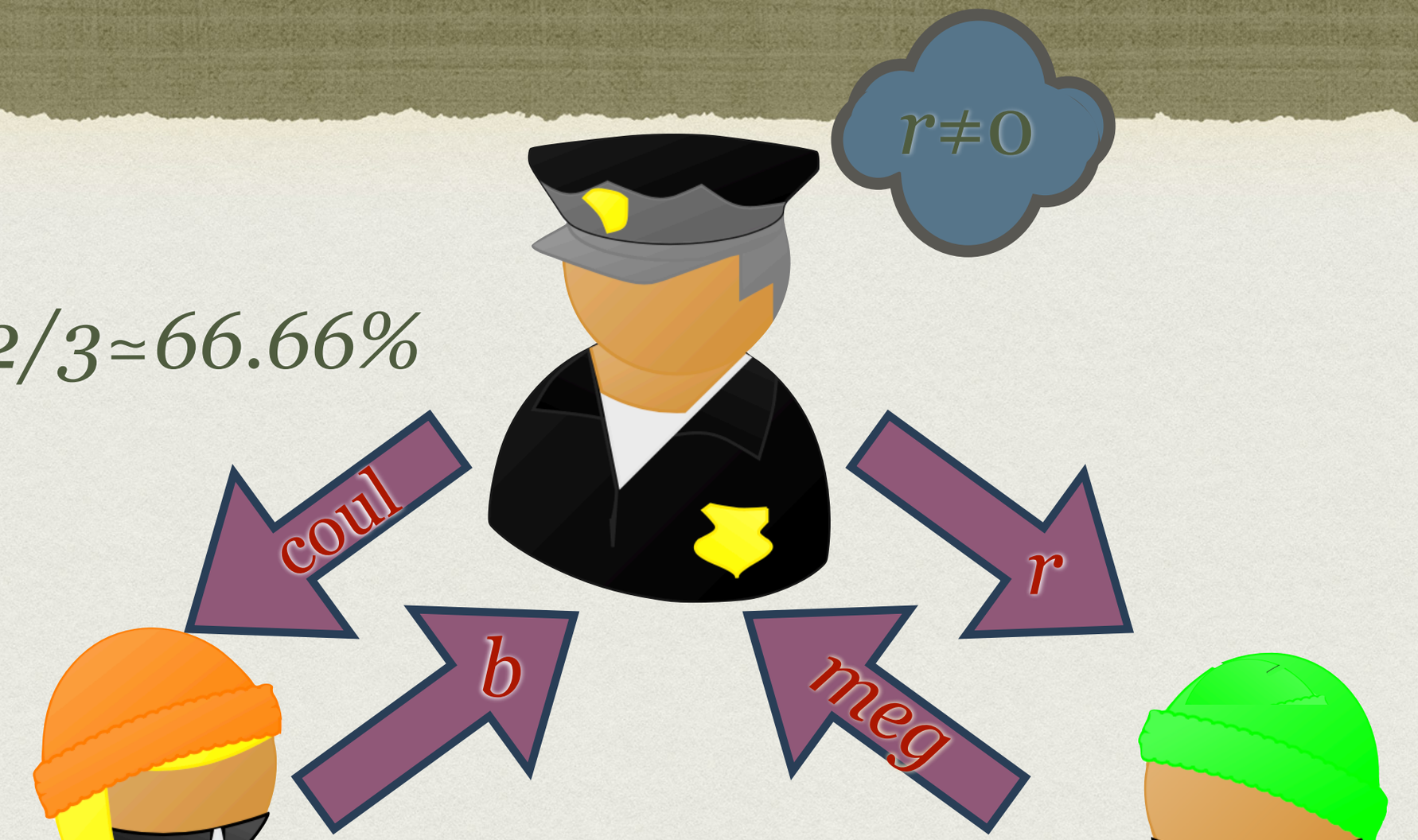


$$b = \frac{meg - coul}{r}$$

MISE-EN-GAGE

LOC=2/3≃66.66%



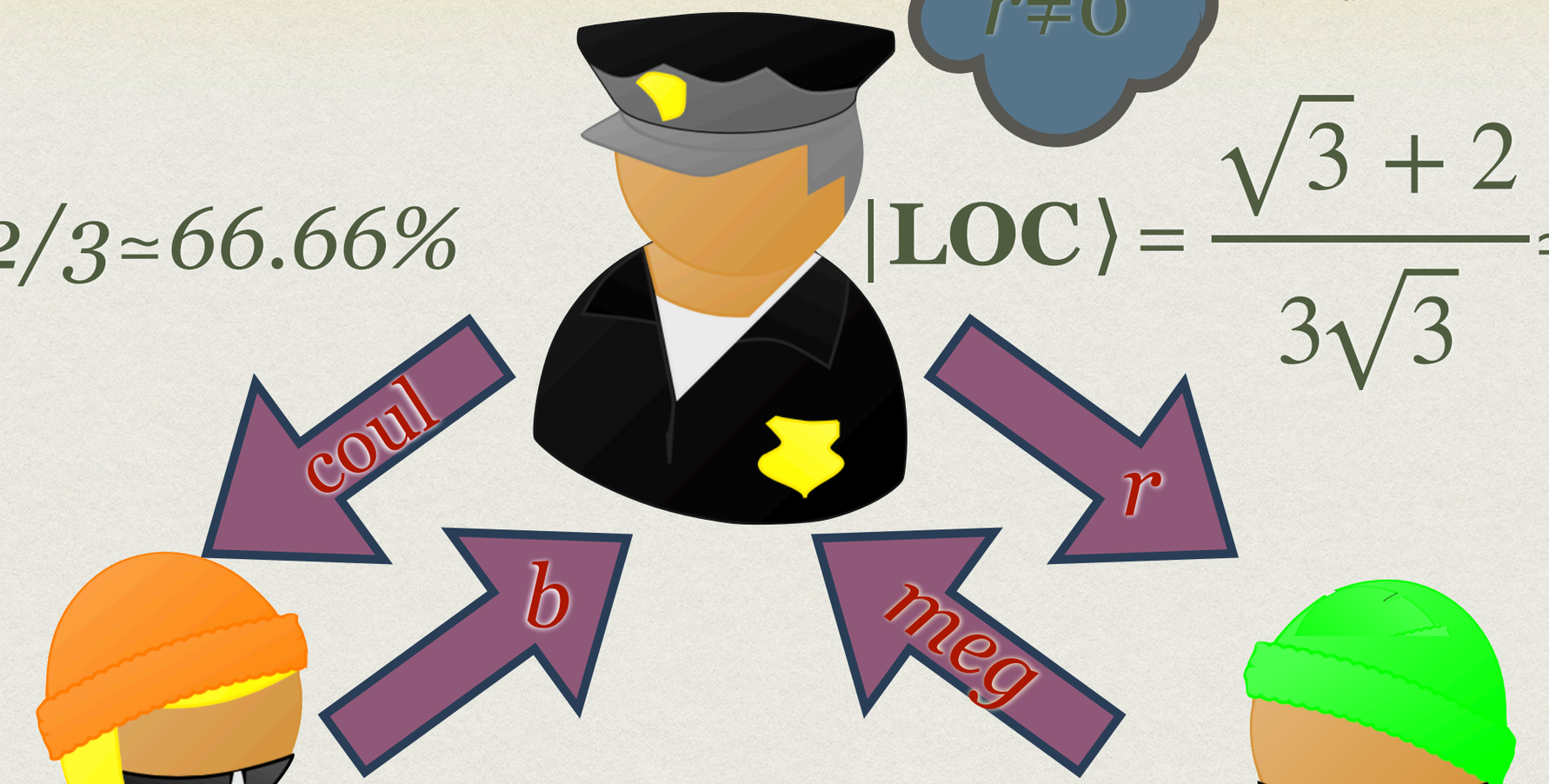
$$b = \frac{meg - coul}{r}$$

MISE-EN-GAGE

$r \neq 0$

LOC$=2/3 \simeq 66.66\%$

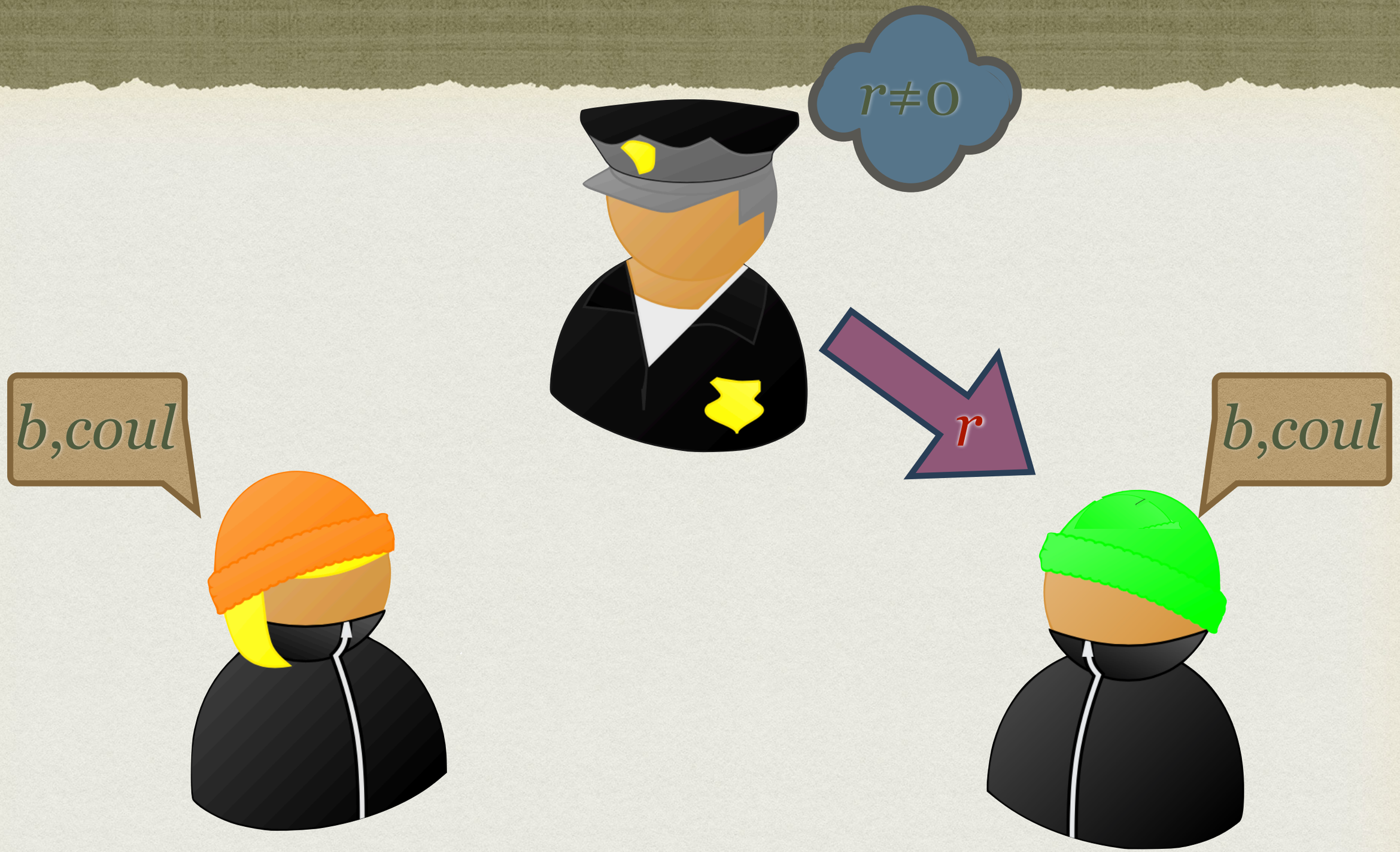
$|\mathbf{LOC}\rangle = \dfrac{\sqrt{3}+2}{3\sqrt{3}} \simeq 71{,}82\%$



$$b = \frac{meg - coul}{r}$$

MISE-EN-GAGE

MISE-EN-GAGE



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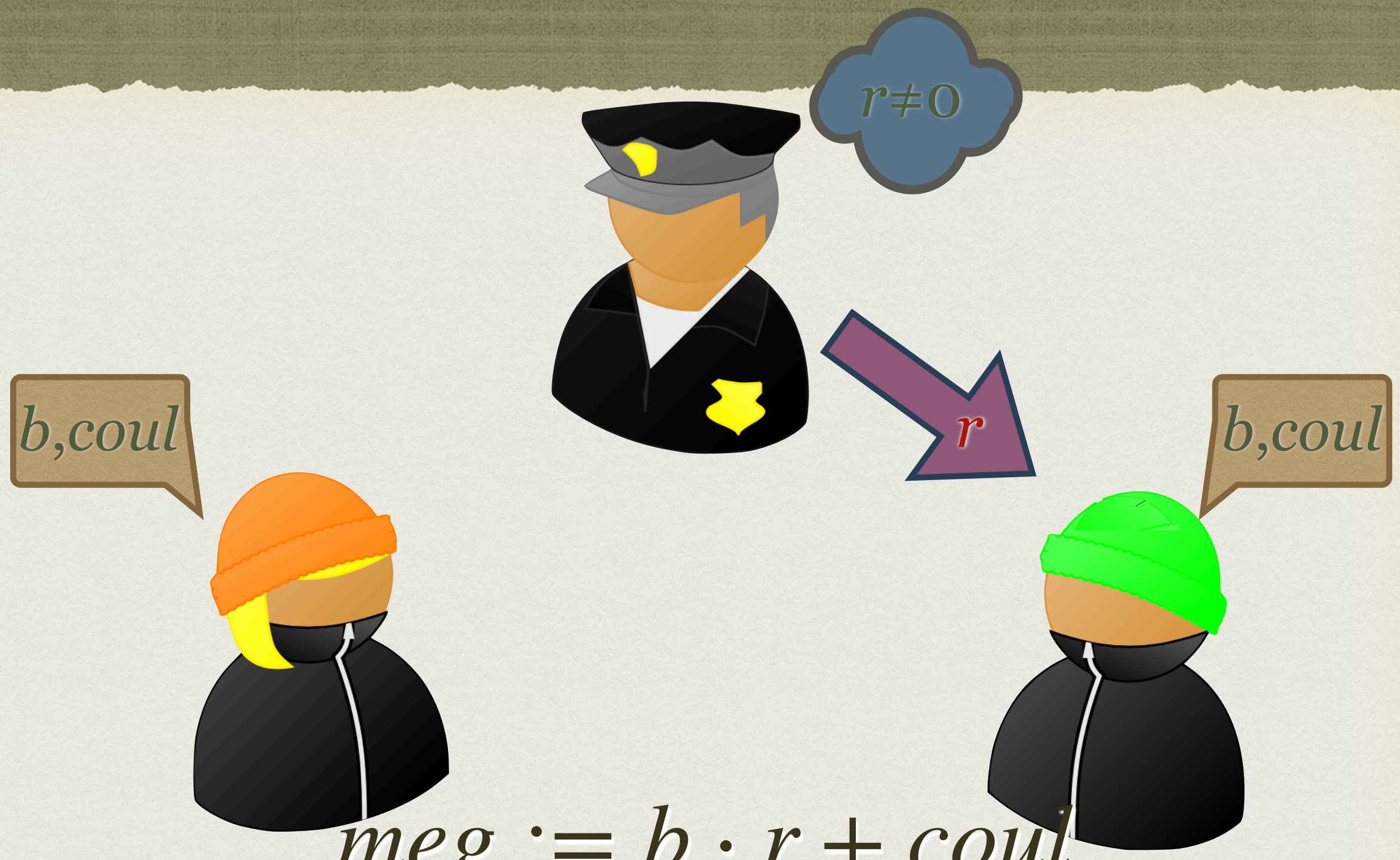
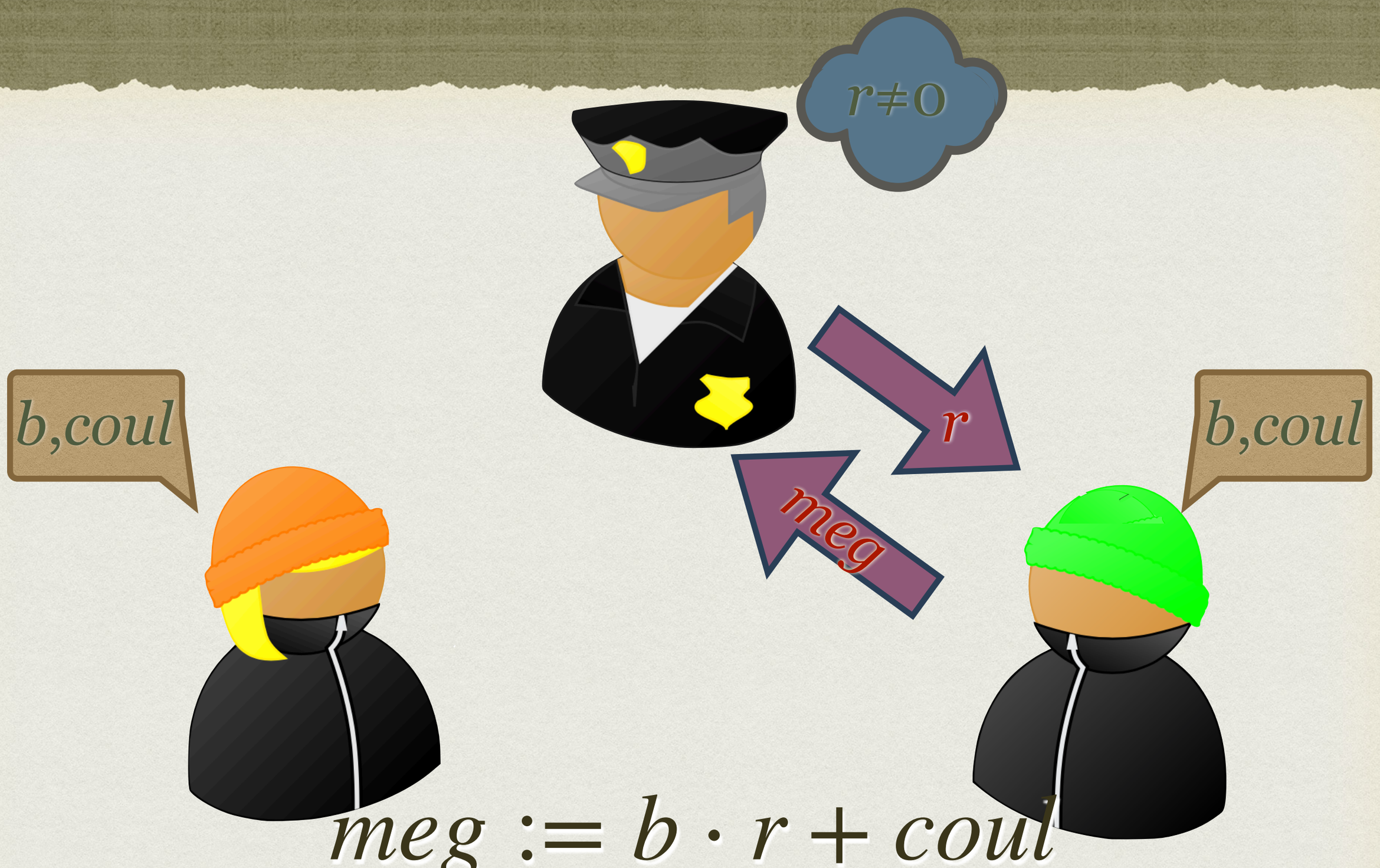


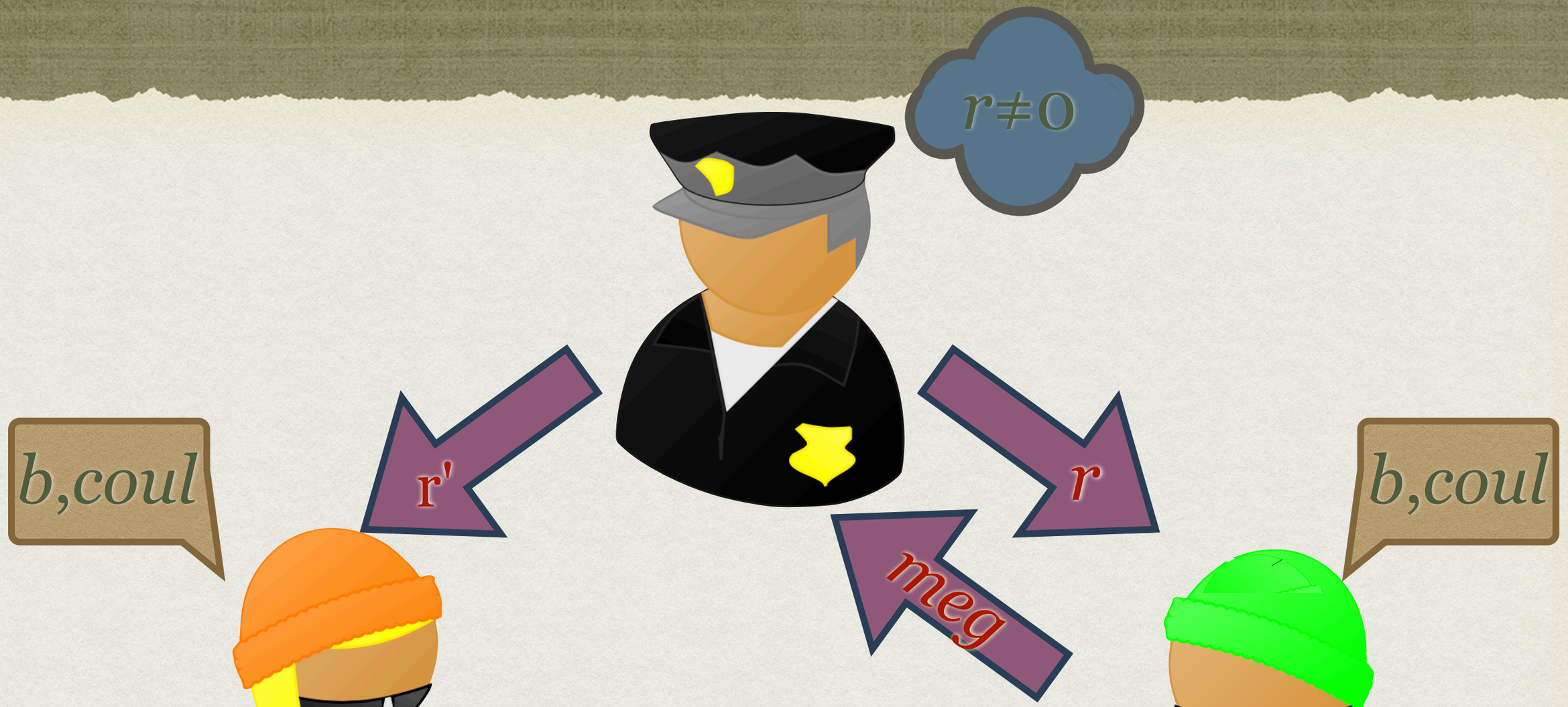
$$meg := b \cdot r + coul$$

MISE-EN-GAGE



$$meg := b \cdot r + coul$$

MISE-EN-GAGE



$$meg := b \cdot r + coul$$

MISE-EN-GAGE

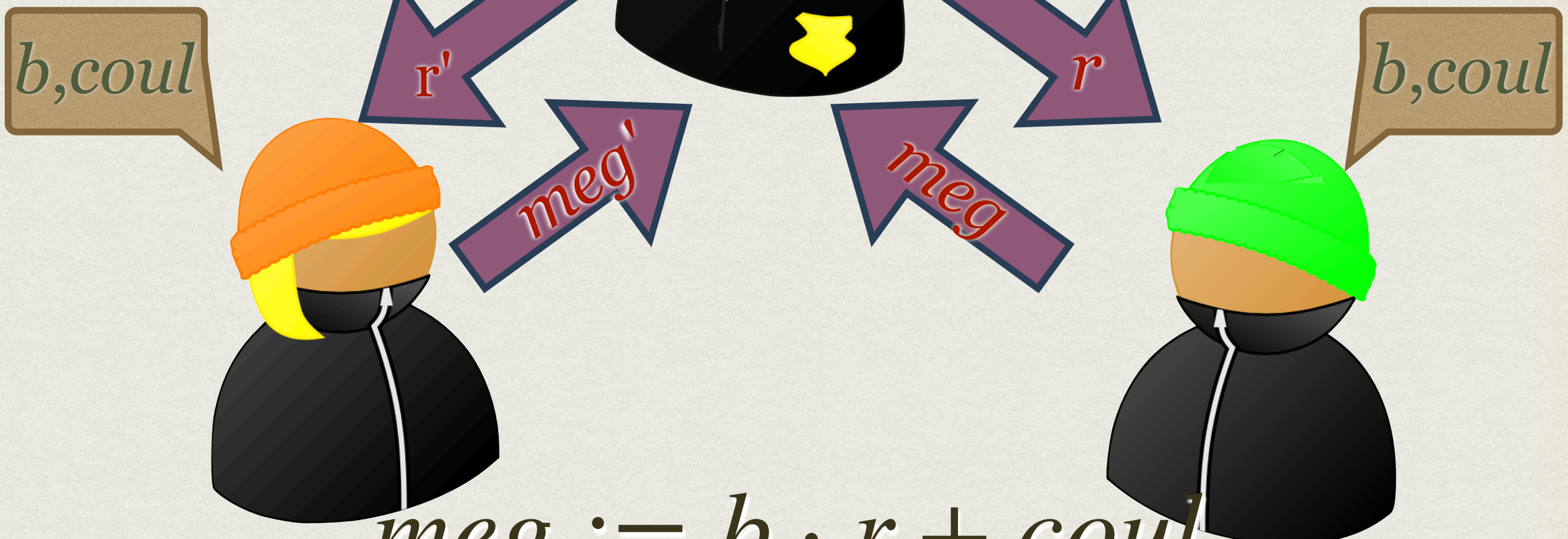
$$meg := b \cdot r + coul$$

MISE-EN-GAGE

$$meg := b \cdot r + coul$$
$$meg' := b \cdot r' + coul$$

MISE-EN-GAGE

$$coul = \frac{meg \cdot r' - meg' \cdot r}{r' - r}$$



$$meg := b \cdot r + coul$$
$$meg' := b \cdot r' + coul$$

MISE-EN-GAGE

PRINCIPE DE DÉVOILEMENT VIA M-E-G

MISE-EN-GAGE

PRINCIPE DE DÉVOILEMENT VIA M-E-G

=

DOUBLE-SPENDING DETECTION MECHANISM

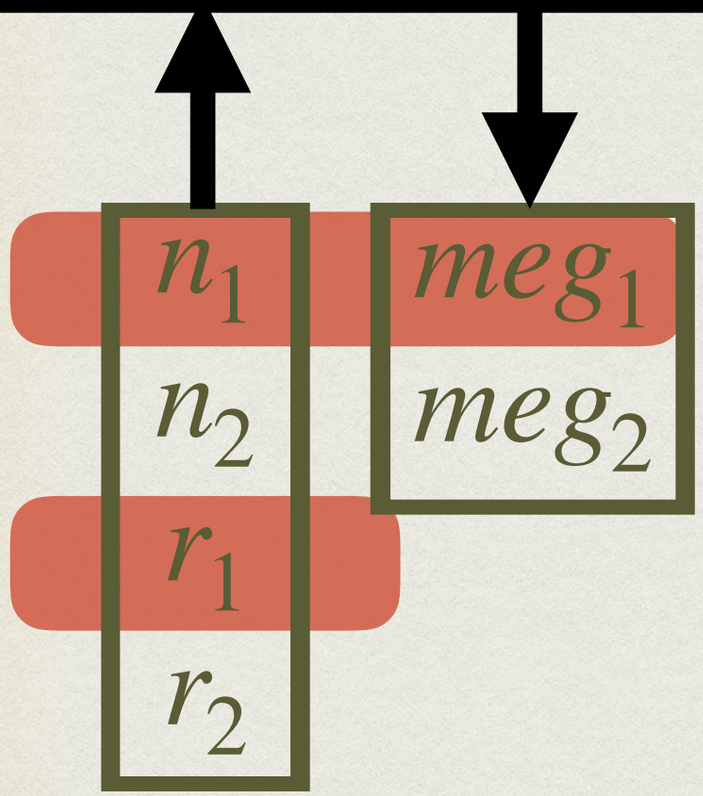
$$meg_i = coul_{n_i} + b_{n_i} r_i$$
$$meg_j = coul_{n_j} + b_{n_j} r_j$$

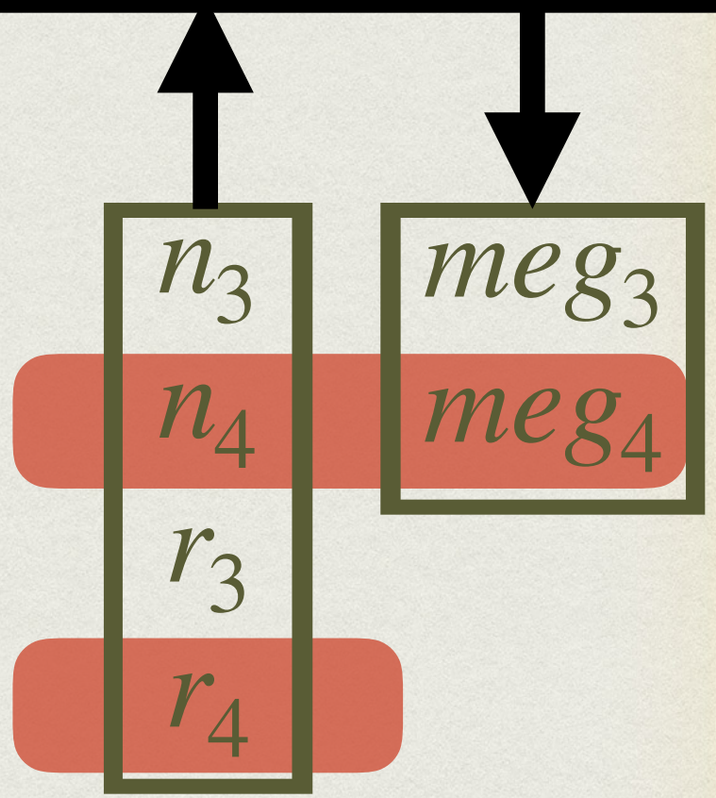
P_1

$(n_1, n_2) \in E$

P_2

$(n_3, n_4) \in E$





$$meg_i = coul_{n_i} + b_{n_i} r_i$$
$$meg_j = coul_{n_j} + b_{n_j} r_j$$

P_1

$(n_1, n_2) \in E$

Demander à deux prouveurs le même noeud avec même r vérifie la consistence.

P_2

$(n_3, n_4) \in E$

n_1	meg_1
n_2	meg_2
r_1	
r_2	

n_3	meg_3
n_4	meg_4
r_3	
r_4	

$$meg_i = coul_{n_i} + b_{n_i} r_i$$
$$meg_j = coul_{n_j} + b_{n_j} r_j$$

P_1

$(n_1, n_2) \in E$

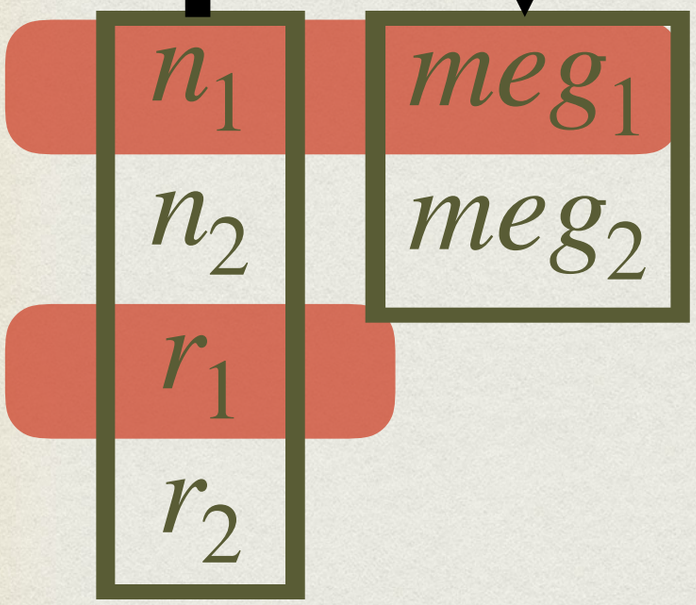
Demander à deux prouveurs le même noeud avec même r vérifie la consistence.

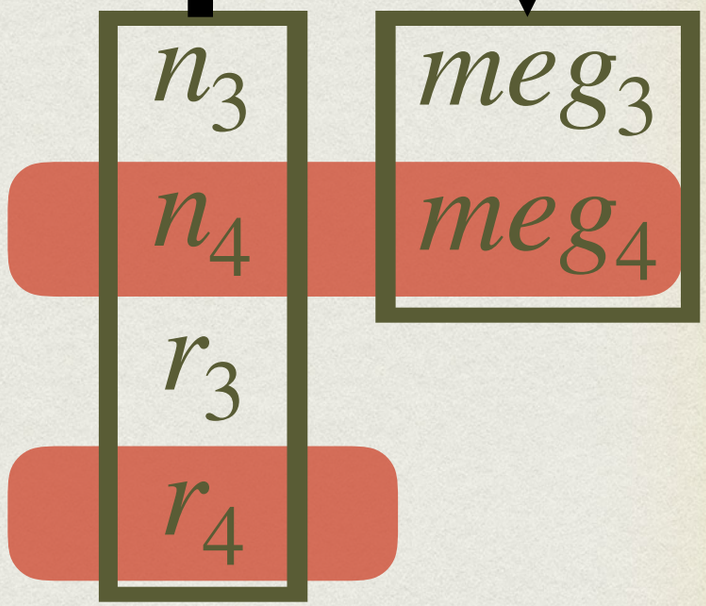
Asking two provers the same node with same r checks their consistency.

$$n_i = n_j \wedge r_i = r_j$$
$$\Longrightarrow meg_i = meg_j$$

P_2

$(n_3, n_4) \in E$





$$meg_i = coul_{n_i} + b_{n_i} r_i$$
$$meg_j = coul_{n_j} + b_{n_j} r_j$$

P_1

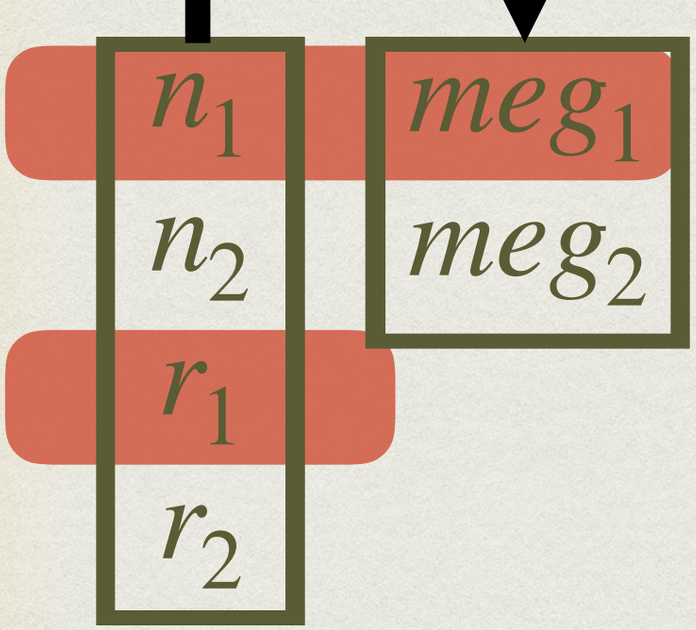
$(n_1, n_2) \in E$

Demander à deux prouveurs le même noeud avec même r vérifie la consistence.

Asking two provers the same node with same r checks their consistency.

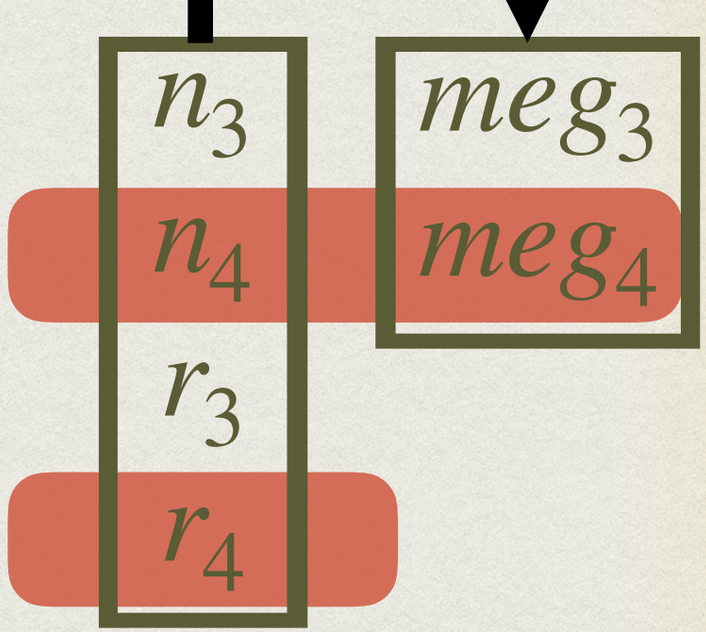
$$n_i = n_j \wedge r_i = r_j$$
$$\Longrightarrow meg_i = meg_j$$

Demander à deux prouveurs le même noeud avec deux r's donne la couleur.



P_2

$(n_3, n_4) \in E$



$$meg_i = coul_{n_i} + b_{n_i} r_i$$
$$meg_j = coul_{n_j} + b_{n_j} r_j$$

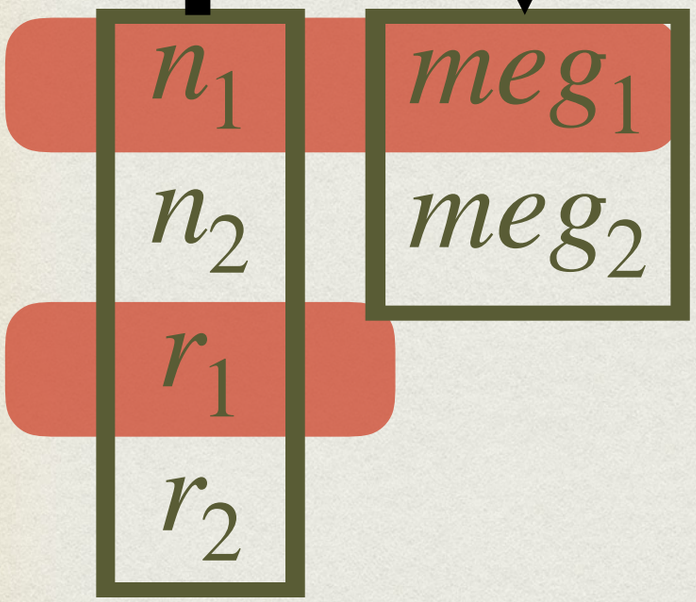
P_1

$(n_1, n_2) \in E$

Demander à deux prouveurs le même noeud avec même r vérifie la consistence.

Asking two provers the same node with same r checks their consistency.

$$n_i = n_j \wedge r_i = r_j \implies meg_i = meg_j$$



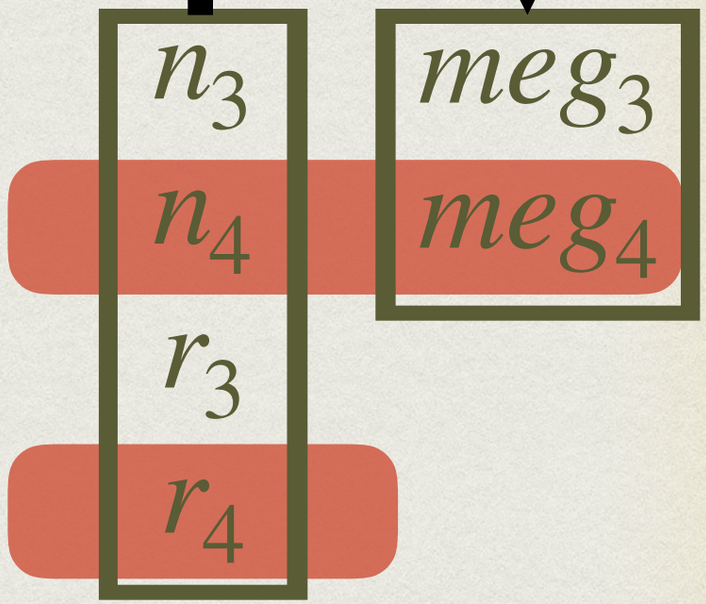
Demander à deux prouveurs le même noeud avec deux r's donne la couleur.

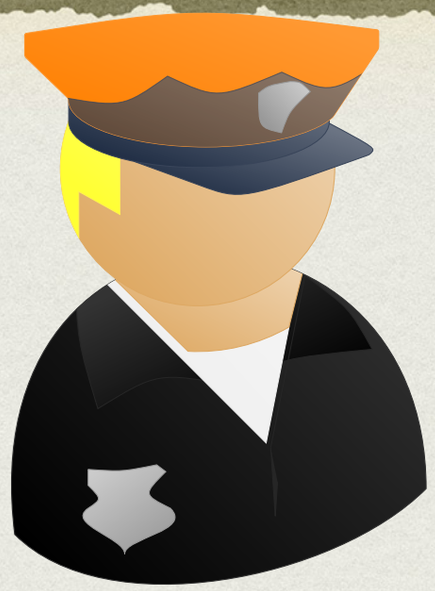
Asking two provers the same node with distinct r's unveils that node colour.

$$n_i = n_j \wedge r_i \neq r_j \implies coul_{n_i} = meg_j + meg_i$$

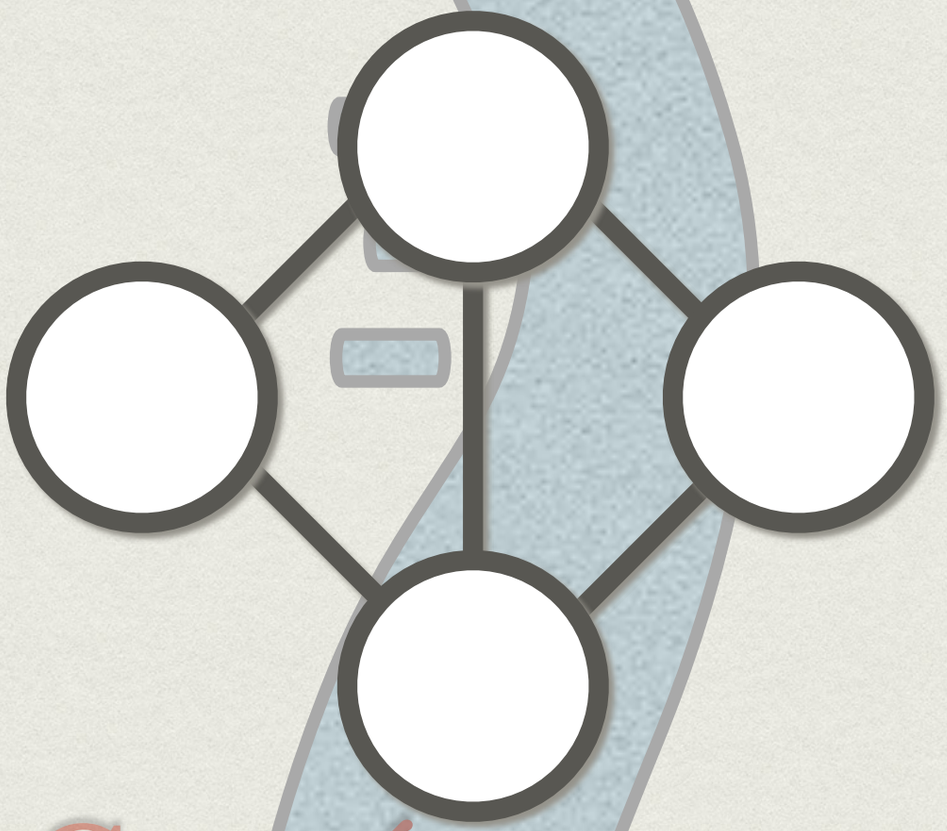
P_2

$(n_3, n_4) \in E$

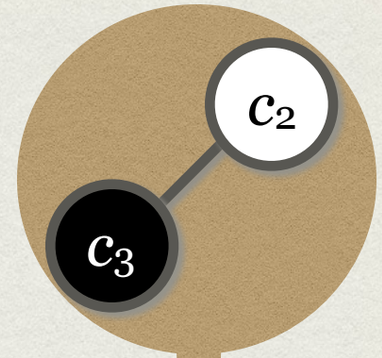


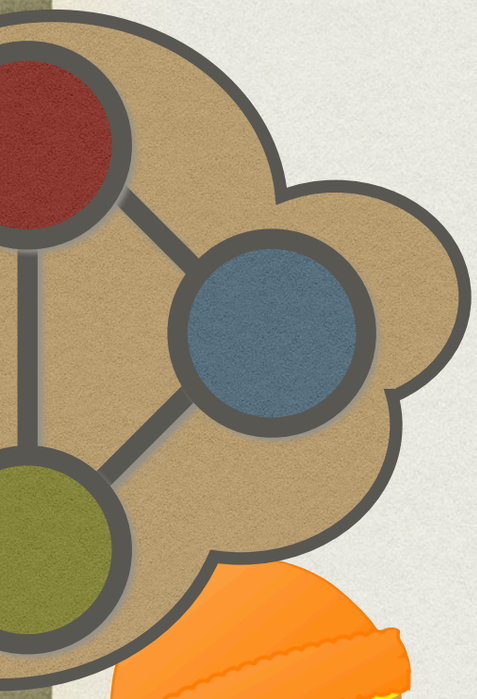


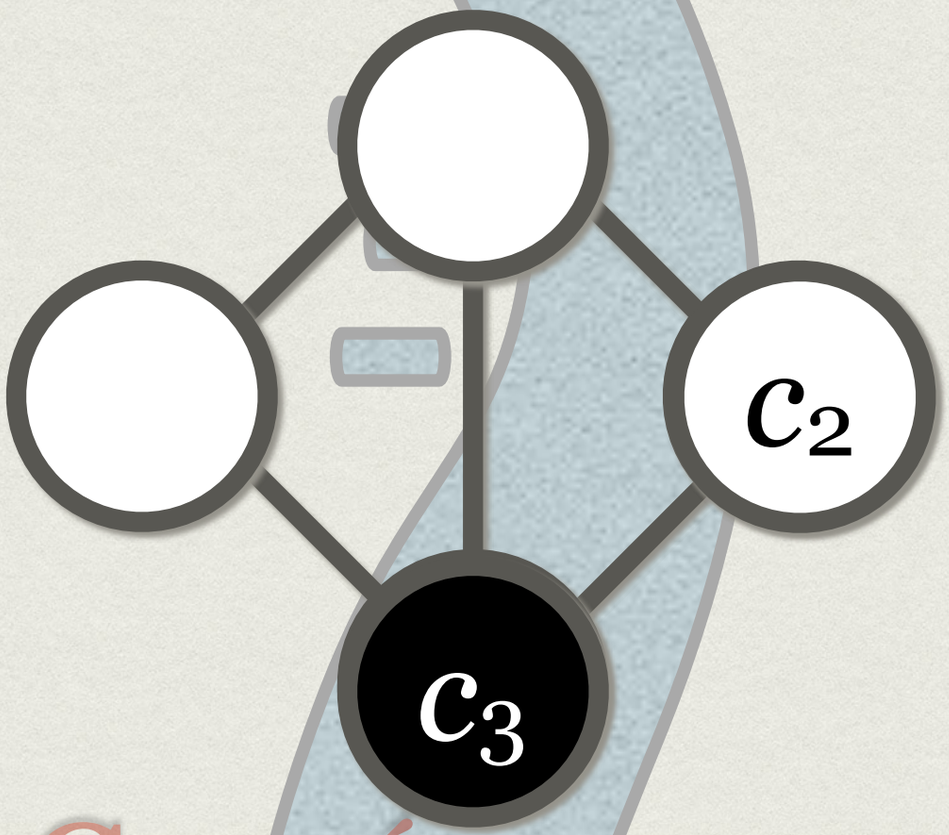
Complétude



Cohérence







Complétude

Cohérence

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c_3

2-3

Complétude

c_0

c_2

c_3

Cohérence

c_0

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0-3

c_2

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2-3

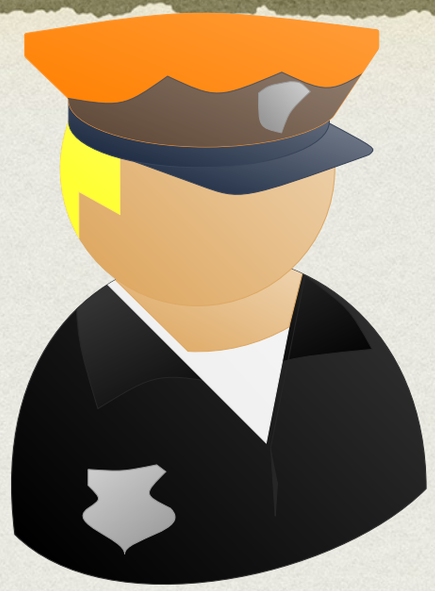
c_0

c_2

c_3

COMPLÉTUDE

COHÉRENCE



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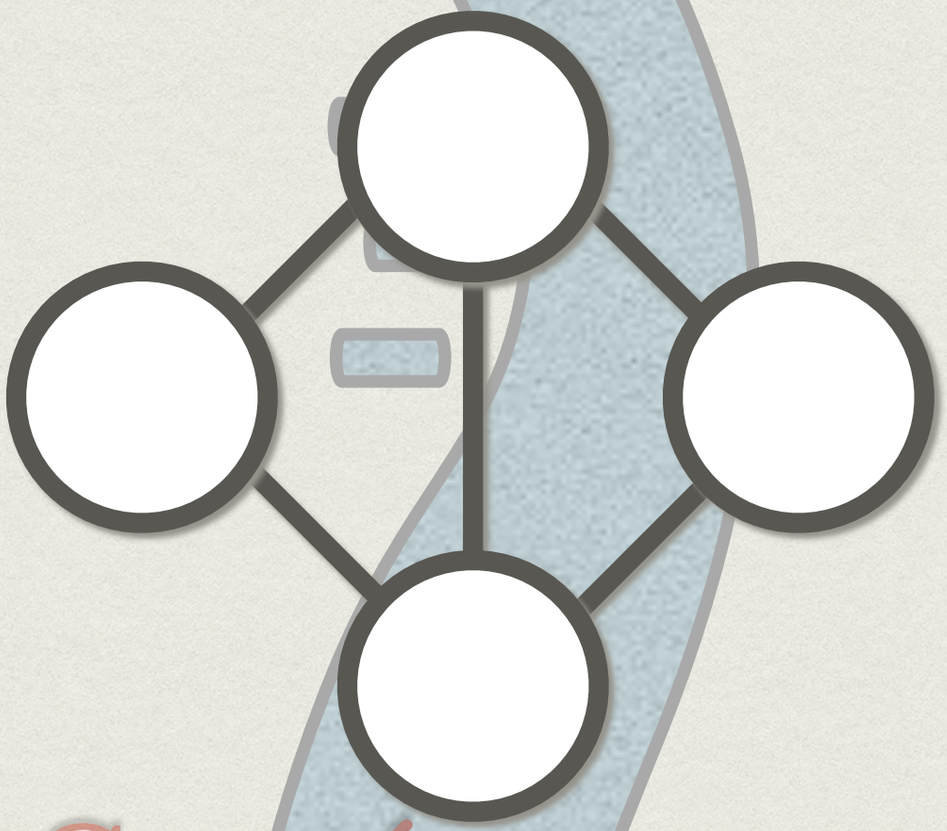

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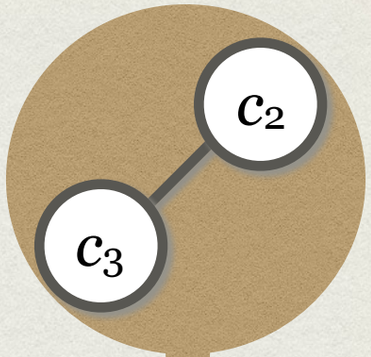

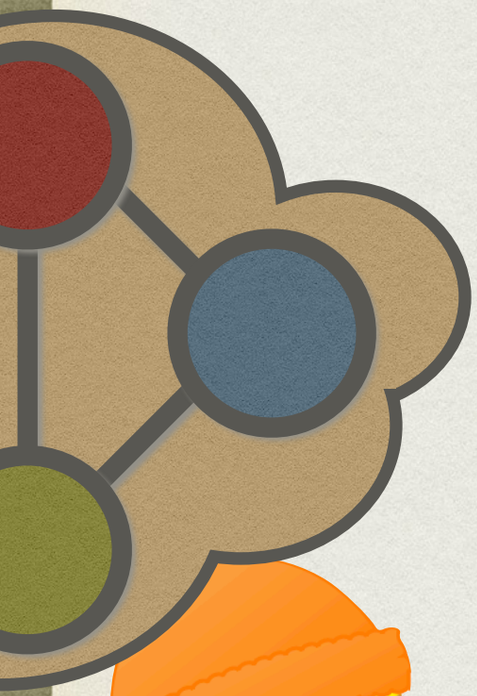

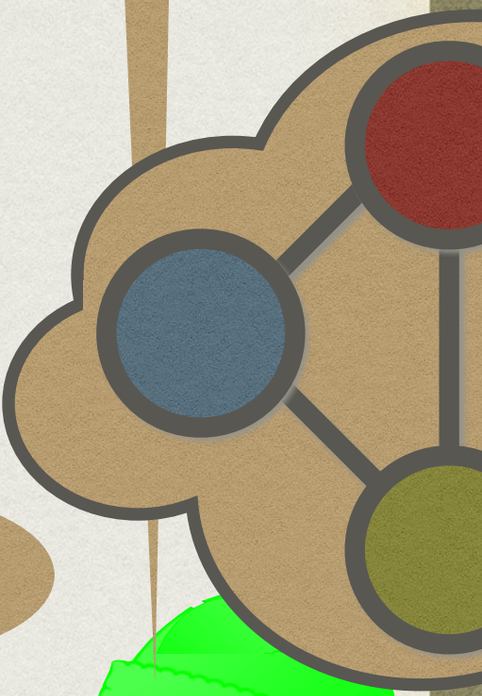

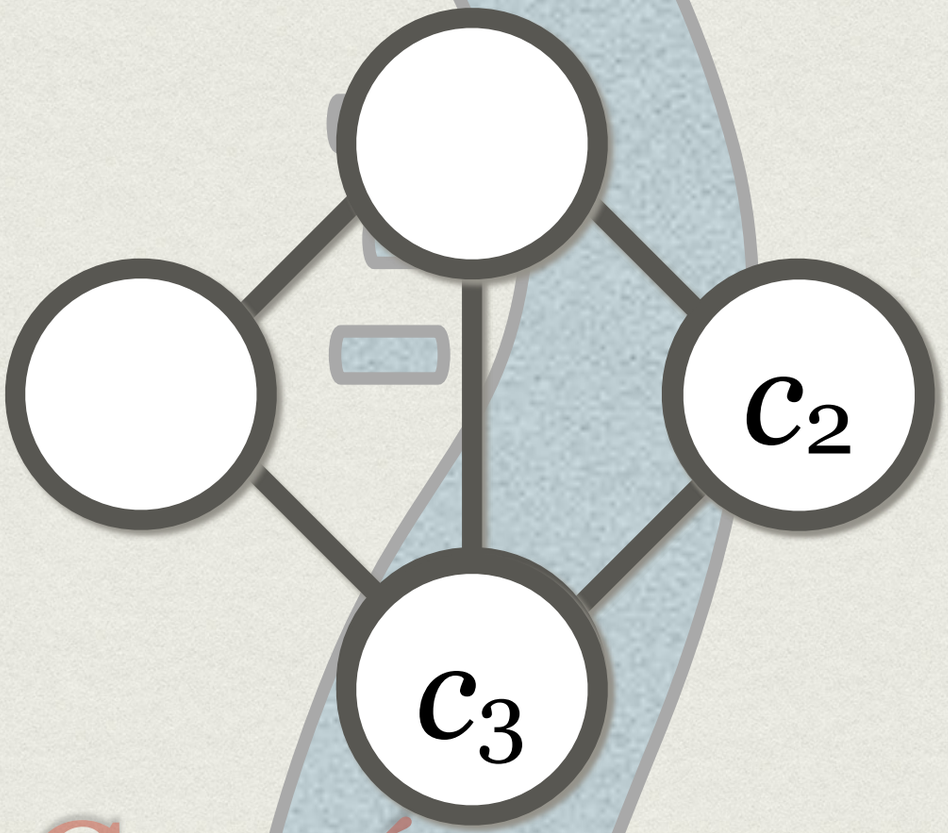

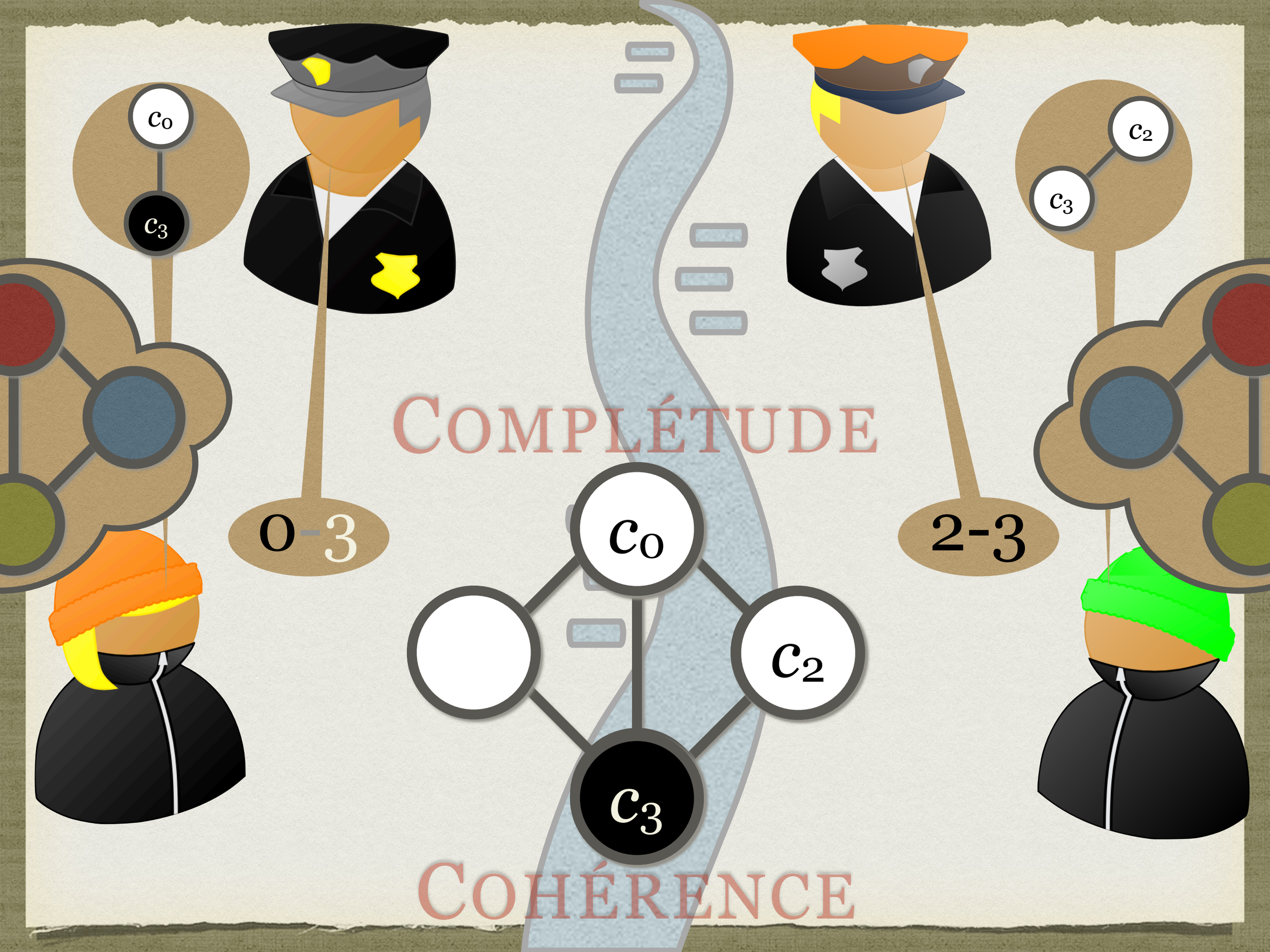
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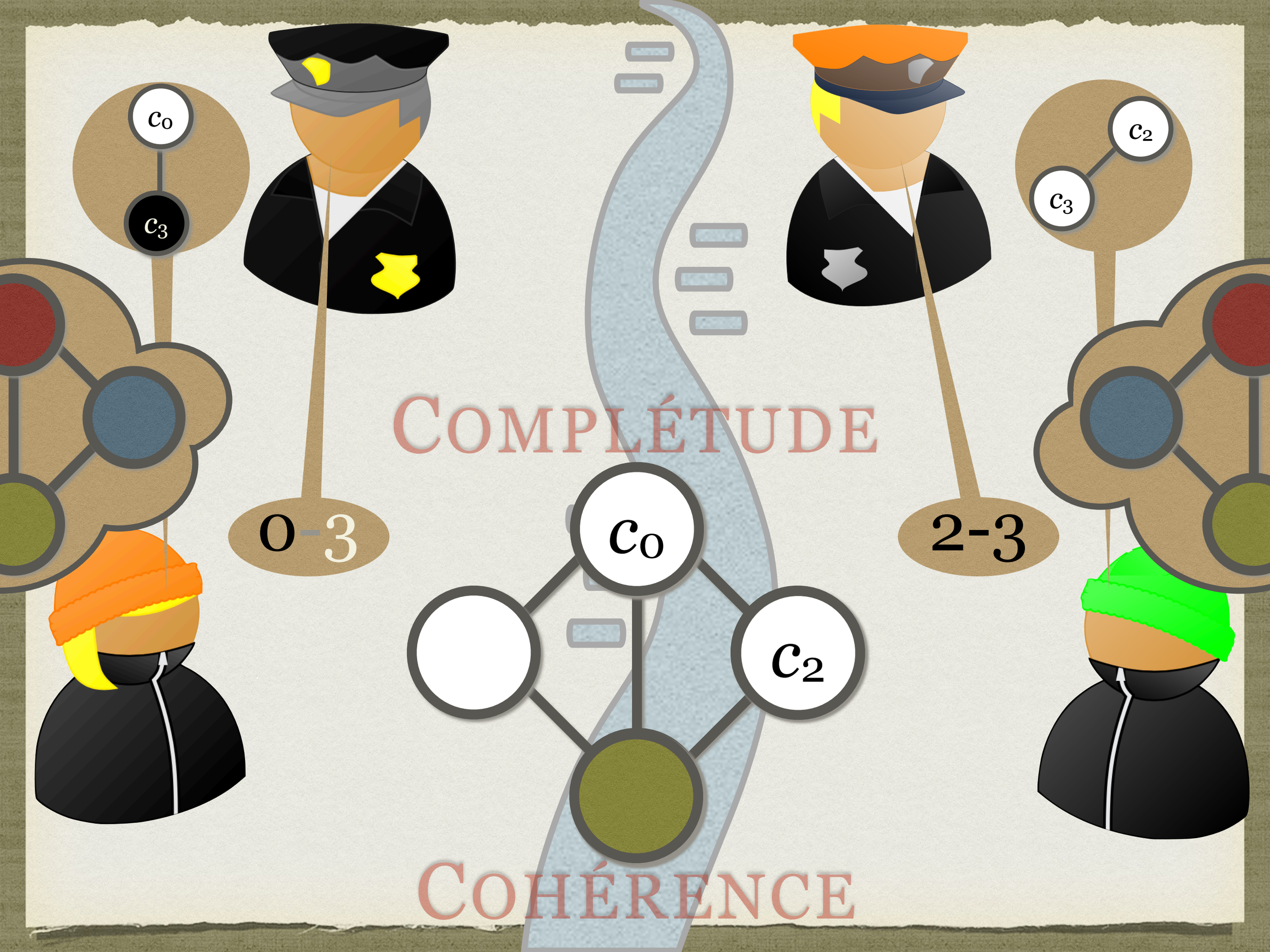
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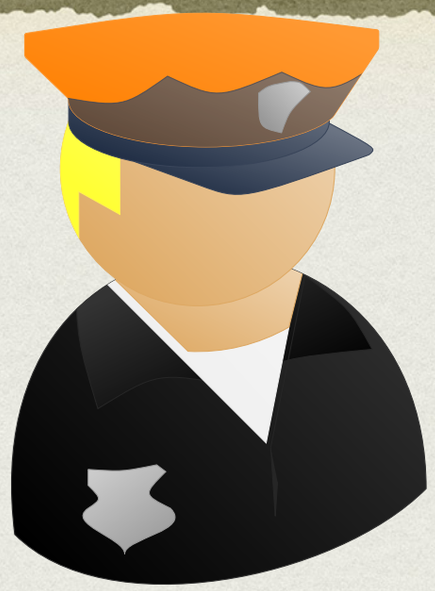

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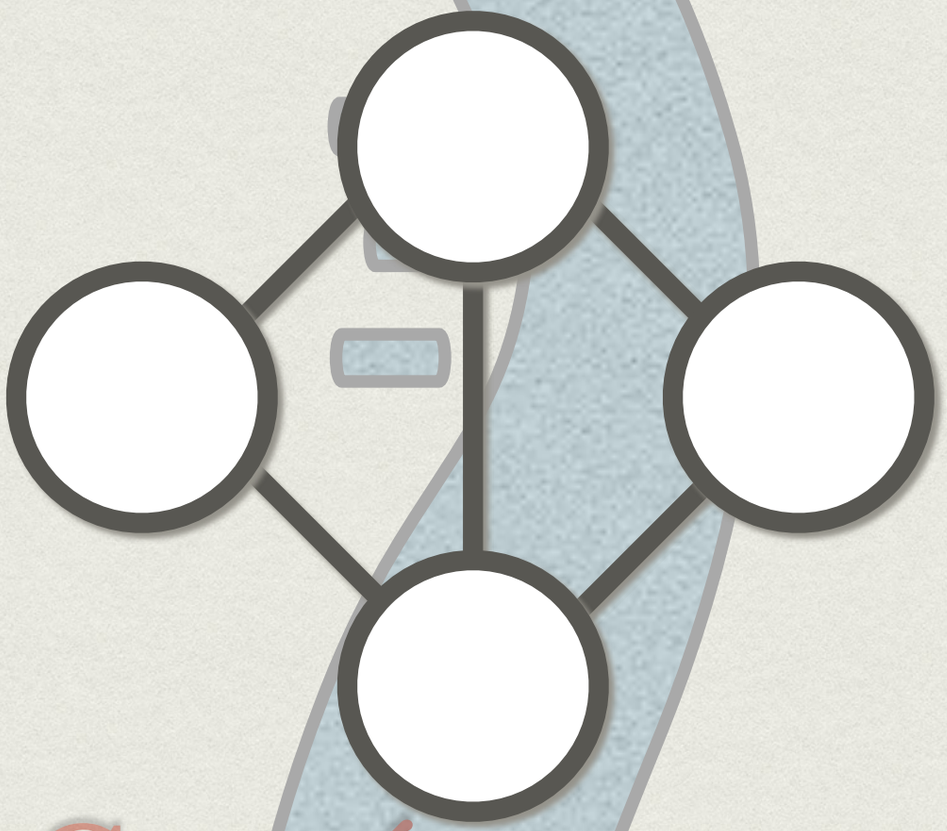

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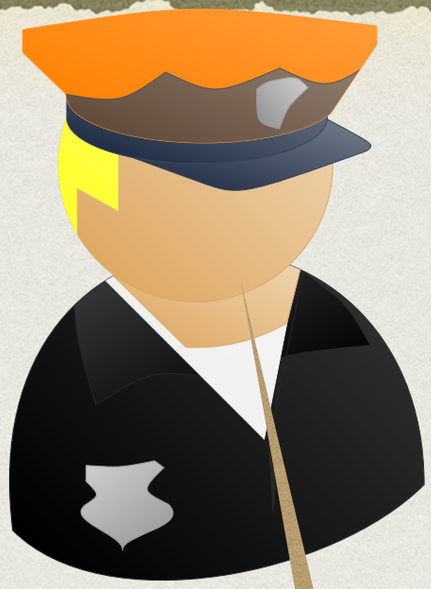

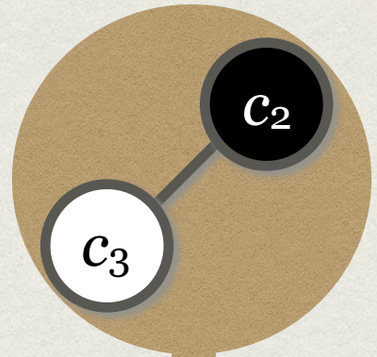

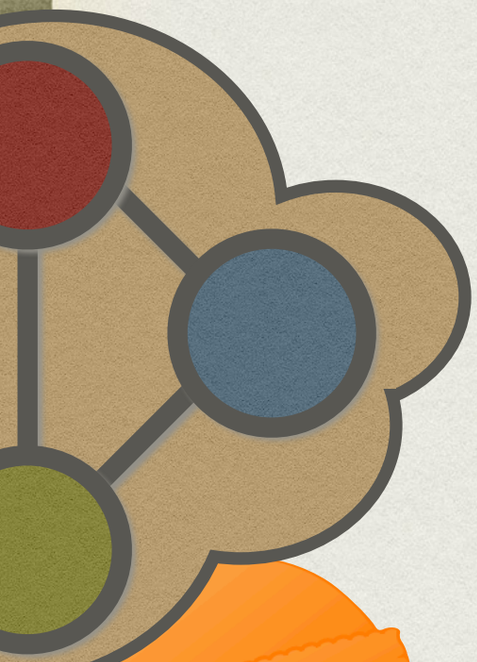

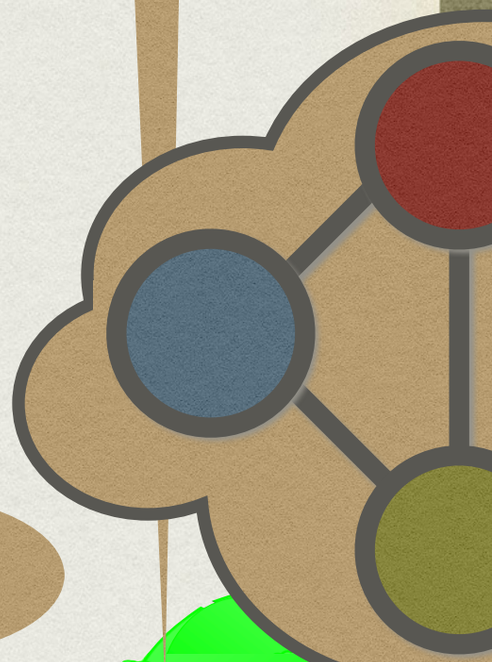

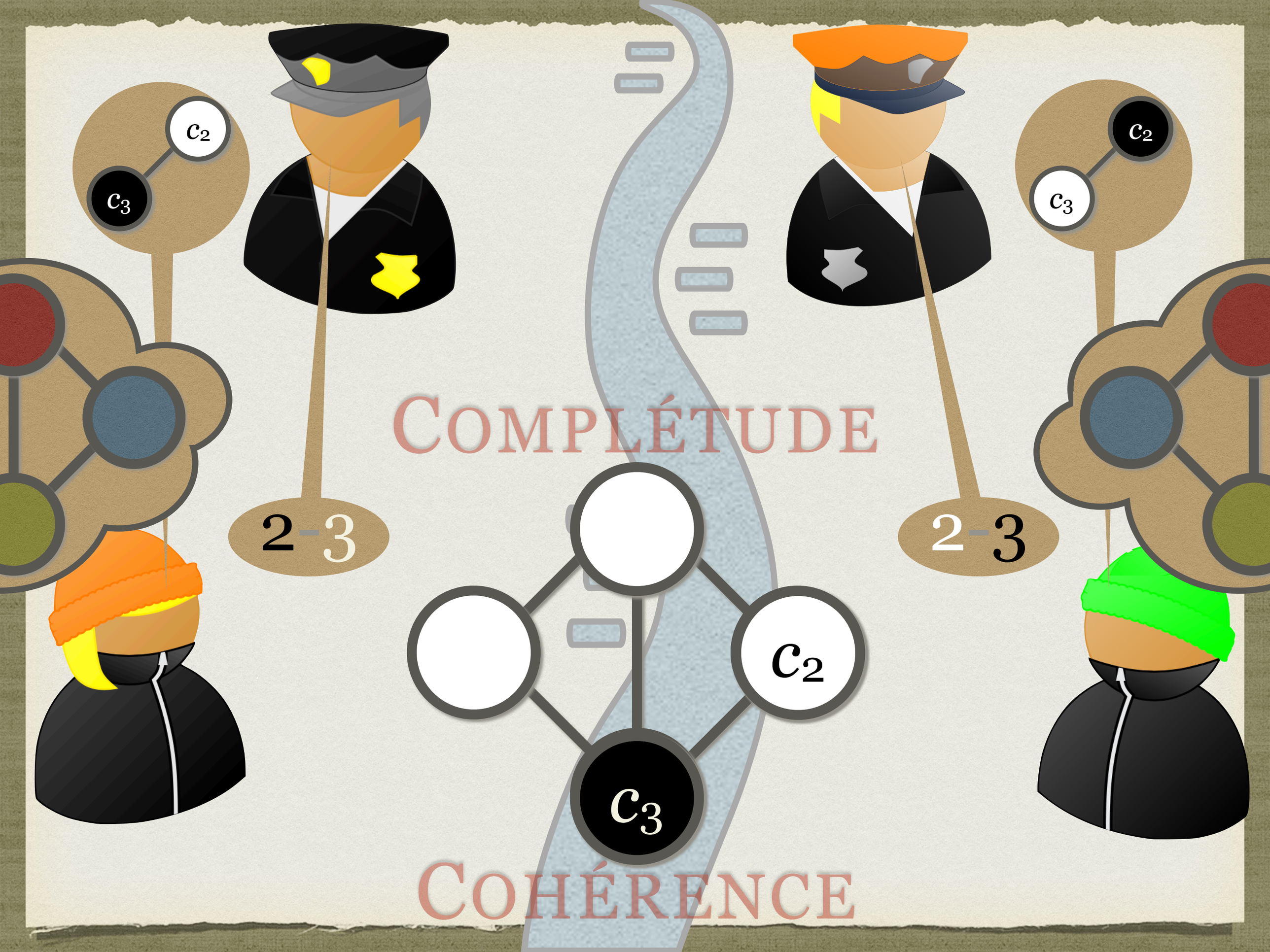
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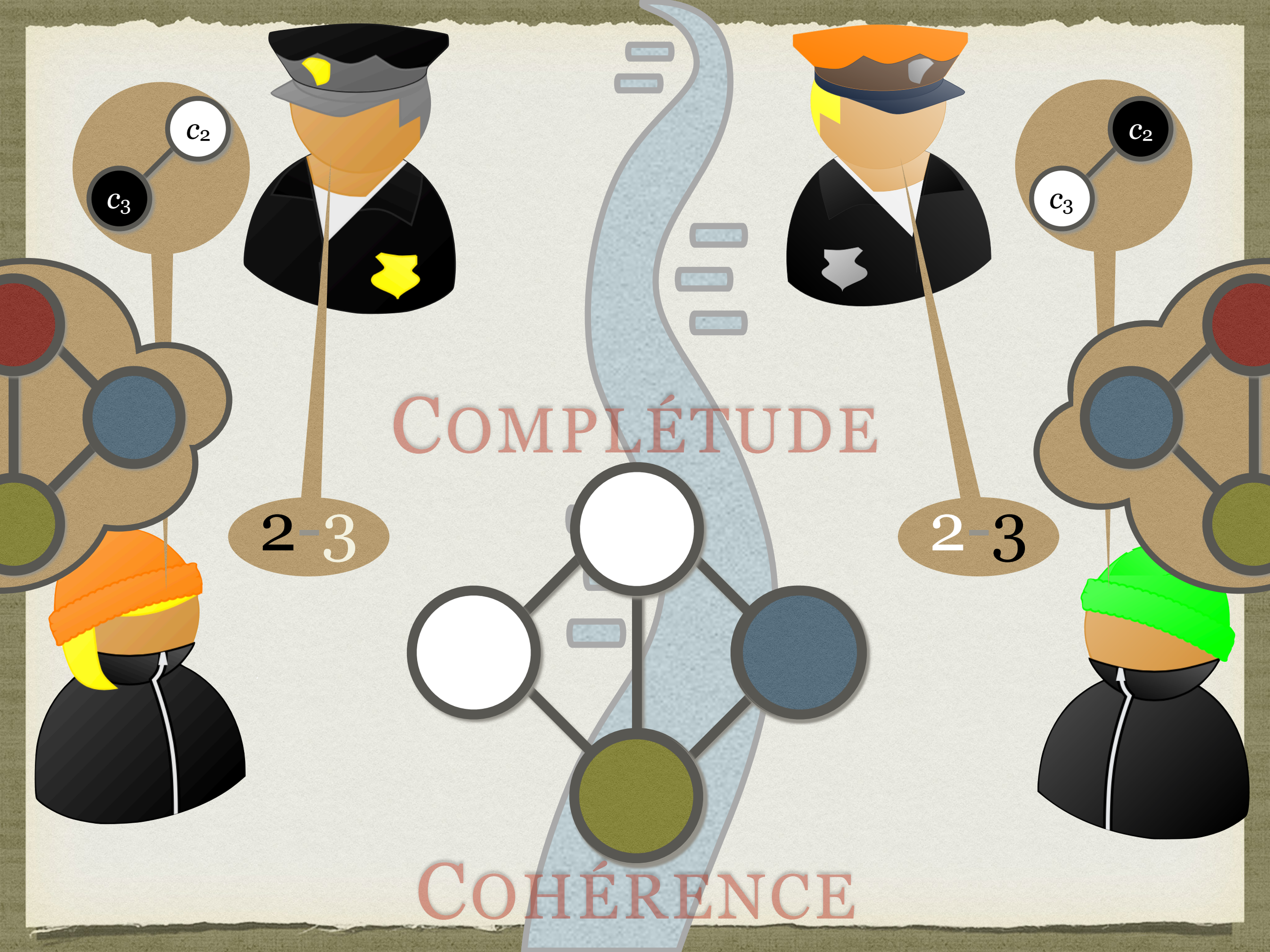
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Complétude
Cohérence

COHÉRENCE MALGRÉ L'INTRICATION

HONNÊTE:

$$MEG^{k}[n_i, r_i, n_j, r_j] = (coul_{n_i} + b_{n_i} r_i \ , \ coul_{n_j} + b_{n_j} r_j)$$

ANALYSE DE CAS

COHÉRENCE MALGRÉ L'INTRICATION

HONNÊTE:

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MALHONNÊTE:

ANALYSE DE CAS

COHÉRENCE MALGRÉ L'INTRICATION

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MALHONNÊTE:

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ANALYSE DE CAS

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MALHONNÊTE:

$$MEG^k[n_i, r_i, n_j, r_j] = \text{arbitraire}$$

$$MEG[n_i, r_i] = \text{bien-défini}$$

ANALYSE DE CAS

COHÉRENCE MALGRÉ L'INTRICATION

HONNÊTE:

$$MEG^k[n_i, r_i, n_j, r_j] = (coul_{n_i} + b_{n_i} r_i \ , \ coul_{n_j} + b_{n_j} r_j)$$

MALHONNÊTE:

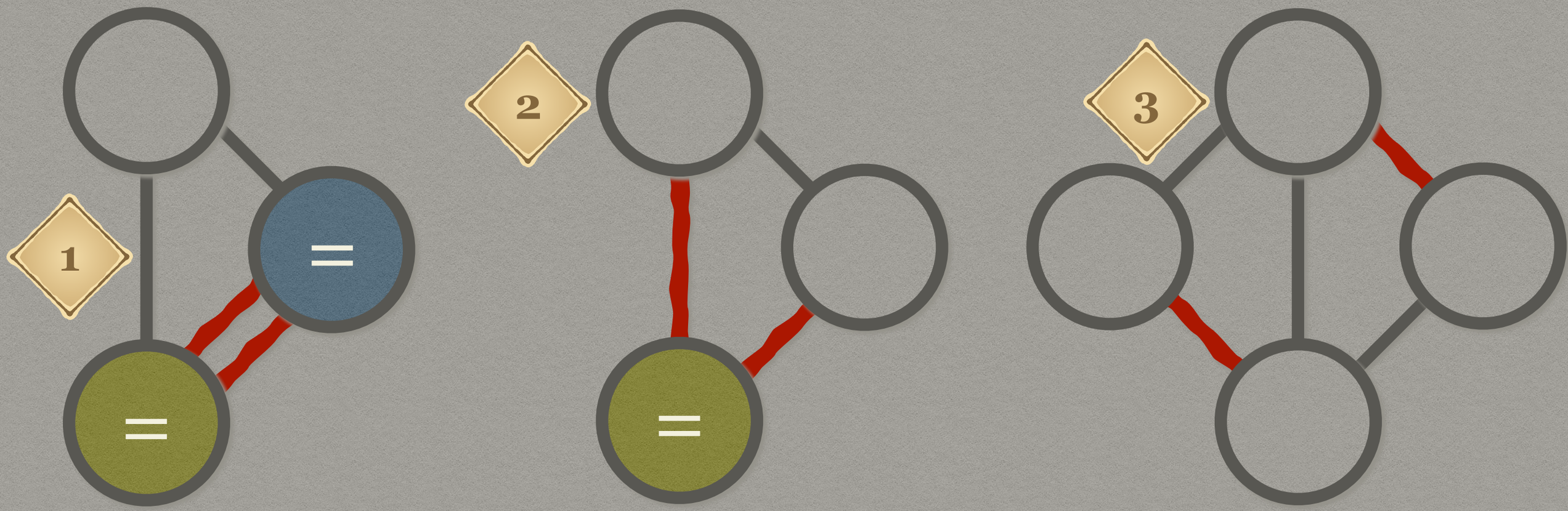
$$MEG^k[n_i, r_i, n_j, r_j] = \text{arbitraire}$$

$$MEG[n_i, r_i] = \text{bien-défini}$$

$$COUL[n_i] = \text{bien-défini}$$

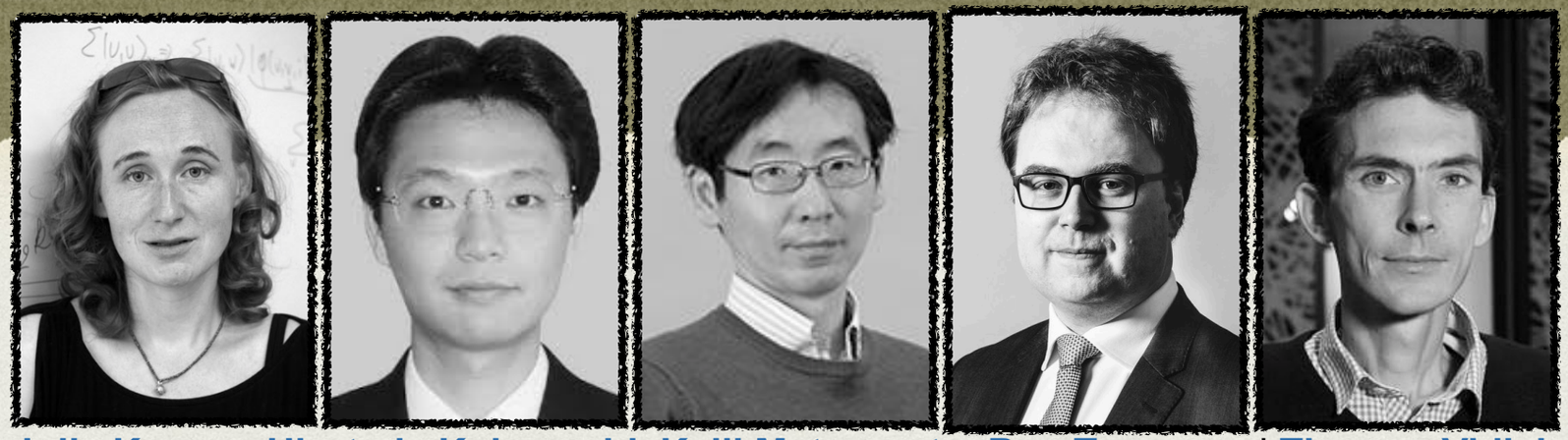
ANALYSE DE CAS

SIMULATION ZK



ANALYSE DE CAS

POWERFUL THEOREM



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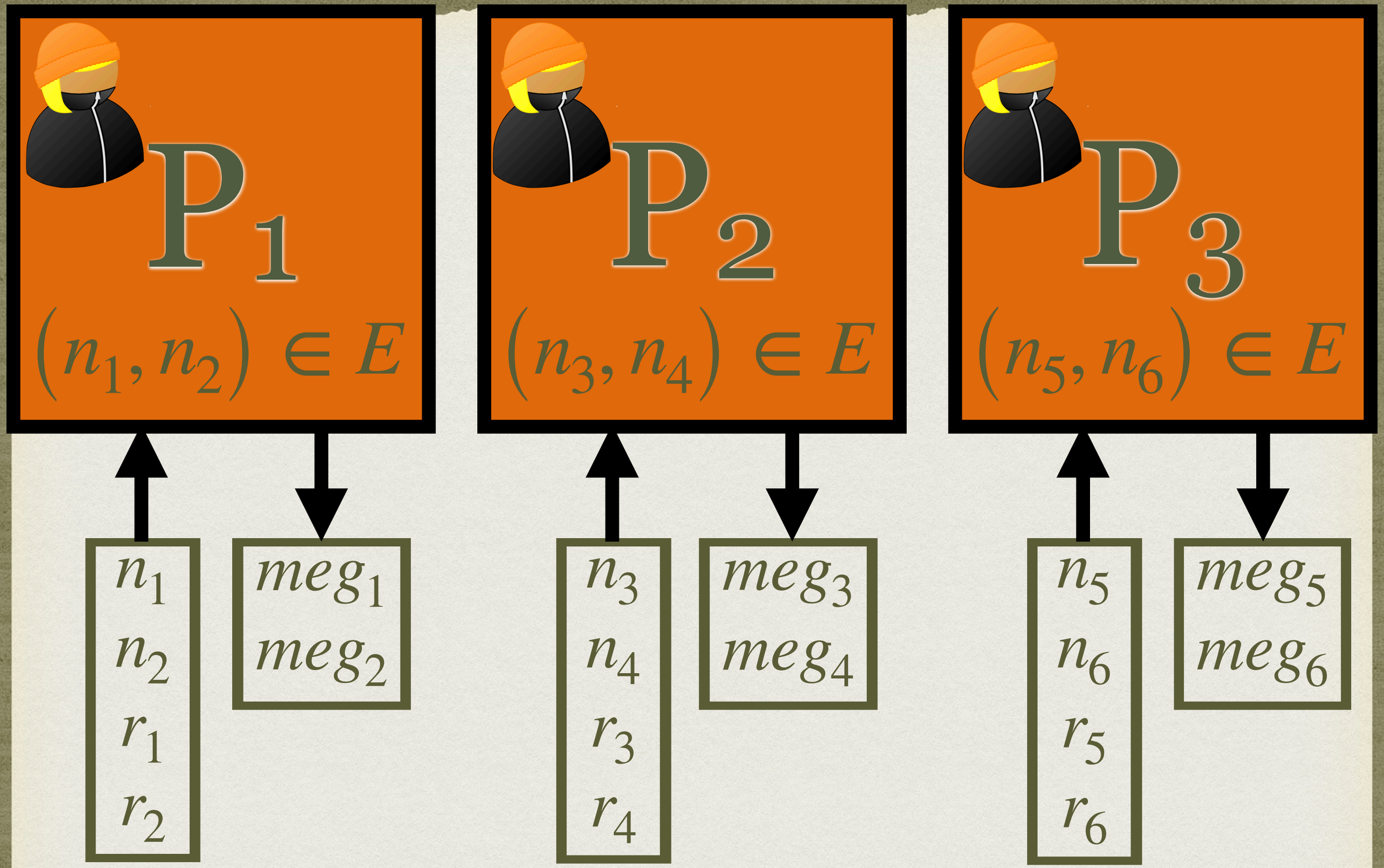
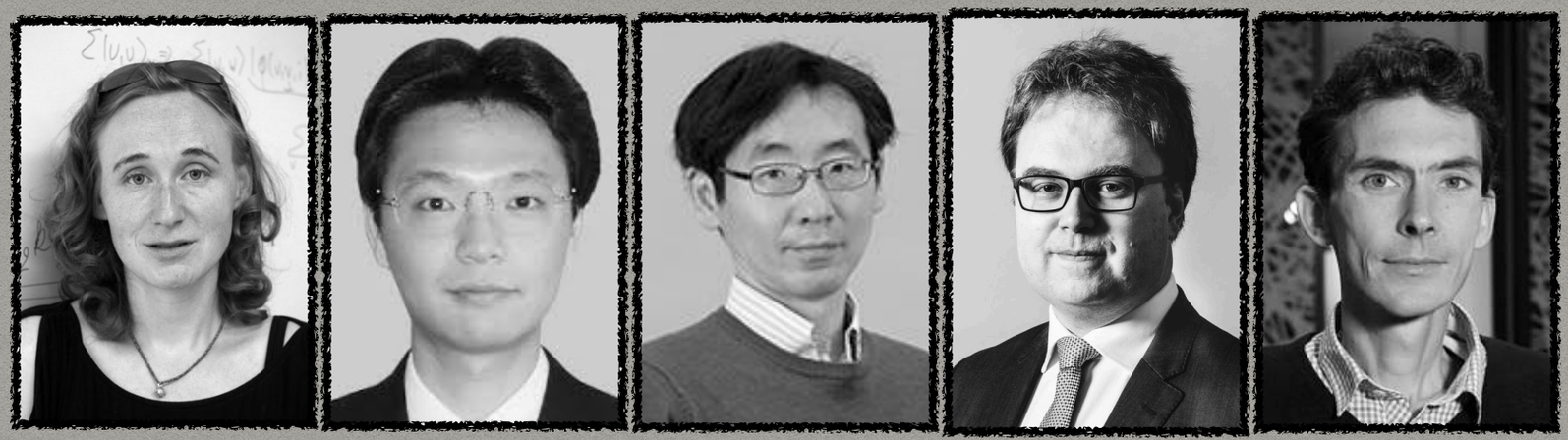
Entangled Games Are Hard to Approximate

- Si PI est cohérente face aux prouveurs *locaux* *alors* PI augmenté grâce à *1* prouveur imitant les premiers est cohérente face aux prouveurs *intriqués*



$$meg_i = b_{n_i} r_i + coul_{n_i}$$

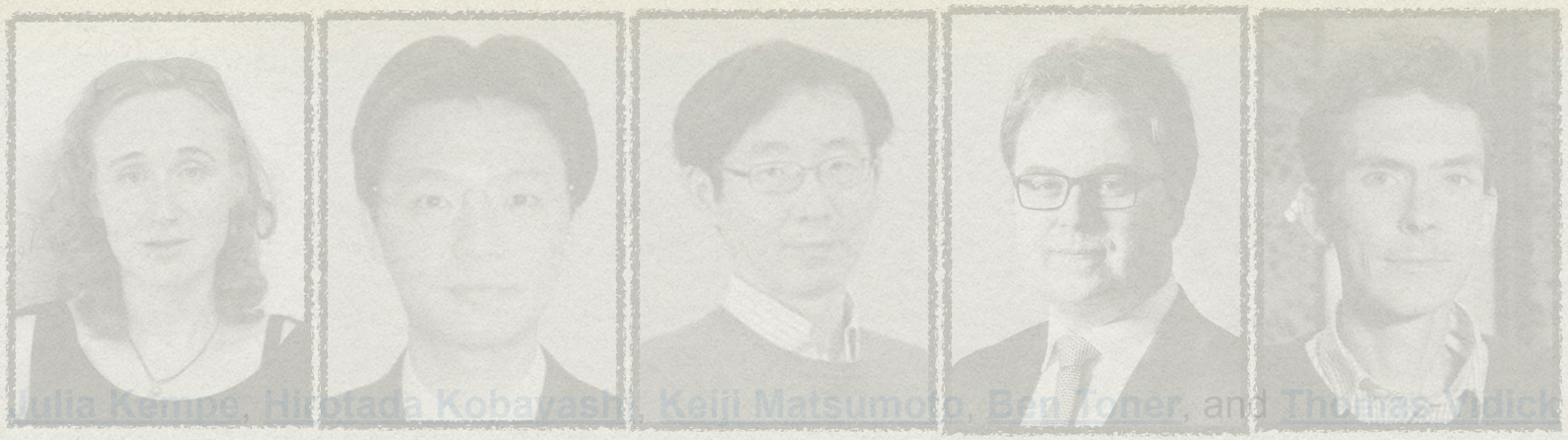
COHÉRENCE MALGRÉ L'INTRICATION



ANALYSE DE CAS

GROUPE TECHNOLOGIES QUANTIQUES
UNIVERSITÉ DE GENÈVE

QUESTIONS OUVERTES: THÉORÈME ANALOGUE?



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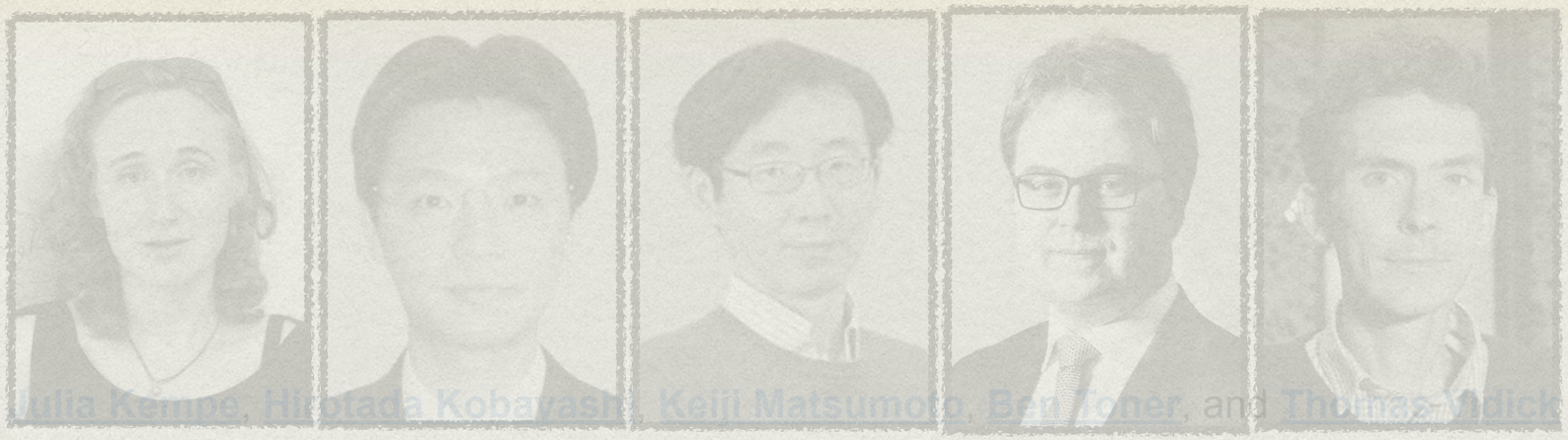
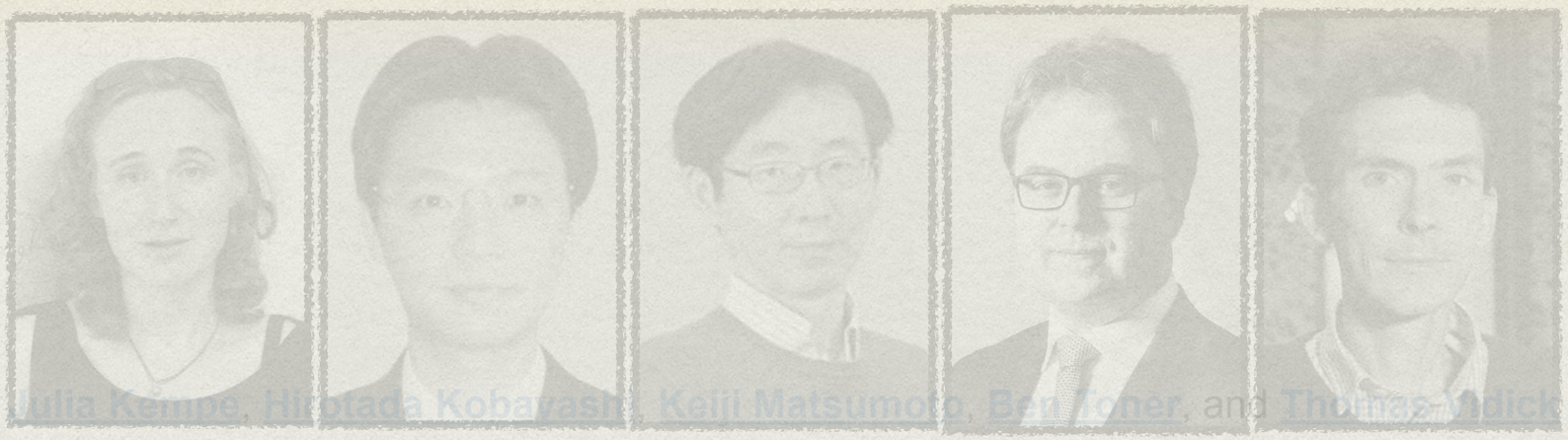
QUESTIONS OUVERTES: THÉORÈME ANALOGUE?



Julia Kempe, Hirotada Kobayashi, Keiji Matsumoto, Ben Toner, and Thomas Vidick

- Si PI est cohérente contre prouveurs *locaux/intriqués* alors PI augmenté grâce à *N* prouveurs imitant les premiers cohérente face aux prouveurs *Non-Signalants* ?

QUESTIONS OUVERTES: THÉORÈME ANALOGUE?



Julia Kempe, Hirotada Kobayashi, Keiji Matsumoto, Ben Toner, and Thomas Vidick

- Si PI est cohérente contre prouveurs *locaux/intriqués* alors PI augmenté grâce à *N* prouveurs imitant les premiers cohérente face aux prouveurs *Non-Signalants* ?

- Zero-Knowledge ?

Arnaud Yoh Massenet-Oshima
Louis Salvail
Lucas Shigeru Stinchcombe
Nan Yang

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Claude Crépeau

McGill