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Cover art: Bird Shot, by Barbara M. Tomotani & Rodrigo B. Salvador (2015).
A joke with the signature "barrel shot" from the James Bond series, substituting the agent's silhouette for that of a sad flycatcher (*Myiarchus barbirostris*), an endemic Jamaican bird.

Death and remembrance in *Final Fantasy Type-0*

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The Final Fantasy video game series is famous for its over-the-top cataclysmic-world-end stories and absurd hairstyles. The latest entry in the series is *Final Fantasy Type-0*, released in March 2015 for the PlayStation 4 and Xbox One consoles. (The original game, however, dates from October 2011, released only in Japan for the PlayStation Portable.) This game brought some nice changes (gameplay-wise) for the franchise, but this is not my interest here. What is unique about this game (besides its nonsensical story and awful dialogues) is how one particular facet of its fictional world works, namely the memories of the deceased.

Allow me to explain. The world of *Final Fantasy Type-0*, called Orience, is comprised of four nations. Each of these nations has a Crystal (the capital "C" indicates it is a huge and sentient mineral) that grants them unique powers. However, with great power comes great... costs; and the price to pay is a certain degree of memory loss. The Crystals make the common people of Orience forget those who have died. (Also, I should remark that treating the memories of the dead in a bizarre way is not a first for the series; see Box 1 for a quick overview of the topic in *Final Fantasy X*). This means that

once a person – let's call him Bob – dies, nobody will remember anything about him. Even Bob's relatives, friends or whatever, immediately forget everything they knew about him: his name, his appearance, his stories, his deeds, his achievements etc. The only way to "remember" Bob is to read something that was written about him. One of the game's characters synthetize the idea nicely:

> "*If people's actions fade away from our memories with time, then all we can do to prevent them from slipping away is to keep written records. But if the Crystal erases all our memories of the dead, what good is a list of someone's achievements when we can't remember who they were?*"
> —Ace, one of the main characters of *Final Fantasy Type-0*.

Of course that, not knowing any better, the people of Orience thinks this is normal. They believe this is the way in which the Crystals encourage people to carry on with their lives after a loved one passes away, instead of being held back in mourning for them. This reasoning is presented repeatedly in the game by the characters, mainly in response to Rem, a girl

who thinks it is rather sad to forget all about your loved ones.

The Vermillion Bird Crystal in *Final Fantasy Type-0*. (Screenshot from the game.)

However, this "memory mechanics" is, of course, custom-made for the game, which revolves around young people throwing away their lives in a senseless world war. Therefore, it is simply an excuse to explain why all the soldiers, free from the fear of death and loss, are so eager to vainly sacrifice themselves. Fear of death is, after all, intimately linked with the instinct of self-preservation, as argued by Zilboorg (1943). However, that does not work as neatly for everyone in Orience, as the following quote implies:

"I'm not going to let myself die, even if it means I have to take someone else's life instead. I… don't want to be forgotten."
—Dominion Legionary, a NPC (non-player character) from *Final Fantasy Type-0*.

In any case, this kind of forgetfulness poses a serious problem to how Orience's advanced civilization actually came to be. It would be very complicate to keep accumulating knowledge and technological advances if the folk would keep forgetting the inventions and ideas of dead people. This is especially true for the stages of civilization predating the invention of writing systems.

Anyway, instead of pinpointing the failings of a video game's narrative and its lack of logic or cohesion, let us simply accept it and move forward to focus on a different aspect of death and memory. I want to talk a little more about the importance that the (memory of the) dead had in the history of religious belief in our species.

DEAD ANCESTORS

Whenever humans started thinking about causal relations (either true or imagined ones), superstitious behavior accompanied them (this is also observed in other animals; see Box 2). Consequently, the seeds of religion started to form. At first, the nomad human tribes would try to deal with basic stuff through ritualized superstition (much like the pigeons from Box 2), like, for instance, ask for a good hunt or good weather, propitiate a spirit to stop a storm etc. Soon they added spirits and ancestor worshiping to their beliefs – and death (and the memory of the departed) played a major role in this. (It is way beyond the scope of this article to explain how religion emerged and took root; for that, please refer to the amazing books of Daniel Dennett [2006] and Nicholas Wade [2009] – the discussion below is largely based on their research).

Since we are not in Orience, after someone passes away we still remember him/her. As Dennett says: "A considerable portion of the pain and confusion we suffer when confronting a death is caused by the frequent, even obsessive, reminders that our (…) habits throw

up at us like annoying pop-up ads but much, much worse." He goes on to say that we "can't just *delete the file* from our memory banks" (his italics), which is precisely what the Crystals do to the people of Orience. Dennett continues stating that actually "we wouldn't want to be able to do so"; which is the same thing that Rem tells everyone in the game.

Box 1. The dead in *Final Fantasy X*

Final Fantasy X was released in 2001 for the PlayStation 2 console, getting remakes in 2013/2014 for the PlayStation 3 and PlayStation Vita and in 2015 for the PlayStation 4. The game is set in a world named Spira and has the most different and best delineated setting in the series.

There is no mystery about what happens after you die in *Final Fantasy X* – I mean, besides the "Game Over" screen. The dead (or, more precisely put, their spirits) go to a place called the Farplane (although the Al Bhed people have a different theory). The good and the bad, all end up there. The curious thing is that the Farplane is not a sort of heaven, hell or Hades – it is an actual place in the city of Guadosalam that people can physically visit (and no doubt a major tourist attraction!). The living go there to talk to their deceased loved ones. As such, there is no uncertainty about the afterlife and thus little need for an actual fear-based religion revolving around eternal punishment (such as in our real-world monotheisms). The fear in Spira is much more straightforward – it involves a giant Leviathan-like monster (called Sin) that swims around destroying towns and punishing people for the sins of their ancestors from a thousand years ago (much like the god of our monotheisms' stories).

The Farplane, in *Final Fantasy X*. (Concept art of the game.)

The deceased play an important role in people's lives, even long after their deaths. We preserve reminders of the dead, relics, stories, images. With time, their unseen presence in our lives goes beyond the simple "Oh, I wonder if he/she would like this" to a more complex

"virtual presence", namely a spirit. That is part of how ancestor worshipping came to be, where they were honored or propitiated with prayers, offerings and sacrifices. But I am getting ahead of myself here, so let us get back to track.

Perhaps the most pungent reminders of the dead are our dreams. A dream is thus a "place" where we can actually "see" the deceased (like the Farplane, from Box 1). As Wade (2009) puts it, this is perhaps how the idea of an afterlife and a "spirit world" first appeared. Since people would keep "meeting" their deceased relatives and acquaintances in dreams, then perhaps they were not truly dead, just "somewhere" else. This led the ancient humans to the conclusion that the spirit world could be visited in dreams – or also in trances, which was achieved at first during ritual dances and later during induced trances by shamans (with the use of natural-occurring psychotropic substances).

With the establishment of both an afterlife and a spirit world, the ancient tribal religions could transform into a more organized and specialized set of beliefs, led by an also specialized class of priests. This accompanied the transition from a nomad existence to a settled one. Still, the ancestors retained an important part in this context and were thus still remembered and worshiped. Well, why would anyone want to meet an ancestor in dreams/trances in the first place? To access their knowledge, of course. The elder were always (and rightly so) regarded as wise and people asked their counsels in solving difficult matters. The ancestors, of course, also filled that role. Finally, as the state religions were solidified, meeting the ancestors in dreams or trances slowly gave way to more controlled

forms of divination (conducted by the priest class), involving birds, bones, shells etc. The psychologist Steven Pinker (1997) even makes the stinging commentary about how these ancestor cults took hold and endured: "Ancestor worship must be an appealing idea to those who are about to become ancestors." Perhaps the powerful presence of an important ancestor, like a leader or hero, transformed from a simple spirit to a full-fledged god.

THE WORM AT THE CORE

The "ancestors in dreams" idea explained above is not the only explanation for the appearance of the belief in an afterlife. Another idea, likely complimentary to it, revolves around the fear of death. It is called "Terror Management Theory" (henceforth, TMT) and was developed by Greenberg et al. (1986), being derived from the Pulitzer-winning book *The Denial of Death*, by Ernest Becker (1973).

Becker argues that a major part of what humans do is related to ignoring/avoiding the inevitability of death. Knowing that we, like all living creatures, will eventually die is a very unwelcome realization. Moreover, knowing that death may come at any moment for reasons we cannot predict or control just makes it worse. Thus, the terror of total annihilation haunts people, creating a strong subconscious anxiety; as a result, people spend their lives attempting to avoid this feeling. William James (1902) called death the "worm at the core" of human existence and endeavors and Zilboorg (1943) linked it to the instinct of self-preservation, arguing that an organism would not function if this fear were constantly present on the top of one's mind. Becker's book is then a nice

argument on how civilization and culture are, in part, ultimately an unconscious intricate defense mechanism against the anxiety caused by the knowledge of our mortality.

The TMT builds on Becker's research. This theory states that cultures are symbolic systems whose purpose is to give meaning and value to life. And by giving life meaning, cultural values manage the terror of death (see also Solomon et al., 1991; 2015). Of course, the most obvious example of a cultural value that "grants" immortality is the idea of an afterlife, alongside its accompanying religion (which would dictate who is worthy of receiving immortality in the thereafter). The invention of a soul that endures after death in the spirit world was thus achieved by all human cultures.

Box 2. Superstitious pigeons

Skinner (1948) conducted a fantastic experiment with pigeons in his lab. He starved some pigeons a little to make them really crave food. A mechanism in their cages would feed them a couple of times per day. Of course, as classical experiments (and experience with domestic animals) had shown before, animals learn quickly how to get food after doing some chore, like raising their paws or pressing a button. However, Skinner decided to feed his pigeons at random, independently of any behavior the animals were displaying.

He saw that the behavior of the pigeons did not remained random though. In fact, after being fed randomly a couple of times, the animals started to show consistent behavior, each doing some odd thing of its own, like keep circling clockwise for instance. They were simply repeating the behavior they thought had made the food appear. This is superstition.

As Skinner himself puts it: "The bird behaves as if there were a causal relation between its behavior and the presentation of food, although such a relation is lacking. There are many analogies in human behavior. Rituals for changing one's luck at cards are good examples. A few accidental connections between a ritual and favorable consequences suffice to set up and maintain the behavior in spite of many unreinforced instances. The bowler who has released a ball down the alley but continues to behave as if he were controlling it by twisting and turning his arm and shoulder is another case in point. These behaviors have, of course, no real effect upon one's luck or upon a ball half way down an alley, just as in the present case the food would appear as often if the pigeon did nothing – or, more strictly speaking, did something else."

There are some later research confirming Skinner's finding (for instance, Timberlake & Lucas, 1985) while a few others seem to partially contradict it (Staddon & Simmelhag, 1971). It is strange that such an interesting topic has barely been studied to this day. Perhaps this is just to avoid hurting the sensibilities of our religious species, since many still believe the myth of humans-as-masters-of-Creation.

In addition, further research in TMT uncovered other cultural values that also manage the fear of death, such as posterity, patriotism, humanity's purported superiority over other animals (Becker had already pointed out how humans dislike the fact that they are animals), beliefs regarding sex etc. Some of these values at first glance do not seem to be related to death at all, but they in fact offer some kind of symbolic immortality.

But not everything is so bleak, as Sam Keen says in his foreword to *The Denial of Death*, "the bitter medicine that he [Becker] prescribes – contemplation of the horror of our inevitable death – is, paradoxically, the tincture that adds sweetness to mortality."

NEVER FORGET

Returning to *Final Fantasy Type-0*, the "idea" of the Crystals seems to resonate with the TMT.

By erasing the memories of the dead from people's minds, the Crystals also relieve people from this pressing fear of the inevitability of death. As I said above, people in Orience seem more prone to throw their lives ways at war (although more often than not religion does the same thing in our world).

Could then the people in Orience, unbound by this fear of death, have built their civilization? Moreover, would it be anything like ours (as the game clearly is) or would it be something completely alien to us? Maybe the latter; although it should be pointed out that Becker clearly states that our species still largely lives in tribal ways and easily sheds blood to purchase our token of immortality. But once again I was sidetracked – lacking the fear of death is a just secondary symptom in Orience, the cause of which is the erasure of the memories of the dead.

Ending scene of *Final Fantasy Type-0*, with nearly all the main characters dead after their final sacrifice in the war. After this, their "mother" (Arecia, a god-like creature) finally capitulates: "The world will change to one where death cannot be forgotten. So please, I ask that you remember my children." (Screenshot taken from the game.)

I know that in the beginning of this article I asked you to ignore the fact that Orience could not have become what it is if its people kept forgetting the dead and their stories. Well, now I want you to think about it again. The deceased obviously continue to play a big role in our lives long after they die – and they have done so in the whole story of our species. Would it be actually possible to live and thrive without their memory? Of course not! Our species can only

thrive on accumulated knowledge and each generation adds to what was achieved by the preceding one. As many historians and scientists have said before, the past is the key to the future.

> *"Everyone has lost something precious. Everyone here has lost homes, dreams, and friends. Now, Sin is finally dead. Now, Spira is ours again. Working together, now we can make new homes for ourselves, and new dreams. (…) Just, one more thing… the people and the friends that we have lost, or the dreams that have faded… Never forget them."*
> — Yuna, ending speech of *Final Fantasy* X.

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Egyptian mythology in the *Shin Megami Tensei: Persona* games

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Shin Megami Tensei is a Japanese RPG series famous for its monsters, which are taken from many different mythologies and folkloric legends from around the world. The player can "capture" these monsters and use them in battle in a very *Pokémon*-like manner. In the *Shin Megami Tensei: Persona* "sub-series", more specifically these monsters are called "personas" (although some were called "demons" in the first three games). Since I am fascinated by monsters, mythologies and games, I decided to take a closer look at how my favorite mythology, the ancient Egyptian, is represented in the *Persona* games.

For the present study, the following games were analyzed (the abbreviation in parenthesis are used throughout the whole text): *Revelations: Persona*, also known by the Japanese title *Megami Ibunroku Persona* (P1), *Persona 2: Innocent Sin* (P2-IS), *Persona 2: Eternal Punishment* (P2-EP), *Shin Megami Tensei: Persona 3* (P3), *Shin Megami Tensei: Persona 4* (P4). The remake versions of P3 and P4 (*Persona 3 Portable* and *Persona 4 Golden*, respectively) were preferred, since they have extra content and were the last to be released. The following spin-offs and/or non-canon games

were completely ignored: *Persona 4 Arena*, *Persona 4 Arena Ultimax*, *Persona Q: Shadow of the Labyrinth*, *Persona 4: Dancing All Night*. Just to situate the games, P1, P2-IS and P2-EP were released for the PlayStation respectively in 1996, 1999 and 2000 (Japanese dates). Curiously, P1 also had a later port to Microsoft Windows. Both P3 and P4 were released for the PlayStation 2, respectively in 2006 and 2008. All of the games eventually found their way into Sony's handheld consoles too.

Below, all the Egyptian gods and goddesses featured in the *Persona* games are listed alphabetically (a summary can be found on Table 1). My original intention was only to include personas, but I decided to also include the so-called demons, since there are only two of them. In each entry, there is a brief description of the god(dess), his/her role in Egyptian mythology and society and his/her usual depiction in Egyptian art. All the information regarding the Egyptian mythology was taken from the books listed on the References section further below. I use the most commonly found version of the gods/goddesses' names, but other variant spellings can also be found. Following this, there is a brief description

of how the persona/demon is represented in each *Persona* game and a comparison with its mythological inspiration, pointing out what game designers got right or wrong. In some cases, I have also included the official artwork of the *Shin Megami Tensei* series, if it would bring more information and material for further discussion.

Table 1. List of all persona and demons in the *Shin Megami Tensei: Persona* series, with their names in each game.

Persona	Category	P1	P2-IS	P2-EP	P3	P4
Amun / Amun-Re	Persona	Amen Ra				
Anubis	Persona	Anubis			Anubis	Anubis
Apep	Demon		Apep	Apep		
Bennu	Persona	Bennu	Phoenix	Phoenix		
Hathor	Persona	Hathor	Hathor	Hathor		
Horus	Persona				Horus	Horus
Isis	Persona		Isis	Isis	Isis	Isis
Serket	Demon	Selket				
Seth	Persona		Seth	Seth	Seth	Seth
Sokar	Persona		Seker	Seker		
Thoth	Persona				Thoth	Thoth

I suppose that the reader is familiar with a few things about ancient Egypt, such as: that religion played a central role in their life; that human, animal and hybrid forms are all part of their religious symbolism; that the afterlife and mortuary rites and cults were given major prominence etc. It is impossible for me to explain every single aspect of Egyptian mythology here and the reader is encouraged to explore further topics on his/her own (I even left some points barely explained to see if this can pique someone's curiosity). The works listed on the References section are an excellent starting point, but a quicker way would be the English version of Wikipedia (sometimes the French or German versions are also very complete), although it is a very arid reading and some information there should be taken more cautiously.

Table 2. Periods of Egyptian history, with indication of the dynasties of rulers and approximate dates (according to Shaw, 2004).

Period	Dynasties	Date
Predynastic Periods (Neolithic)	–	5300–3000 BCE
Early Dynastic Period	1–2	3000–2686 BCE
Old Kingdom	3–8	2686–2160 BCE
First Intermediate Period	9–11	2160–2055 BCE
Middle Kingdom	11–14	2055–1650 BCE
Second Intermediate Period	15–17	1650–1550 BCE
New Kingdom	18–20	1550–1069 BCE
Third Intermediate Period	21–25	1069–715 BCE
Late Period	25–"31"	715–332 BCE
Macedonian Era	–	332–304 BCE
Ptolemaic Era	–	304–30 BCE
Roman Era	–	30 BCE – 395 CE
Byzantine Era	–	395–641 CE
Arab conquest	–	641 CE

Moreover, it is important to keep in mind the fact that Egyptian myths sometimes disagree among themselves; for instance, there are several distinct cosmogonies, stemming from different cities (the solar Heliopolitan, the Memphite, the Theban etc.). The Egyptians did not mind this contradiction and could embrace

all of them as complementary. In addition, some gods were more important in a given period of Egypt's history, while others changed a lot through the three millennia the kingdom lasted. Here, I tried to always indicate the period and the geographical location of cults, works of art etc.; so, to give a better idea of these aspects, I included a table with the periods of Egyptian history (Table 2) and a map with the location of the main ancient cities (Fig. 1).

AMUN / AMUN-RE

The first record of Amun dates from the end of the First Intermediate Period and the very beginning of the Middle Kingdom. He was a local god from Thebes, who quickly displaced the other local god, Montu, and then rose to prominence when the Theban dynasty started to rule Egypt. Then, Amun was promoted to national god, becoming conjoined with the former national god, the sun god Re. This version of the gods became known as Amun-Re (Fig. 2A), who remained as chief god throughout most of the remainder of Egypt's history.

Amun was originally a member of the Ogdoad, a group of eight gods from Hermopolis who was said to predate creation. Arranged in four pairs, they represented the concepts of the primeval waters, darkness, eternity and concealment. Amun belonged to the last category and together with his feminine counterpart, Amaunet, was the god of the hidden power of air and wind. He then took a role of demiurge, creating the world with his thoughts. All these aspects as a "hidden creative force" became a little antithetical when Amun was conflated with the sun god Re (after all, the sun is a very conspicuous thing). Amun was seen

as a universal god, whose essence was in everything. Amun-Re's status as chief of the Gods led the Greeks to equate him with Zeus (Fig. 2B).

Another conjoined form was Amun-Min (or *Amun kamutef*), where Amun took the divine features of Min, the god of fertility, and was shown, accordingly, in an ithyphallic manner (Fig. 2C). As "Lord of Victory", Amun also was a god of war to some extent, a feature that he may have absorbed from Montu.

Amun was often represented in fully human form, wearing his characteristic crown with two long feathers (Figs. 2A, C). After the Amarna Period (a heretical surge in the Middle of the 18th Dynasty), Amun started to be constantly depicted with blue skin (Fig. 2A), perhaps symbolizing his original role as an air god. He could also be depicted as a ram (Fig. 2D) or a ram-headed human; his Greek conjunction with Zeus often included the ram's horns (Fig. 2B).

In the game P1, Amun-Re appears in a very Egyptian manner, wearing his feathered crown (Fig. 2E). In the *Shin Megami Tensei* official artwork, he keeps the crown and adds some other features (Fig. 2F). Firstly, he has a greenish skin, which, as seen above, should actually be blue. Secondly, he is shown in a full white jumpsuit; in Egyptian art, Amun had a very characteristic tunic (Fig. 2A). Finally, he has a strange-looking scepter, with a broad circular head and two flail-like structures hanging from it. Amun could indeed be depicted with a flail (Fig. 2C), but more usually he was shown holding a *was* scepter (Fig. 2A). This kind of scepter has a very unique shape (Figs. 2A, 4A, 8A, 10A) and symbolizes power and dominion.

Figure 1. Map of ancient Egypt, with the main cities (the modern Cairo is included for reference). Image by Jeff Dahl (2007); extracted and modified from Wikimedia Commons.

Figure 2. A. Amun-Re receives offerings (temple of Seti I, Abydos; 19th Dynasty, New Kingdom). **B.** The Greek depiction of Zeus-Amun (Nile delta; 5th century BCE); Roman copy of the Greek original. Photo by Dan Mihai Pitea (2013); image extracted and modified from Wikimedia Commons. **C.** The ithyphallic Amun-Min, from the temple of Deir el-Medina (New Kingdom). Photo by S F-E-Cameron (2009); image extracted and modified from Wikimedia Commons. **D.** Amun, as a ram, protecting the Pharaoh Taharqa (25th Dynasty, Late Period). **E.** The persona Amun-Re (Amen Ra) in the game P1. Screenshot from the game. **F.** Amun-Re's (Amon-Ra) official artwork from the *Shin Megami Tensei* series.
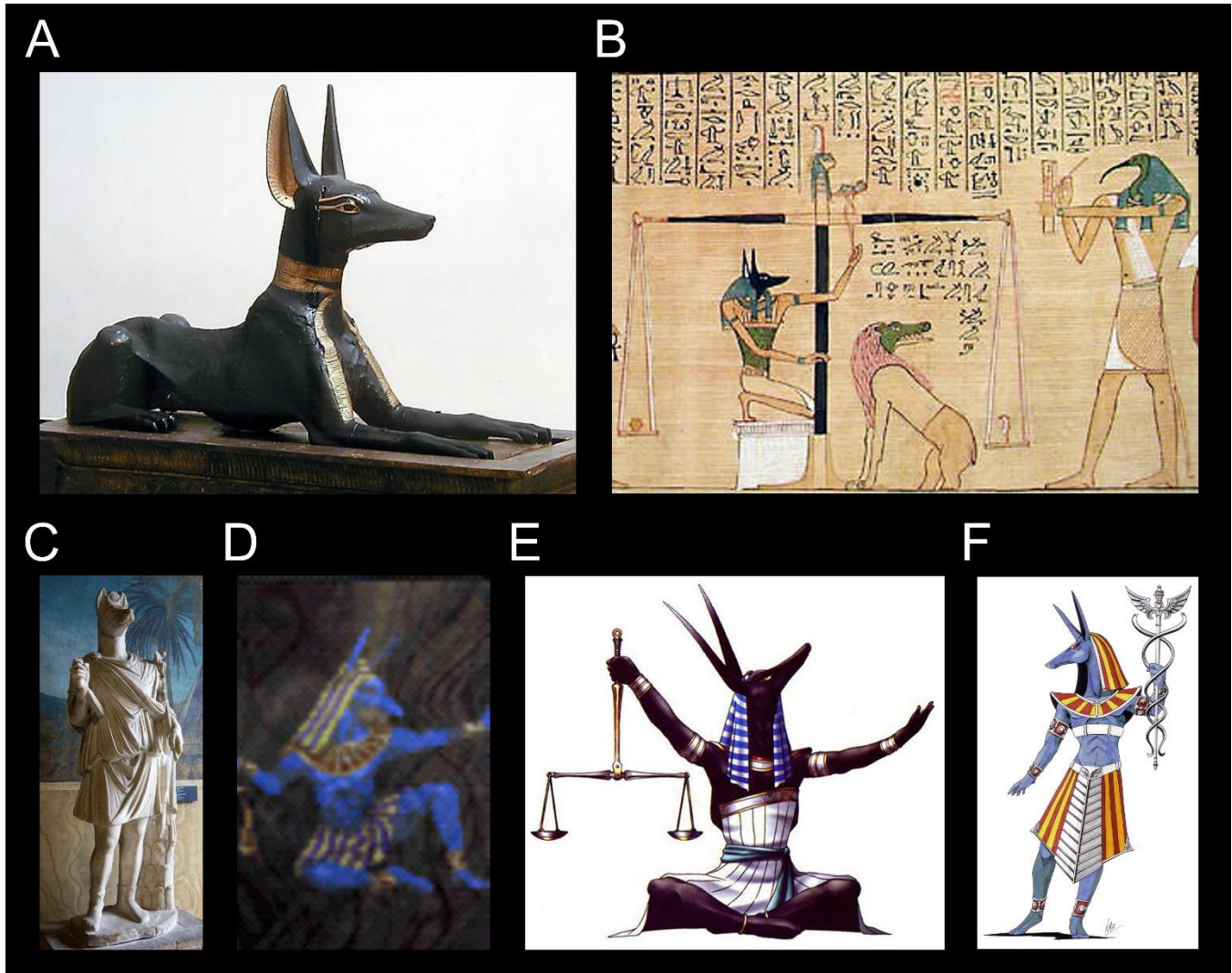
ANUBIS

The jackal-headed god Anubis is probably the first thing that comes to people's mind when thinking about Egyptian mythology. He is the god of cemeteries, burial and embalming and was the most important funerary god in Egypt

until the rise of Osiris (his cult was later largely assimilated into that of Osiris). Anubis was said to have wrapped the body of Osiris (who was said to be his father in most myths), during the embalming of the dead god.

Figure 3. A. Statue of Anubis as a crouching jackal, from the Tomb of Tutankhamun in the Valley of the Kings (18th Dynasty, New Kingdom). Photo by Jon Bodsworth (2007); image extracted and modified from Wikimedia Commons. **B.** The weighting of the heart ceremony, from the Papyrus of the scribe Hunefer (Thebes; 19th Dynasty, New Kingdom). Anubis conducts the weighing on the scale of Maat, while Thoth records the result and the monster Ammit waits to devour Hunefer in case he fails the test. Photo by Jon Bodsworth (2007); image extracted and modified from Wikimedia Commons. **C.** Statue of the conjoined god Hermanubis holding the *caduceus* on his left hand. Photo by Colin (2012); image extracted and modified from Wikimedia Commons. **D.** The persona Anubis in the game P1. Screenshot from the game. **E.** The persona Anubis as it appears in the games P3 and P4. Screenshot from the game. **F.** Anubis' official artwork from the *Shin Megami Tensei* series.

Egyptian priests wore masks of Anubis during the mortuary rites and possible also during the embalming process. One of the most important of these rites was the ceremony of

the "opening the mouth"; its aim was to symbolically revivify a mummy (or statue of the deceased) for his/her new life in the thereafter. This ceremony is known since the Old Kingdom and it used an adze-like tool, which was partly made of meteoritic iron. Anubis was though to provide this iron from the sky.

Anubis is a prominent figure in yet another important ceremony: the weighing of the heart (Fig. 3B). This ceremony was a form of judgement, described in the Book of the Dead, which took place in the Underworld. The deceased was led by Anubis into the Hall of Two Maats (Maat is the goddess of truth, balance and order), where he/she would plead his innocence (of 42 sins) before 42 judges. After this, the deceased's heart was weighted on a scale against Maat, represented by a feather. The god Thoth would record the result. If the scales were balanced, Anubis would take the deceased before Osiris, who would grant him/her entrance to the afterlife. However, if the heart was heavier than Maat, the monster Ammit would devour the deceased, erasing him/her completely from existence.

Anubis is either depicted as a black crouching jackal (Fig. 3A) or a jackal-headed man (Fig. 3B); only very rarely does he appear fully human. His canine form is likely derived from people observing golden jackals (*Canis aureus* Linnaeus, 1758) and/or wild dogs scavenging bodies from the shallow graves during the Predynastic Period. It was common in Egyptian magic to use the form of the threat as a protective symbol; thus, a jackal god would repel scavengers. However, Anubis' completely black color is entirely symbolical; it is linked to his role as god of embalming and afterlife. The

god's black fur is thought to represent the discoloration of the corpse during the mummification process and might also be linked to the ideas of fertility and rebirth, since black is the color of the Nile silty soil after the inundation, which made Egypt such a fertile place for agriculture (Egypt was called "the Black Land").

In the *Persona* games (P1, P3 and P4), Anubis appears as a jackal-headed man, but his entire body is black (Figs. 3D–E); in Egyptian depictions, the body is of normal human coloration (Fig. 3B). In the games, the god is holding the scales (Figs. 3D–E), a reference to his role in the weighing of the heart ceremony (Fig. 3B).

In the official artwork of the *Shin Megami Tensei* series (Fig. 3F), however, Anubis appears holding the *caduceus*, the staff of Hermes. Hermes was a Greek god and his staff represented the domains over which he had power, such as commerce and negotiation. (Just a note: Hermes' *caduceus* should not be confused with the rod of Asclepius, which is the symbol of medicine.) During the Ptolemaic Era in Egypt, it was common to have merged representations of Anubis and Hermes (as Hermanubis), since both deities shared some similarities (the statue from Fig. 3C, for instance, carries the *caduceus*).

APEP

Apep (also known as Apophis) was the greatest enemy of the sun god Re. It was the embodiment of darkness and chaos. Egyptian culture was all about standing your ground against chaos, so a monstrous god who symbolized primeval chaos was a big deal. It was said Apep existed before creation and, since

references to it only appears during the Middle Kingdom, scholars believe that the idea of Apep was conceived during the uncertain and turbulent times of the First Intermediate Period. It is only during the New Kingdom that the myths surrounding Apep take a more definite shape.

Every night, the sun (Re) would travel through the Underworld on his barque. There, the great serpent Apep (some sources even give its length: over 16 meters) was always ready to attack him, its terrible deafening roar echoing through the whole underworld. In some versions of the myth, the god Seth protects the barque from Apep (Fig. 4A). In other versions, Apep was beaten and cut to pieces by the gods in Re's entourage, but the serpent was always reborn each day.

Paintings and words were thought to hold power by ancient Egyptians. As such, since Apep was a particularly powerful and terrible enemy, it was always depicted being attacked or subdued (Fig 4A). Obviously, Egyptians did not have a cult for Apep (who would worship a god bent on destruction anyway?), but the serpent appeared in many religious settings as a symbol of all things related to chaos, darkness and natural catastrophes. There was a plethora of magic spells and amulets to avoid such things and even a book (the so-called Book of Apep, from the New Kingdom) devoted to this. In the Late Period, there were even daily rites to protect the world from the chaos serpent, in which a wax model of Apep was cut into pieces and thrown in the fire.

Apep is a demon in the Persona series, appearing in the games P2-IS and P2-EP. Contrary to the Egyptian depictions, in the games Apep is shown as a very short serpent

("*chibi*" would be an apt Japanese term) with bat wings (Figs. 4B–C). The reason for including wings would be sort of a mystery, because Apep is not only said to have swam in the primordial ocean but also to swim daily in the Underworld, where it attacked the solar barque. However, the mystery is quickly solved: Apep was regarded by the Greeks to be the same being as their monster Typhon, which was usually depicted as a dragon. Apep can be thus considered the first documented dragon – and good dragons must have wings nowadays, right?
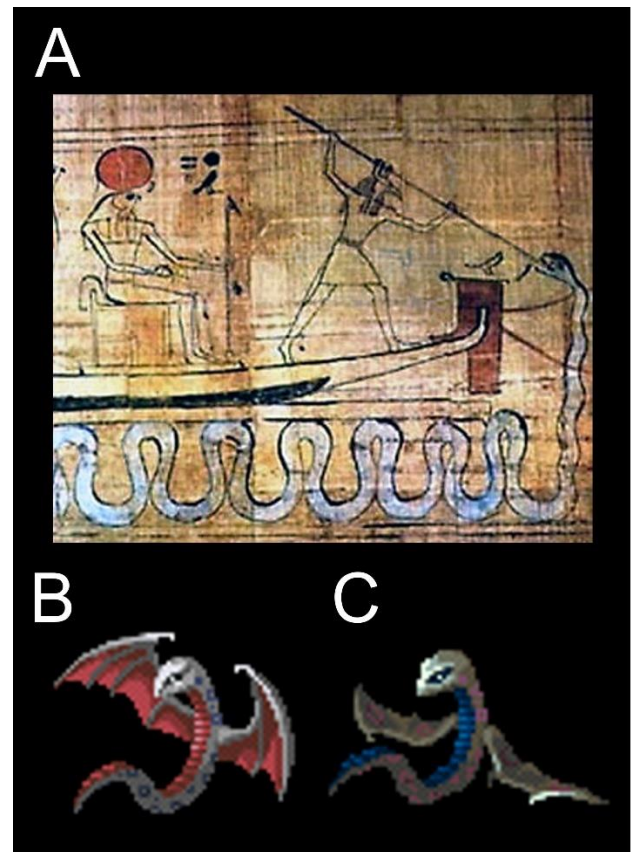
Figure 4. A. Scene from the papyrus of Her-Weben (Third Intermediate Period) showing the solar barque of Re (seated), with the god Seth spearing Apep. **B.** The demon Apep in the game P2-IS. Screenshot from the game. **C.** The demon Apep in the game P2-EP. Screenshot from the game.

BENNU

The Bennu bird, albeit little known nowadays, is an extremely important figure in the solar myths. The first mentions of Bennu date from the Pyramid Texts of the Old Kingdom: the bird was associated with (or was one of the forms of) the creator god Atum, which in turn was an aspect of the sun god Re (Atum was the evening sun, Khepri the morning sun and the nominal Re the midday sun). Later, during the Middle Kingdom, Bennu was considered the ba of the sun god Re, which originated Atum. The ba is one of the souls that make up things in Egyptian beliefs; it is roughly equivalent to our notion of personality.

Bennu is said to have flown over Nun, the primordial ocean, right before creation. He finally perched on a rock and let out a loud cry (in the sense of the usual animal call), which broke the primeval silence. This first cry was said to have determined what was and what was not to be in the soon-to-be-unfolded creation by the hands of Atum.

Very little is known of Bennu's cult, but his role in the solar mythology of Heliopolis probably made him very important in the region's cults. Bennu's titles were "He who Came into Being by Himself" and "Lord of Jubilees", reflecting, respectively, his self-generative birth and its long life. Bennu is usually depicted as a heron (Fig. 5A), sometimes atop of the *benben* stone (the rock or mound where it first perched, which represents Atum/Re) or on a willow tree (which represents the god Osiris). But where did Osiris come from in this story? Bennu became linked with Osiris as a symbol of anticipated rebirth in the Underworld; as such, the bird is sometimes depicted wearing Osiris's

atef crown (a feathered white crown; Fig. 5A). Rarely, Bennu is depicted as a heron-headed man.

Bennu appears as a persona only in the very first game in the series (P1). Its depiction in the game is completely stylized and rather bizarre (Fig. 5C), not being very reminiscent of a heron at all. However, the official artwork of the Bennu in the *Shin Megami Tensei* series is more similar to the Egyptian drawings (compare Figs. 5A and 5B). Nevertheless, it has a short neck and a long and curved beak, looking more like a hybrid of a vulture and an ibis than a proper heron. In addition, it wears not the *atef* crown of Osiris, but the headdress of the goddess Hathor (the sun disk amid cow horns), which has nothing to do with the Bennu.

Archaeological remains found in the United Arab Emirates, dating from the Umm an-Nar period (2600–2000 BCE), contained bird bones, some of which belonged to a large heron. These bones were deemed to belong to a new species, which was named *Ardea bennuides* Hoch, 1979 (its common name is "Bennu heron"). This now extinct species is considered to have been the inspiration for the Bennu – for an idea of what the animal might have looked like, take a look at the grey heron (Fig. 5D), which belongs to the same genus.

The date of the remains of the Bennu heron coincides with Egypt's Old Kingdom and First Intermediate Period (Table 2). However, the Bennu only started to be depicted as a heron later in Egyptian history, during the New Kingdom. Back in the Old Kingdom days, we find another bird that might have been the first inspiration for the Bennu – and it has absolutely nothing to do with a heron. This bird is the

yellow wagtail, *Motacilla flava* Linnaeus, 1758 (Fig. 5E), which in the Pyramid Texts is considered a representation of Atum himself. A

very modest bird for such an important role, perhaps?
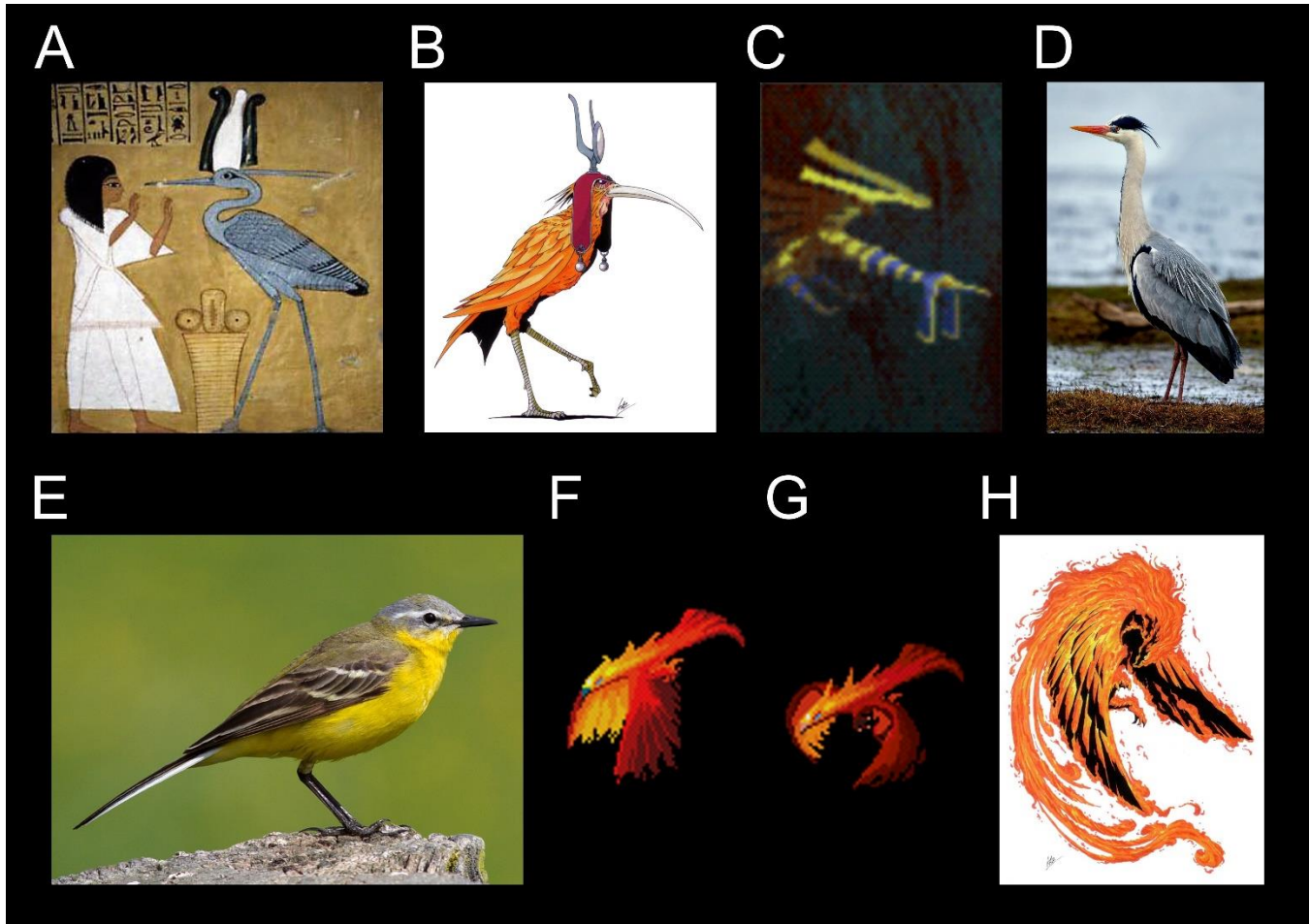
Figure 5. A. Drawing from the Tomb of Inherkha (Deir el-Medina; 20th Dynasty, New Kingdom) depicting the Bennu bird. **B.** Bennu's official artwork from the *Shin Megami Tensei* series. **C.** The persona Bennu in the game P1. Screenshot from the game. **D.** The grey heron (*Ardea cinerea* Linnaeus, 1758), a living species related to the extinct Bennu heron (*Ardea bennuides* Hoch, 1979; family Ardeidae), winters in the Nile Valley. Photo by Andreas Trepte (2015); extracted and modified from Wikimedia Commons. **E.** Western yellow wagtail (*Motacilla flava* Linnaeus, 1758; family Motacillidae), the original Bennu bird from Old Kingdom times. Photo by Frebeck (2014); extracted and modified from Wikimedia Commons. **F.** The persona Phoenix in the game P2-IS. Screenshot from the game. **G.** The persona Phoenix in the game P2-EP. Screenshot from the game. **H.** Phoenix's official artwork from the *Shin Megami Tensei* series.

Finally, I should say something about another famous mythological bird, the phoenix. The Greek historian Herodotus visited Egypt during the 5th century BCE. There, he learned about the Bennu bird from the priests and called

it Phoenix in his native language (the name was likely derived directly from "Bennu"). In later Greek tradition, the phoenix was often likened to an eagle, but kept the characteristics of its origin: its role as a sun-bird and a symbol of

resurrection, its self-generative birth and its long life. These characteristics might have given rise to the legend that the phoenix is reborn anew in a fiery conflagration, like the sun rising at dawn.

As such, we may consider that Bennu is also present in the games P2-IS and P2-EP, under the guise of "Phoenix" (Figs. 5F–H). In this depiction, the persona is clearly following the Greek eagle tradition.

HATHOR

Some scholars believe that the goddess Hathor has its origin in the predynastic period, mainly by reference to an artifact from the reign of Narmer, the very first pharaoh (Fig. 6A). On the so-called Narmer Palette, there is the representation of a cow goddess. Nevertheless, most Egyptologists now agree this depiction actually represents the goddess Bat, and Hathor likely subsumed her attributes later on (and also those of Mehet-Weret, yet another cow-goddess). Hathor quickly became a very important goddess from the late Old Kingdom onwards, and was multi-faceted, appearing in many different contexts. As such, Hathor's myths seems to contradict each other sometimes.

To begin with, Hathor was firstly alluded to as mother of Horus (and, by extension, symbolic mother of the pharaoh); Isis might have taken this role later, when Hathor's myths were incorporated in the Heliopolitan tradition. Hathor was also said to have restored Horus' sight after Seth injured him, but this role sometimes falls to Thoth. Later, Hathor was usually treated as Horus' wife. Hathor could also be a sky-goddess, especially linked to the night sky and the Milky Way.

Besides being a goddess of motherhood, Hathor also presided over love, sex and beauty. Especially venerated by Egyptian women, she was called "the beautiful one" (or sometimes "mistress of the vagina"); the Greeks identified her with Aphrodite. Hathor was also the goddess of music, dance and joy. As such, music was very prominent in her cult and two musical instruments became her symbols (and were used by her priestesses during the rites): the *sistrum* and the *menat*. The *sistrum* is a rattle-like instrument (Fig. 6B), while the *menat* was a heavy necklace (not to be worn, but shaken); both led to ecstatic religious dances.

Hathor was also the goddess of foreign lands, especially of the material goods that the Egyptians explored abroad, such as timber and minerals. She thus received titles such as "lady of Byblos" (a commercial center) or "mistress of turquoise" (mineral explored in the mines of Wadi Maghareh). Finally, Hathor was one of the goddesses that were referred to as the "Eye of Re"; the others were Sekhmet, Bastet, Mut and Wadjet. The Eye of Re was an extension of the Re's power and his feminine counterpart. She protected him from any threats – in a very violent manner, actually – and is often depicted as a lioness. In her rage, the goddess was said to have almost extinguished the human race once.

Hathor was worshiped throughout all of Egypt, but her greatest cult center was Dendera. Hathor can be depicted as entirely human (Figs. 6D, E), entirely cow (Fig. 6C) or as a cow-headed human (or even with mixed facial features). Other unusual representations of Hathor includes a lioness (as the Eye of Re), a snake, a sycamore tree (as a protective and nurturing goddess of the afterlife) or a papyrus plant.

Figure 6. A. Upper portion of the Narmer Palette (Abydos; 1st Dynasty, Early Dynastic Period), with the cow goddess Bat appearing twice on the top. Image extracted and modified from Wikimedia Commons. **B.** Bronze *sistrum* (ca. 380–250 BCE, Late Period or Ptolemaic Era). Photo by the Walters Art Museum (2012); image extracted and modified from Wikimedia Commons. **C.** Statue of Hathor as a cow protecting the high official Psamtik (Late Period). **D.** Hathor in human form alongside the Pharaoh Menkaure (4th Dynasty, Old Kingdom). Image extracted and modified from Wikimedia Commons. **E.** Hathor greets Queen Nefertari in this painting from the tomb of Nefertari (Valley of the Queens; 19th Dynasty, New Kingdom). **F.** The persona Hathor in the game P2-EP. Screenshot from the game. **G.** Hathor's official artwork from the *Shin Megami Tensei* series.

In the *Persona* games, Hathor appears as cow-headed woman (Fig. 6F), a form of depiction more rarely used in Egyptian art. Moreover, her scepter seems to be a new invention, bearing only a very slight resemblance to Hathor's typical headdress (the solar disk between cow's horns). What exactly are the two *pokéballs* floating around her is a complete mystery, though. The goddess' official artwork of the *Shin Megami Tensei* series shows her entirely human (Fig. 6G), wearing the aforementioned headdress and her

characteristic long hair (or wig, actually). The adornments hanging from her hair in this artwork could be a reference to one of Hathor's symbols, the *menat* cited above, but this seems rather unlikely. The huge golden thing on the back of her dress is shaped like the tip of a cow's tail.

HORUS

One of the first Egyptian deities, Horus is known since the very early Dynastic Period, but very likely already existed in the Predynastic. He was one of the most important deities in Egypt and featured in many myths, displaying many different but intermingling aspects.

Horus' original form was as "lord of the sky", his name likely meaning "the one on high" or "the distant one", linking his image to that of a falcon soaring high. The right eye of this celestial falcon was the sun and the left, the moon. His earliest recorded cult center was Nekhen; which the Greek later called Hierakonpolis, meaning "city of falcons". From sky-god was just a small step for him to become a full solar god, often represented in art as a falcon-winged solar disk. As Horakhty ("Horus of the two horizons"), he was the god of the rising and setting sun. This aspect was later fused with the Heliopolitan sun god Re, becoming Re-Horakhty.

Later, Horus became known as the son of Isis and Osiris. Some scholars believe that this was a different deity from the elder Horus described above, but who just happened to have the same name. If they were indeed two gods, they were fused in the Osiris myths; if not, the younger Horus is just a very elaborate incorporation of the older Horus into the Osirian tradition. In this regard, Horus was commonly depicted as an

infant (the sidelock hairstyle was typical of children), called simply "Horus the Child" by the Egyptians or "Harpokrates" by the Greek. He was usually shown being suckled by his mother Isis (Fig. 8B). From the Late Period onwards, Horus was depicted on *cippi* (a kind of stela) dominating some dangerous fauna (Fig. 7A), such as crocodiles, serpents, scorpions, lions and oryxes. Water poured over these *cippi* was believed to cure poison.

Perhaps more than anything else, Horus was intimately linked to Egyptian monarchy. First, he was the son of Isis and Osiris and thus the mythical heir and ruler of Egypt. He fought for 80 years against his usurper uncle (sometimes brother), Seth, for the rule of the land. After all the gods decided in his favor, Horus finally managed to unite and rule Egypt. Just a note: the kingdom was considered to be composed of two parts, Upper (south) and Lower (north) Egypt (Fig. 1); Horus (and the pharaoh) was thus called the "Lord of Two Lands". Secondly, the pharaoh was considered "the living Horus" and two of the pharaonic names (they had five) are related to the god: the "Horus name" (written within a rectangular vignette, called *serekh*; Fig. 7B) and the "golden Horus" name. Horus was usually seen in statues protecting the pharaoh (Fig. 7C); ever since the Old Kingdom, the outstretched wings of birds were a symbol of protection in Egypt.

Horus' iconography is one of the best known from Egyptian art: the falcon (Figs. 7B–D). However, a falcon-headed man was also a very common depiction of the god (Fig. 7E). His avian form was most likely based on the lanner falcon (*Falco biarmicus* Temminck, 1825; Figs. 7F–G), although some argue that the peregrine falcon

Figure 7. (Captions on next page.)

(*Falco peregrinus* Tunstall, 1771) might also have influenced it. Despite the falcon depiction being so common, the Persona games managed to get it wrong, showing Horus as a hawk instead (Fig. 7H). The confusion between falcons and hawks is rather common, including among Egyptologists, but the two kinds of animal are easily told apart (they even belong to different orders: Falconiformes and Accipitriformes, respectively). Broadly speaking, falcons (Figs. 7F–G) are usually smaller, with more delicate features; they have a tooth-like projection on the upper mandible of the beak, dark markings around the eyes (Horus has them too!) and pointed wings. Hawks (Figs. 7I–J) are larger, have larger and curved bills and round wings. The difference of their wings is easily seen in flight (compare Figs. 7G and 7J).

Finally, an ironic remark: a fossil genus from the Eocene of France, *Horusornis*, received the god's name (the name means Horus-bird). However, the single species known so far, *Horusornis vianeyliaudae* Mourer-Chauviré, 1991, is actually considered a basal hawk, not a falcon. So, if Egyptologists do not know (or do not care about) their Ornithology, ornithologists also do not seem to know their Egyptology.

ISIS

Isis was one of the most important Egyptian goddess from as early as the Old Kingdom. She is an undeniable symbol of kingship: (1) she is the mother of Horus (god of kingship); (2) she is the symbolic mother of the pharaoh (the king was the "living Horus", after all); (3) she is usually depicted in a queenly manner and with a throne-shaped headdress (Fig. 8A); (4) her name even contains the hieroglyph for "throne".

She was featured in dozens of myths, but the most well-known is probably the tale of how she resurrected her brother/husband Osiris. Osiris, the earthly king, had been killed and mutilated by his treacherous brother Seth. Isis sets off to gather all of Osiris parts scattered through Egypt and reassemble him. She guards her dead husband as a kite with protective wings, which is also reflected in her iconography (Fig. 8A). As such, Isis was the Egyptian role model of the loyal wife and mother and thus also a goddess of marriage. (For those wondering, "kite" is a term

« **Figure 7. A.** Inferior portion of the Metternich stela (a *cippi*), with scene of Horus the Child (center) dominating dangerous animals (30th Dynasty, Late Period). The other deities represented are Isis (far left), Re-Horakhty (left), Thoth (far right) and Bes (the face above Horus). **B.** Tombstone of Pharaoh Djet, showing his Horus name (the snake hieroglyph) within a *serekh* (Abydos; 1st Dynasty, Old Kingdom). Note the Horus falcon atop the rectangular vignette. Photo by Guillaume Blanchard (2004); image extracted and modified from Wikimedia Commons. **C.** Horus, as a falcon, protecting Pharaoh Khafre (valley temple of Khafre, Giza; 4th Dynasty, Old Kingdom). **D.** Statue of Horus as a falcon (temple of Horus, Edfu; Ptolemaic Era). Photo by Merlin-UK (2006); image extracted and modified from Wikimedia Commons. **E.** Wall carving depicting Horus as a falcon-headed man (temple of Horus, Edfu; Ptolemaic Era). **F.** A lanner falcon, *Falco biarmicus* Temminck, 1825 (family Falconidae). Photo by Peter Pauly (2012); image extracted and modified from Wikimedia Commons. **G.** A lanner falcon in flight. Photo by Alan Manson (2010); image extracted and modified from Wikimedia Commons. **H.** Horus' official artwork from the *Shin Megami Tensei* series. **I.** A red-tailed hawk, *Buteo jamaicensis* (Gmelin, 1788) (family Accipitridae). Photo by Jason Crotty (2011); image extracted and modified from Wikimedia Commons. **J.** A red-tailed hawk in flight. Photo by Brocken Inaglory (2007); image extracted and modified from Wikimedia Commons.

commonly used for some species of hawk, but in this case it likely refers to the genus *Milvus* and perhaps more specifically to the species *Milvus aegyptius* Gmelin, 1788.)

Figure 8. A. Depiction of Isis with outstretched protective wings and throne headdress. This is a painting from the tomb of Seti I in the Valley of the Kings (19th Dynasty, New Kingdom). Photo by the Yorck Project (2002); image extracted and modified from Wikimedia Commons. **B.** Statue of Isis suckling the baby Horus (ca. 600 BCE, Late Period). Photo by the Walters Art Museum (2012); image extracted and modified from Wikimedia Commons. **C.** Statue of Isis from the Roman Empire (circa 138–117 BCE, Ptolemaic Era). Photo by Marie-Lan Nguyen (2006); image extracted and modified from Wikimedia Commons. **D.** The persona Isis belonging to Yukari. Official artwork from *Persona 4 Arena Ultimax*. **E.** Isis as she appears in P4. Official artwork from the *Shin Megami Tensei* series.

Isis was also the goddess of magic and, through her unparalleled domain of magic spells, she revivified Osiris' whole reproductive system and got pregnant of him, later giving birth to Horus. The dead-but-resurrected Osiris then became the king of the Underworld. Isis then brings up Horus in secrecy, so that one day he might avenge his father.

The Pyramid Texts from the Old Kingdom say that Horus (and by extension the king) drinks divine milk from the breasts of Isis. This image was a favorite in Egypt (Fig. 8B) and was a symbol of protection and healing, especially for children. This iconography was copied by Christians, who transformed it in the image of Mary and Jesus. Every Christian artist should thus be grateful that ancient Egyptians did not count the copyright among their many inventions.

Isis was worshipped throughout all Egypt and she grew so popular that she ended up absorbing other deities, such as Astarte/Ishtar, Bastet and even a large part of Hathor, another important Egyptian goddess. That is why Isis is often depicted with some of Hathor's trademark symbols, such as her headdress (the sun disk amid cow horns; Fig. 8B) and *sistrum* (Fig. 6B). Moreover, as soon as the Romans discovered Isis, they loved her and the goddess' cult spread quickly across the whole empire. She was often depicted in Roman statuary in the typical Roman style (Fig. 8C), although she still bore her usual symbols, such as the *sistrum*. Isis was so important that her temple in Philae (currently an island in Aswan) endured long after the Roman emperor's prohibition of all faiths other than the Christian one. This temple amazingly survived

the monotheistic cultural onslaught until the 6th century CE.

In the *Persona* games, Isis is the sole Egyptian persona that belongs to one of the main characters in the player's party. It is the second form of Yukari Takeba's persona in P3. The design of Yukari's Isis is extremely stylized, but it bears some of the goddess iconography, such as the outstretched wings and Hathor's headdress (Fig. 8D). The golden lines on her body were typical of Egyptian art to depict tunics and other fancy clothing (see statue of Serket, Fig. 9B). Curiously, Yukari's Isis has a bull's head. This is a reflection of her persona's first form, called Io. In Greek mythology, Io was a mortal priestess of Hera who was seduced by Zeus. Zeus had to disguise Io as a young cow so she could escape Hera's wrath (by the way, Hera was pissed because she was Zeus' wife).

In P4, however, Isis is depicted in a form astoundingly faithful to the goddess' image (Fig. 8E), with wings and the throne headdress.
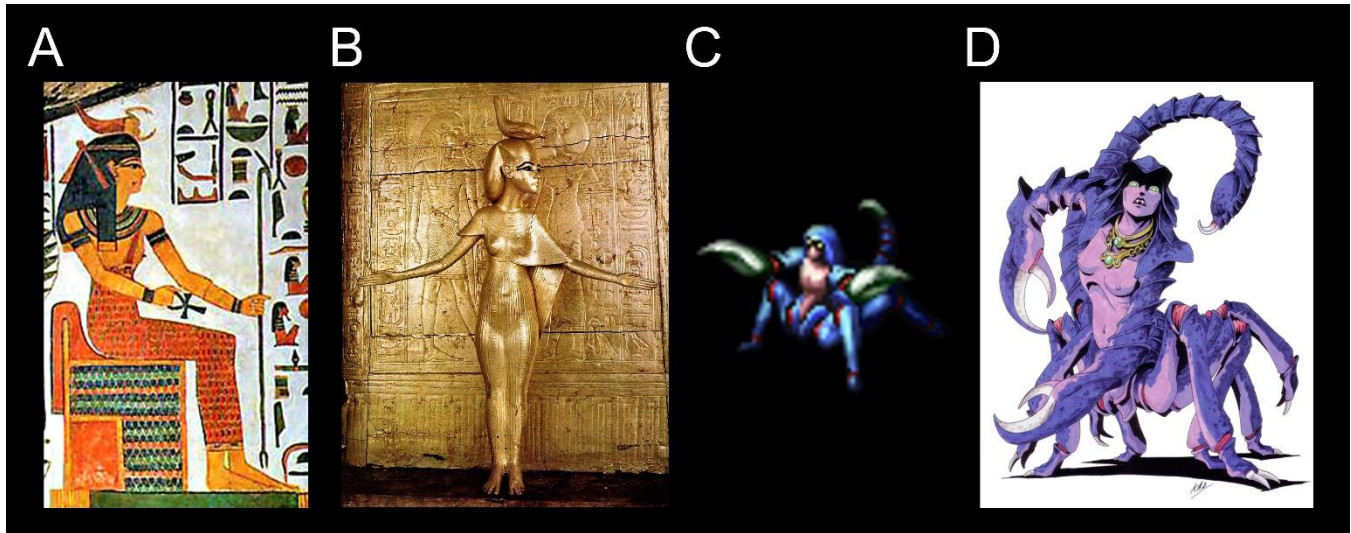
SERKET

The scorpion goddess Serket is known since the very 1st Dynasty. She is mainly a protective deity, guarding the deceased (especially the deceased king) together with Isis, Nephthys and Neith. Her main responsibility is to protect Qebehsenuef, one of the four sons of Horus and the god who guards the canopic jar with the deceased's intestines. Serket is also a goddess of healing and patron of "magician-medics" who dealt with poisonous bites. Her full name is *Serket hetyt*, meaning "she who causes the throat to breathe", and relates to the fatal danger of scorpions – the goddess may heal or destroy. Scorpions were also symbols of

motherhood and so Serket was said to nurse the king; she also helped to protect Horus during his infancy.

Serket is depicted as a woman with a scorpion over her head (Figs. 9A–B); the

scorpion's tail is raised and poised to sting. She appears in a single *Persona* game (P1) as a horrid woman/scorpion hybrid (Fig. 9C), although her design looks more crustacean-like than scorpion-like (Fig. 9D).

Figure 9. A. Painting of Serket from the tomb of Nefertari (Valley of the Queens; 19th Dynasty, New Kingdom). **B.** Statue of Serket guarding the shrine (in the background) with Tutankhamun's canopic jars (Valley of the Kings; 18th Dynasty, New Kingdom). **C.** The demon Serket in the game P1. Screenshot from the game. **D.** Serket's official artwork from the *Shin Megami Tensei* series.

SETH

Seth (also spelled "Set") was the god of the desert, representing the forces of chaos. He is known since the Predynastic Period. The "Red One" has a very convoluted history, being incorporated in the Heliopolitan tradition, where he killed his brother Osiris and fought with his nephew Horus for the throne. He destroyed Horus' eye and was castrated by him in turn. He was the god of storms and even the sea (something Egyptians most certainly did not like or trust), of violence, strife and rage. Even his sister/wife Nephthys abandoned him to join "team Horus".

However, Seth had other, more benefic, aspects. He was considered the god of metals

(iron was called "bones od Seth") and strength (his scepter was said to weigh 2 tons). Pharaohs prayed to him in war and even the gods relied on his strength – he stood on the prow of the solar barque to fight off Apep every night in order to protect Re (Fig. 4A). His more protective character even extended to common people, who prayed for him, and to the pharaoh, who was sometimes depicted protected by him and Horus (Fig. 10A); in this quality, Seth represented Upper Egypt, while Horus represented Lower Egypt (in later art, however, Seth was substituted for nicer gods, such as Thoth). There is even a tale in which he rescues the foreign goddess Astarte/Ishtar from the also

foreign sea god Yam (Astarte later became Seth's wife).

The importance of Seth decreased from the early dynastic period onwards, but, during the time when the Hyksos occupied Egypt (the Second Intermediate Period), he rose to prominence again. This was because the invaders considered Seth the same being as their chief god Baal. In the New Kingdom, he fell in importance again, but was treated as a sort of patron deity of the Ramessid pharaohs.
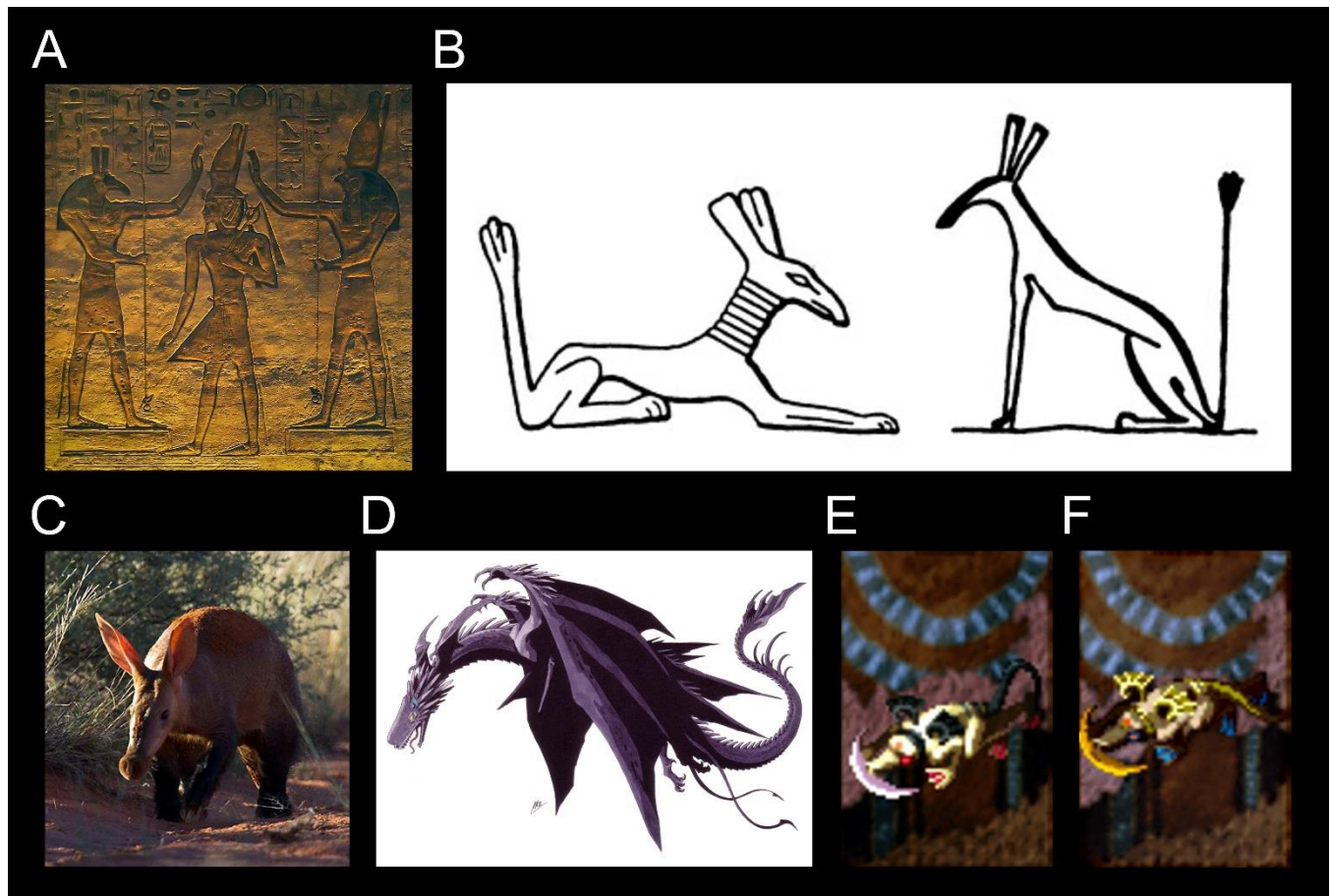
Figure 10. A. Seth (left) and Horus (right), both in hybrid forms, protect the Pharaoh Ramesses II (center) (temple of Ramesses II, Abu Simbel; 19th Dynasty, New Kingdom). Photo by Chipdawes (2010); image extracted and modified from Wikimedia Commons. **B.** Two examples (reproductions) of the "Seth animal" from the Old Kingdom (left) and Middle Kingdom (right). Image reproduced from te Velde (1967). **C.** An aardvark, *Orycteropus afer* (Pallas, 1766) (family Orycteropodidae). Photo by Louise Joubert (2013); image extracted and modified from Wikimedia Commons. **D.** Seth's official artwork from the *Shin Megami Tensei* series. **E.** The persona Seth in the game P2-IS. Screenshot from the game. **F.** The persona Seth in the game P2-EP. Screenshot from the game.

Seth was depicted as a strange animal (Fig. 10B), which Egyptologists, in a major stroke of creativity, call "the Seth animal". This animal is said to be entirely fabulous (meaning invented) or a hybrid of a number of real animals. However, given the Egyptians' naturalistic art, these two hypotheses are hard to swallow. Some Egyptologists consider the Seth animal to

be based on a real animal, most prominent of which is the aardvark (Fig. 10C), or on a then-living-but-now-extinct animal (which could also be the case for the Bennu heron, as seen above). However, the "Seth animal" sometimes appear with other entirely fabulous creatures of the desert, such as the griffin (yes, the griffin is Egyptian in origin) and a serpent-headed carnivore-like animal. This could indicate that in fact, it is a fabulous creature instead of a real-world one; but this claim is also very weak.

Seth also appeared as a human with the head of the "Seth animal" (Fig. 10A). In the Late Period, however, the "Seth animal" disappears from art and the god is represented with the head of a donkey or ass. This confusion over the zoological identity of Seth's symbol is somewhat ironic though; after all, he was the god of chaos.

In the *Persona* series, Seth appears as a black dragon (a very typical fantasy-RPG dragon, by the way) in P3 and P4 (Fig. 10D). This is obviously due to a long line of confusion and conjunction: Seth, in his character of enemy and bringer of chaos, was sometimes equaled to Apep, who, as seen above, was in turn equaled with the Greek Typhon. Typhon was usually depicted as a dragon, thus explaining *Persona*'s confusing depiction. Nevertheless, I'll grant that an aardvark would probably be a little less threatening than a dragon. Finally yet importantly, the color black was an astoundingly poor choice for the dragon. Seth was the "Red God", the color of the dangerous desert. Black, as seen above, was the color of the good agriculture-friendly silt of the Nile.

In the P2-IS and P2-EP games, Seth appears as a part mammal, part lizard and part amphibian creature, with tiny malformed wings

and a scythe stuck to its nostrils (Figs. 10E–F). I have absolutely no idea whatsoever of what that's supposed to represent.

SOKAR

Sokar (also spelled Seker) is a falcon-headed god from the region of Memphis (Fig. 11A).
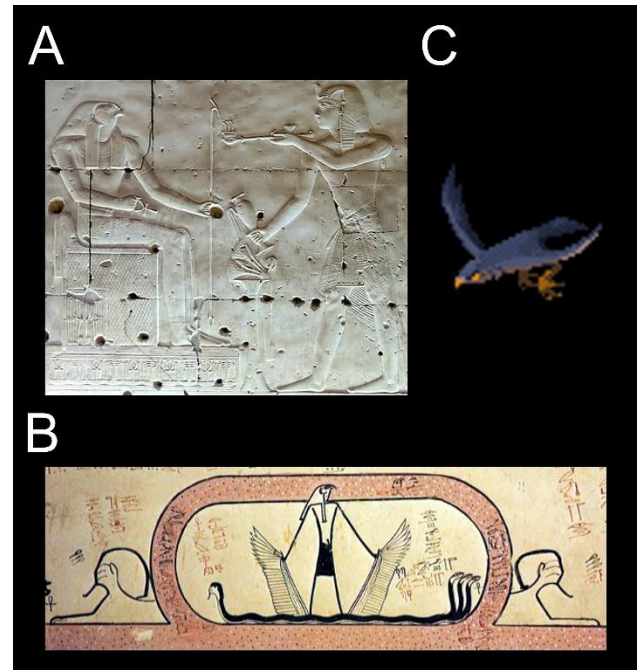
Figure 11. A. The Pharaoh Seti I making offerings to Sokar. Walls of the temple of Seti I, Abydos (19th Dynasty, New Kingdom). **B.** Sokar as Lord of the Mysterious Regions of the Netherworld. Wall painting from the tomb of Tuthmosis III in the Valley of the Kings (18th Dynasty, New Kingdom). **C.** The persona Sokar (Seker) in the game P2-IS. Screenshot from the game.

Scholars believe that he was a god of craftsmanship who eventually became associated with the regional necropolis and thus became a god of the afterlife and the Underworld. As a god of craftsmen, Sokar then became associated with Ptah, the god of artisans (and a creator god according to Memphite cosmogony). As a chthonic god, he later was

associated with Osiris (ruler of the Underworld). As such, already in the Middle Kingdom, these three gods were conjoined in the tripartite deity Ptah-Sokar-Osiris, who remained an important deity in Egypt thereafter and was a favorite in the depictions of New Kingdom tombs in the Valley of the Kings, in Thebes (Fig. 11B).

The cult center of Sokar was naturally his home region of Memphis, but by the New Kingdom his festival was an important event also in Thebes, almost rivaling the New Year Festival of Opet. The festival served to give continuity to the royal mortuary cult.

Sokar is usually depicted as a falcon-headed man (Figs. 11A–B). In the Persona games, however, he is shown simply as falcon (Fig. 11C). He appears only in the games P2-IS and P2-EP.

THOTH

Thoth is actually a Greek rendering of the name, which in Egyptian was something in the lines of "Djehuty". He was present since Predynastic times and was originally an important moon god, a companion of the sun god Re, and identified as the "night sun" or, later, as the "silver Aten". Only later Thoth assimilated the aspects of knowledge and became the god of scribes and scholars. Thoth was often considered a son of Horus, being born from the forehead of Seth after the latter ate some lettuce with the semen of the former.

Thoth invented writing and was said to record everything (including the result of the weighing of the heart ceremony, as seen above; Fig. 3B). He also determined the length of each pharaoh's reign (he was thus called "Lord of Time"), recording it on a palm leaf (Fig. 12A); however, this function was most commonly

attributed to his wife (or sometimes daughter) Seshat, who shared most of his aspects anyway. Thoth had thus a pristine reputation of integrity and truth. As patron of all areas of knowledge, he also had access to magic and secrets unknown to the other gods.

Finally, Thoth was also a messenger of the gods and usually conciliated quarreling deities. This led the Greeks to equate him with their messenger-god, Hermes. The so-called "Hermes Trismegistus" (meaning the "thrice great") may be a syncretic combination of Hermes and Thoth. (Trismegistus, by the way, is the second form of Junpei Iori's persona in P3; his starting persona is Hermes.)

The city housing Thoth's largest cult center became known to the Greeks as Hermopolis Magna (Khemnu, in Egyptian). To the west of Hermopolis, lies the necropolis of Tuna el-Gebel, where the catacombs known as the "Ibeum" holds hundreds of animal mummies of ibises and baboons, Thoth's sacred animals.

Thoth is most usually depicted as an ibis-headed man (Figs. 12A–B), but can also appear as a full ibis (Fig. 12C); his depiction as a baboon (Fig. 12E) is secondary, but very common. Here is a good place to remark that Egyptian art was very naturalistic when it came to animals (Fig. 12C), representing them in natural poses and lively activities and in a manner that makes possible for us to easily identify the species in question. Thoth's ibis is aptly called "African sacred ibis" (Fig. 12D); its scientific name is *Threskiornis aethiopicus* (Latham, 1790), meaning the "religious (or worshipping) bird from Ethiopia". The ibis' white plumage and long sickled bill probably had lunar symbolic significance. Is his ibis or hybrid form, Thoth is

usually shown wearing his own brand of the *atef* crown (Fig. 12C): it is made of two twisting ram's horns on its base, from where sprouts three bundles of reeds (each topped by a sun disk), which in turn are flanked by ostrich feathers and *uraeus* serpents.
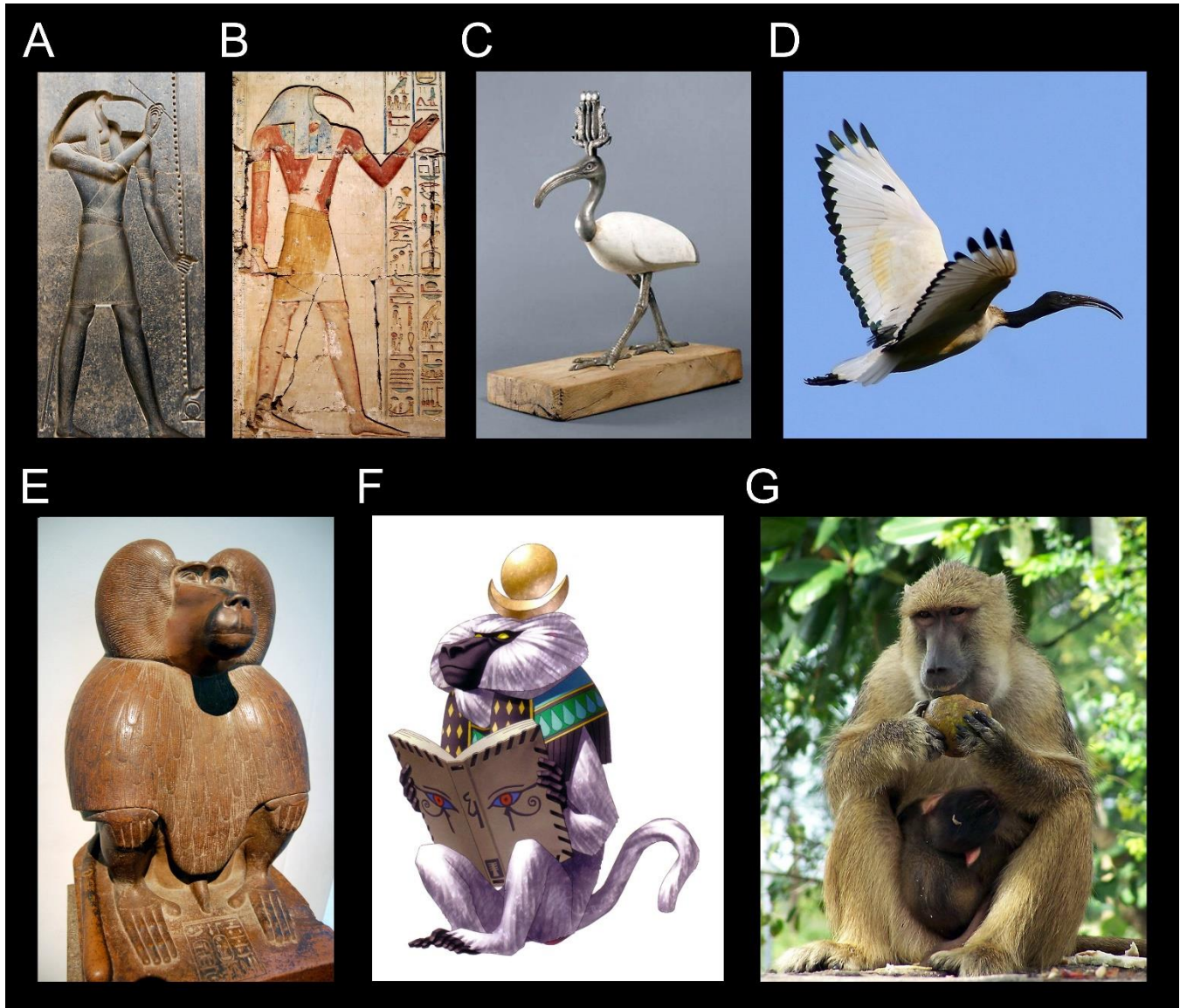
Figure 12. A. Thoth records the length of the pharaoh's reign on a palm leaf (Luxor temple; 18th–19th Dynasties, New Kingdom). **B.** Painting of Thoth in the temple of Ramesses II (19th Dynasty, New Kingdom). **C.** Statue of Thoth as an ibis (6th century BCE, Late Period). Image is a courtesy of the Kunsthistorisches Museum Wien. **D.** The sacred ibis, *Threskiornis aethiopicus* (Latham, 1790) (family Threskiornithidae). Photo by Johan Wessels (2009); image extracted and modified from Wikimedia Commons. **E.** Statue of Thoth as a baboon (ca. 1400 BCE, New Kingdom). Photo by Steven G. Johnson (2010); image extracted and modified from Wikimedia Commons. **F.** Thoth's official artwork from the *Shin Megami Tensei* series. **G.** A yellow baboon, *Papio cynocephalus* (Linnaeus, 1766) (family Cercopithecidae). Image extracted and modified from Wikimedia Commons.

Unfortunately, the *Persona* games went for the baboon look (Fig. 12F), but, instead of the *atef* crown, he has a small solar disk on his head. I call it a solar disk because it is golden instead of the lunar silver. The baboons were sacred to the sun god, because these animals sit on their hinds legs at sunrise and raise their hands, which was interpreted as a sign of reverence for the sun. Thoth's representation (likely based on the yellow baboon, *Papio cynocephalus* (Linnaeus, 1766); Fig. 12G) was always a sitting baboon with his arms in resting position (Fig. 12E), precisely to differentiate him from the solar baboons. Finally, the book in the official artwork is of a rather modern look; it surely gives a nice effect, though. The *wedjat* (Eye of Horus) depicted on the book's covers was sometimes found in amulets of Thoth.

CONCLUSION

After going through all *Persona* games, I am very disappointed to have only encountered 11 deities from the Egyptian mythology. As we can see on Table 3 below, the number of Egyptian personas was kept constant throughout the games. However, the total number of personas increased, resulting in increasingly smaller proportions of Egyptian personas in each new game in the series.

Table 3. Total number and proportion of Egyptian-themed personas (but not demons!) in the *Shin Megami Tensei: Persona* series. The Greco-Roman-themed personas are shown for comparison; the value for P3 is a little inflated, since all party members had Greek-themed personas. Also, I did not include: (1) the four prime personas (from P2-IS), since they are the same gods or goddesses that appear in non-prime form; (2) Cybele, who, despite being wholly incorporated in Greco-Roman traditions, retained her foreigner character.

Game	Total number of personas in game	Egyptian personas		Greco-Roman personas	
		Total number	Percentage	Total number	Percentage
P1	97	4	4.12%	6	6.18%
P2-IS	149	5	3.35%	22	14.76%
P2-EP	163	5	3.07%	21	12.88%
P3	163	5	3.07%	24	14.72%
P4	226	5	2.21%	7	3.10%

The mythology of Ancient Egypt is astoundingly rich and its culture outright amazing – besides, they were the very first in the whole civilization business. If we compare these numbers with the percentage of Greco-Roman-themed personas (Table 3), for instance, the difference is very clear. I agree that Greek mythology is awesome in its own right, but the Egyptian one does not lag behind. (Sometimes, there are even the Greek and Roman versions of the same god in the same game: for instance, Ares and Mars both appear in P2-IS and P2-EP).

Egypt deserved better in the series, especially when faced by the ridiculous choice of including creatures from works of fiction, such as the Goetia and the tales of H.P. Lovecraft. (Of course, religion is just a special case of fiction, but you get my point.) Could Persona 5, to be released later this year (for the PS3 and PS4), be the game to set things right?

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# The Force: a new candidate for dark matter

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Only about 5% of the total mass of the universe consists of ordinary matter (mostly protons, neutrons and electrons, which form atoms). The missing 95% divide into dark matter (ca. 25%) and dark energy (ca. 70%) (Planck Collaboration, 2013) – see Figure 1. In this study, I focus on the former one.
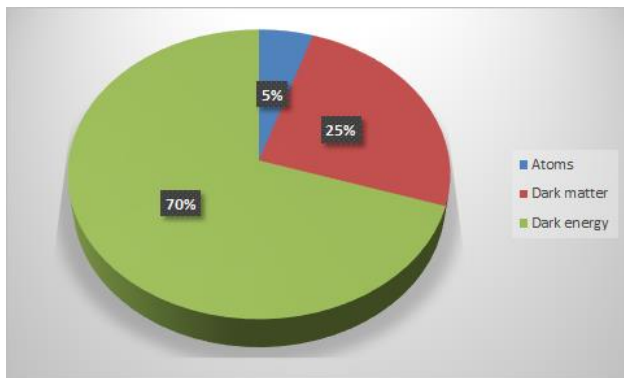
Figure 1. Approximated distribution of matter and energy within the universe.

The existence of dark matter is indicated by the effect of gravitational lenses and the orbital velocities in galaxy clusters as well as galaxy rotation curves (for more information see Carroll, 2007). Long story short, to explain some astronomic observations, there is mass missing, which is not visible to us. This missing mass is a result from the presence of dark matter. One candidate for dark matter are Weakly Interaction Massive Particles (so called WIMPs), which may be supersymmetric particles (Freund, 1988). However, experiments such as those of the Large Hadron Collider have not proven the existence of supersymmetry yet. I propose a different candidate for dark matter here.

Galaxies with rotation curves influenced by dark matter are usually far, far away. Due to the limited speed of light, the events in these galaxies we observe now on earth happened a long time ago.

Therefore, to find a new candidate for dark matter, let's have a look at a place a long time ago, in a galaxy far, far away!

DARK MATTER MIDI-CHLORIANS

This far, far away galaxy, where the plot of Star Wars takes place, is characterized by slightly different physics compared to our own galaxy. The differences in physics may be a result of the presence of dark matter.

What are those differences? As long as they are not jumping into hyperspace and flying faster than light, space ships in Star Wars travel very slowly through space, similar to ships at sea (capital ships such as Star Destroyers) or planes

(X-Wings or TIE-Fighters). They seem to be restricted by some medium, limiting their maximum speed. In addition, their engines emit sound waves, which propagate through the apparent vacuum, making, for instance, the characteristic noises of turbolasers and TIEs flying by (Lucasfilm, 1977). The corresponding sound waves have to travel through some medium filling the vacuum. This medium is our candidate for dark matter! In order to reveal its nature, let's look at an additional characteristic of the Star Wars galaxy: the Force. The Force is an overall present force field in the galaxy, but it interacts only strongly with other atoms when used by a Jedi.

According to Lucasfilm (1999), the carriers of the Force field are particles called Midi-chlorians[1]. Obi-Wan Kenobi states: "The Force is what gives a Jedi his power. It's an energy field created by all living things. It surrounds us and penetrates us." Therefore, the Force seems to interact weakly enough to "penetrate us", but interacts strongly with certain live beings (Jedi). Further, he says that "[it] binds the galaxy together". The Force field has to interact gravitationally to achieve this, and, hence, its carrier particles[2] need to have mass. Like other force carriers (electrons, W- and Z-Bosons, Gluons for electromagnetic, weak and strong nuclear interactions, respectively), Midi-chlorians should be particles with integer spin (Bosons). A Feynam diagram of a Force interaction is illustrated in Figure 2.

With the overall present, massive, but mostly weak interacting Midi-chlorians, we have our candidate for a dark matter particle. Figure 3 shows the particles of an extended Standard Model including the Force and its Midi-chlorian carrier particle.

MIDI-CHLORIAN MASS AND PARTICLE DENSITY

Assuming the Star Wars galaxy is quite similar to our own Milky Way, I can estimate the mass density of dark matter in this far, far away place. The ordinary mass of the Milky Way is $m_{mw} = 4 \times 10^{11}$ times the mass of our sun. Dark matter should be approximately five times this mass (25% compared to 5%).

The galaxy is approximate by a disk with a radius of $r_{mw} = 105$ ly, its thickness is $d_{mw} = 3 \times 10^3$ ly (neglecting the bulge at the center). As a consequence, the mass density ρ_{dm} of dark matter in the Star Wars galaxy is:

$$\rho_{dm} \approx 5 m_{mw} \times (\prod r_{mw}^2 \, d_{mw})^{-1} \approx 5 \times 10^{-20} \text{ kg m}^{-3}$$

As TIEs and X-Wings sound very similar in space and in a planet's atmosphere (Lucasfilm, 1977; Lucasfilm Animation, 2014), I assume a similar particle density of dark matter Midi-chlorians in space and air in the lower planet's atmosphere of $\rho_{Midi} = 2.5 \times 10^{13}$ m^{-3}.

Comparing particle density and mass density allows me to calculate the mass of one single Midi-chlorian: $m_{Midi} = 2 \times 10^{-33}$ kg, which corresponds to about 1 keV.

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[1] As a fan of the old movies, it is quite hard for me to mention this topic. However, I will sacrifice true fandom for the sake of science.

[2] The Midi-chlorians are also referred to as lifeforms, living in creatures. However, Jedi use the force also on non-living objects. Therefore, the Force is not limited to interactions between microscopic lifeforms and has to be a fundamental nuclear interaction. Even if there actually is a microscopic lifeform with strong connection to the Force field or generation behavior for Force, I use the term "Midi-chlorian" here for the force carrier particle of the Force.

That is about factor 500 below the mass of an electron. Midi-chlorians seems to be very, very light weighted – which we would expect for a particle of the overall present invisible field of the Force.

DARTH VADER'S MIGHT

What does the parameters calculated above further tells us?

Let's take into account the fact that Anakin Skywalker (when found by Qui-Gon Jinn), who became later the mighty and evil Darth Vader, has a concentration of 20,000 Midi-chlorians per cell of his body (Lucasfilm, 1999) – the highest measured value so far. Unfortunately, we have no information on the measurement's method, which would allow to verify the theory of dark matter Midi-chlorians on Earth.

With 10^{14} cells in a human body, Anakin's body contains 2×10^{18} Midi-chlorians. Anakin, or at least Darth Vader, is a big guy. I assume his value to be equal 0.1 m^{-3} (neglecting in this approximation, however, his loss of limbs after his fight with Obi-Wan Kenobi). This yields a density of 2×10^{19} Midi-chlorians per m^3 for this user of the Force. That means Anakin's Midi-chlorian density is larger than the galactic background by six orders of magnitude. This seems to be a reasonable value for the mightiest Sith Lord in history.
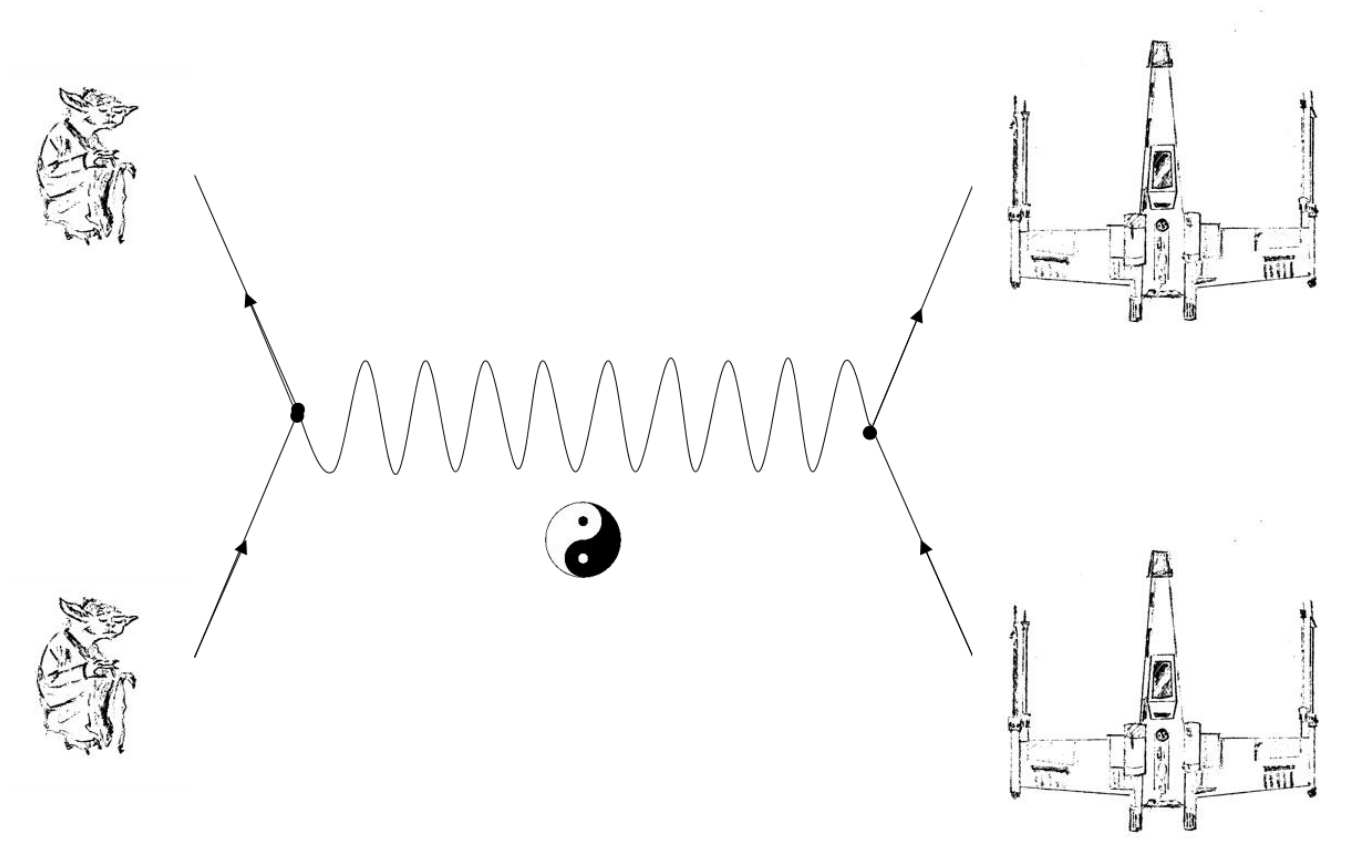
Figure 2. Jedi master Yoda levitating an X-Wing starfigher by the Force as seen in a Feynman diagram. Yoda exchanges Midi-chlorian particles with the X-Wing to lift it.

Figure 3. Extended Standard Model including the Force. The *yin-yang* symbol represents two "flavors" of the Midi-chlorian particle: light side and dark side.

CONCLUSION

I proposed Midi-chlorians from the Star Wars galaxy as reasonable candidates for a dark matter particle, giving their mass as 2×10^{-33} kg (about 1 keV), and showing that Darth Vader has about one million times Force in him than the galactic background. To the best of our knowledge, no Jedi inhabits our Earth and our satellites and probes make no sound in space. As an unfortunate turn of events, we seem to live in a very Force-poor part of the universe – making it very hard to solve the riddle of dark matter on this planet.

Future studies will focus on dark energy and its relation to the dark side. In addition, it will be studied whether there is a yet unknown quantum number defining light side and dark side Midi-chlorians and their spontaneous symmetry breaking near Jedi and Sith.

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Harry Potter and the Draconian Laws

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Anyone would say that a world where brooms and carpets cross the skies, unicorns roam the forests and people depicted in portraits talk to you is wonderful, literally magical. However, not everything is as beautiful as it looks – just you wait for the effect of the polyjuice potion to wear off and you'll see what is hidden behind the reality created by British author J.K. Rowling.

Spells can fix a pair of glasses, turn water into butterbeer, inflate boring aunts and even ignore the immutable law of Lavoisier, creating matter from nothing. However, spells can also be used in not-so-benign activities, as cursing people, destroying things, being inflated by rude nephews and even killing. So in the same way that our international conventions prohibit certain weapons from being used in wars (such as cluster bombs, and chemical/biological warfare; The Biological and Toxin Weapons Convention Database, 1925), so some charms (*Imperius*, *Cruciatus* and *Avada Kedavra*, collectively called "Unforgivable Curses") are prohibited from being practiced (Rowling, 2000: ch. 14). As expected, in the same way that not all countries participate in our conventions, not all wizards follow such rules.

Let's make a brief intermission now. It is true that wizard society has medieval features. However, since it has always been inserted within a community of non-wizards, it was expected to have incorporated the values that were gradually acquired by the international community. Moreover, there are some rights that are guaranteed to all persons, regardless of the country where they live on or its governmental system, which is called "customary law" (ICRC, 2015).

Now back to the spells. The lack of control over spells seen in the books, no matter the severity of the curse, is quite paradoxical, given the intense regulations over magic practiced by minors. Wizards under 17 years old are not allowed to use magic outside their school (unless facing exceptional circumstances), and a Trace Spell detects such activities. To give you an idea, a notification is sent almost immediately to the juvenile offender, which, depending on the gravity of the situation, must then go to the Ministry of Magic (Rowling, 1998: ch. 2; Rowling, 2003: ch. 2). In other words, we may conclude that there is the technical capability to perform this type of identification, namely the age of the offender, the spell used and location. But why

the same technique is not used with the Unforgivable Curses is a mystery.

By the way "Mystery" is, incidentally, the name of one of the Ministry of Magic's departments. An institution so lacking in transparency, and theoretically with such advanced surveillance capabilities of their society (a magic Orwellian Big Brother) is to raise all sorts of suspicions about it. Denying the return of Voldemort (a powerful evil wizard; Rowling, 2003: ch. 4), attempting to use a minor as a mascot in this conflict (Rowling, 2005: chs. 16 and 30), and protecting people who make large donations to them (Rowling, 2003: ch. 9), are just some examples of the Ministry's flaws.

We could also bring up the prison system of the wizards. The main reference is the prison of Azkaban, which is guarded by creatures known as Dementors, whose ability is to absorb all the happiness of those who are around them, and whose "kiss" sucks a person's soul, leaving her in an eternal lethargic state (Rowling, 1999: chs. 10 and 12). A fate, perhaps, even worse than death. Since the 18th century, Cesare Beccaria, an important Italian criminal scholar, wrote on the humanity of penalties, their social function, and the necessary proportionality between crime and punishment (Beccaria, 1764). In this regard, we see that the world of Harry Potter is over 200 years late in comparison to the so-called "muggles" (the name given to non-wizards), which in 1789 had already promulgated the famous Declaration of the Rights of Man and of the Citizen (Déclaration des Droits de l'Homme et du Citoyen). So, because of their outdated and ineffective system (even innocents have been sent to Azkaban; Rowling, 1999: ch. 19), serious insecurities of the criminal point of view

are raised, and the cruelty of sanctions hurts human dignity.

And talking about fundamental rights, we note that some of the creatures that inhabit this universe so fabulous end up enslaved (such as house-elves) or have suffered plenty of persecutions (such as goblins). Other creatures, like the centaurs, suffer severe prejudice. A considerable amount of wizards extends this prejudice to other creatures, like half-giants and werewolves, and in some cases even to wizards that are not "pure-blood", resembling the most foul ideologies ever seen in our world.

In contrast, in our current legal system, other animals have been receiving a human-like treatment, as evidenced by the laws of countries like England (the first one to create animal protection rules; Department for Environment, Food & Rural Affairs, 2013) and Argentina, where a court recently awarded human rights to an orangutan (BBC News, 21 December 2014).

As previously stated, there are exceptions in every group, and it could not be different for the wizards. Also, it is yet to be seen a government without any failures. So, dear reader, take lightly those critics of a muggle who is still waiting for his owl to arrive with his Hogwarts' letter.

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Using Unmanned Aerial Vehicles in Search & Rescue Operations

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TECHNOLOGY IN VIDEO GAMES

In video games, technology has always played an important part (as technological advancements, futuristic technology, lost technology…), often taking a major role in games: the titans in Titanfall, the portal gun in Portal, the metal gears in Metal Gear, and all sorts of armor, equipment and gadgets in Metroid, Crisis, Halo, Batman, Call of Duty etc. This is not a surprise, given that the public of such video games has always been highly connected with the latest technology. Also, while being futuristic and sometimes exaggerated, technological representations in games always try to remain close to real-world tech and science, in order to meet demands for "realism" in games.

In this context, robots (and other automated equipment) have also been widely featured in many games. These devices, though, always have military and war purposes. Besides all the games mentioned above, we have the laptop gun in Perfect Dark, JACK in Gears of War and all the machines in the Final Fantasies. When taking part in search operations, robots are used either for protecting something/-one/-where or for surveillance and repression: the UAVs (Unmanned Aerial Vehicles) in several shooters, the Monokumas in Danganroompa, the 1984-esquee tech from Freedom Wars etc.

This view of technology is pretty much one-sided, overshadowing their possible applications in more humanitarian scenarios, such as using UAVs in "Search & Rescue" (SAR) operations. Although shooting stuff is the core and fun of many games, I think it is worthwhile to explore the more "pacifist" side and to show gamers what this technology is really capable of. After all, the use of UAVs in SAR operations is already a reality.

HUMANITARIAN LOGISTICS IN DISASTER RELIEF OPERATIONS

Modern humanitarian logistics operations originated during the Nigerian civil war, in the conflict of Biafra, which unfolded after an attempted military coup in the 1960s. This conflict was the first in which large-scale humanitarian operations were conducted (Blecken, 2010). Since then, such operations started to be carried out systematically, and humanitarian organizations have often seen their objectives and principles collide with those of other interested parties. The principles of humanitarian operations (humanity, impartiality and neutrality) were established because of the

necessity to position themselves between the two opposing sides of any conflict, and now serve as a guide for all humanitarian organizations (Blecken, 2010).

The basis of humanitarian operations is the belief that individuals affected by crises have the right to life and dignity, and thus are entitled to assistance. The Sphere Project (2011), where several organizations set minimum standards for humanitarian assistance, defines the right to life with dignity as: the right to live free of treatments and punishments that are cruel, inhuman or unworthy. As such, the central ideas of humanitarian operations are: the right to life when it is threatened and taking necessary measures to save lives and reduce suffering.

Humanitarian Logistics is a relatively new academic field, but the number of contributions in the area have increased steadily in recent years (see Leiras et al., 2014, for a thorough review).

Wassenhove (2006) defines a disaster as a "break", something that physically affects a system, threatening its priorities and objectives. Disasters can be classified either as natural or "man-made". Likewise, they can be classified as having a sudden or slow onset. Examples of natural disasters with sudden onsets are earthquakes and hurricanes, while examples of natural disasters with slow onsets are hunger and drought. Examples of man-made disasters with sudden onsets are coups and terrorist attacks, while slow onset man-made disasters are political crises and refugee crises (Wassenhove, 2006).

Traditionally, four stages are defined in Operations Management in disaster scenarios: mitigation, preparedness, response and

recovery (Wassenhove, 2006; Tomasini & Wassenhove, 2009). SAR operations are those conducted in the response phase, aiming to find and provide relief to the greatest number of people in the hours after the disaster, trying to maximize the survival chance of victims (Hoyos et al., 2015). Tsunemi et al. (2015) emphasize the importance of agility in such operations, as statistical studies show that the rate of survival of, for instance, trapped victims in collapsed buildings, plummets within 72 hours of the moment of disaster.

UAVs are able to act autonomously in dynamic and complex environments and thus, are used predominantly for military purposes, such as intelligence gathering, surveillance and reconnaissance (Gupta et al., 2013). This is, of course, what is reflected in video games. However, there has been increasing interest in using UAVs for SAR operations, since they are able to quickly reach areas of difficult access and to quickly build a network of information and communication among the affected areas (OCHA, 2014; Meier, 2015). This is particularly relevant given that the travel speed within a region affected by disasters such as floods or earthquakes tend to be greatly reduced (Yuan & Wang, 2009).

SAR operations have particular difficulties, such as the uncertainty of the time required to inspect different regions and the uncertainty of the number, amount and location of victims. Thus, traditional methods of routing and scheduling may be insufficient to define the best way of working with UAVs. The present study is divided in three parts: (a) a brief review of the literature on the use of UAVs for SAR operations; (b) an evaluation of how different heuristics (in

particular the "sweep method" of Ballou, 2006) stack up against the uncertainties of said operations; and (c) the proposal of improvements in heuristics to adapt them to the specificities of SAR.

> **Heuristic:** Sometimes, an exact (or "optimized") solution to a problem cannot be mathematically guaranteed or would take too much time and resources to be calculated. Many times, though, an approximate solution is acceptable for such problems. A procedure that can produce a practical, though not perfect solution, is a heuristic (Henderson, 2009).

UAVs IN SEARCH & RESCUE OPERATIONS

Tsunemi et al. (2015) classify rescue operations in three types: (1) search operations in a wide area, conducted immediately after the disaster to assess its scale and impacts; (2) search operations in a narrow area, for obtaining more specific information of affected sites discovered by the type-1 search; and (3) pinpoint search operations, which physically access the sites from type-2 search to locate/rescue victims. Constant communication between the search teams and the HQ, as well as using real-time information to update them, is clearly necessary in all three search types (Huang et al., 2013).

Irrespectively of the types above, works usually distinguish between two kinds of SAR operations, according to the area in which they take place: urban and non-urban (or wild). SAR operations in wild areas are searches for people lost in deserts, mountains or any other sparsely populated natural environment. Most works dealing with SAR operations (particularly those that involve UAVs) are interested in these environments (*e.g.*, Goodrich et al., 2007;

Cooper & Goodrich, 2008; Lin & Goodrich, 2009; Lin et al., 2010; Morse et al., 2010; Molina et al., 2012; Karma et al., 2015). For SAR operations in urban areas, there are additional challenges, such as searching through debris and clearing roads (Chen & Miller-Hooks, 2012). However, not many works focus on urban settings (*e.g.*, Jotshi et al., 2009; Ko et al., 2009; Chen & Miller-Hooks, 2012; Huang et al., 2013).

Chen & Miller-Hooks (2012) point that, although there is an extensive literature that addresses the management of emergencies, few studies propose optimization techniques for SAR operations: Jotshi & Batta (2008) present a search heuristic that minimizes the time to find a single stationary entity on a given area; Jotshi et al. (2009) bring solutions for dispatching and routing emergency vehicles in urban settings when roads have been compromised; and finally Chen & Miller-Hooks (2012) themselves propose a multistage stochastic programming algorithm for urban settings, increasing the efficiency of the operations and highlighting the importance of communication between the search teams.

> **Stochastic programming** (or optimization) is a framework that allows the modeling of uncertainty in the input data, in contrast to deterministic optimization, which does not. In some complex cases, the inherent uncertainty of data, coupled with the evolution of such data over time, leads to a sequential optimization-under-uncertainty model (Casey & Sen, 2005), where data is input through a series of stages. Such problems are called multi-stage stochastic programming.

As for the use of UAVs in SAR operations, several works have already tackled different problems, ranging from building communication networks to improving images obtained by the

UAVs' sensors (*e.g.*, image recognition and infrared). In a UAV-based SAR operation, there are four critical personnel roles (Goodrich et al., 2007; Cooper & Goodrich, 2008): (1) the commander responsible for managing the search; (2) the UAV operator; (3) the UAV's sensor operator (it's better to have a different person than the UAV operator for this); (4) the ground search team.

Ko & Lau (2009) built and tested an autonomous UAV for urban environments, which could circumnavigate debris and search for the heat signatures of survivors. Despite this line of research being still on its infancy (Lin et al., 2010), their focus have already changed a little. As a consequence of recent technological advances (mainly in electromechanical systems, communication technology and control theory), many proposals now focus on multiple cooperative robots, known as "swarms". Swarms have many benefits over regular UAVs, such as: robustness against failures (other robots can continue the search if one has problems), increased flexibility in reorganizing as the mission progresses, and economies of scale (Çayurpunar et al., 2008; Waharte et al., 2009).

Regardless of UAV type, the way the search is in fact conducted is the crucial point and it depends on the algorithms used. Lin & Goodrich (2009) proposed and algorithm that considers the priority of the search regions (those most likely to have survivors), in order to define the search routes for the UAVs. Murtaza et al. (2013) proposed a similar algorithm, but using a partially observable Markov decision process method.

A very interesting (and geeky) work was conducted by Megalingam et al. (2012). They proposed the design of a rescue robot with a human-like upper-body that is controlled through gesture-based imitations, acquired through the Microsoft Kinect, a motion sensing input device developed originally for the Xbox 360 video game consoles (and later for Windows PCs and the Xbox One).

Would it look something like this maybe? (Nintendo's R.O.B.; image by Evan-Amos, 2012, taken from Wikimedia Commons).

Waharte & Trigone (2010) tested three types of algorithms (greedy heuristic, heuristic based on attraction/repulsion potentials, and heuristic based on partially observable Markovian decision process) through simulations, and found that estimating the best search paths through the sharing of information between UAVs reduced the duration of the operations, albeit at a high computational cost. They also concluded that there are several important

aspects to be met, such as the quality of the sensors, energy constraints, environmental hazards and communication restrictions between UAVs. Regarding the latter, Asadpour et al. (2012) point out that the communication capability of conventional UAVs is insufficient for the large volume of data required for SAR operations, such as images and videos. They thus proposed hybrid networks made with smartphones and ground stations. Environmental dangers are also quite problematic, as shown by the work of Karma et al. (2015), since they may incur on reduced visibility (thus making detection difficult) or severe damage to the usually fragile UAVs.

> A **Markov decision process** is a model for sequential decision making when under uncertainty, in situations where outcomes are partly random and partly under control of the decision maker (or agent), considering both short-term outcomes of current decisions and opportunities for making decisions in the future. The partially observable Markov decision process is a generalization of the Markov decision process, and considers that the decision maker cannot directly observe the state of the system. Since the true state is hidden, the agent must choose actions based on past actions and observations, composing scenarios of possible state distributions (called belief states).

FORMULATION OF THE PROBLEM

As I mentioned above, here I intend to evaluate how different heuristics (in particular the "sweep method" of Ballou, 2006) stack up against the uncertainties of SAR operations, also proposing improvements for them. Therefore, I need to insert some of the difficulties present in real-life SAR operations. Thus, the problem formulated has the following characteristics:

▪ The maps where the search occurs are generated randomly, with random x and y coordinates being assigned to a defined number of regions (search sites). The maps can have 50, 100 or 500 regions. For the present study, it was decided that the coordinates may vary from (-3) to (+3), and the travel time between two regions is equal to the distance between them in the stipulated coordinated plane.

▪ A command base for the SAR operation is defined on the map at a random position. The base is the starting point of the UAVs' routes. For this study, it was decided that the basis of the coordinates could range from (-1.5) to (+1.5). An example of a map, with the search regions, can be seen on Figure 1. The application for the map generation was developed in VBA, and its interface can be seen on Figure 2.
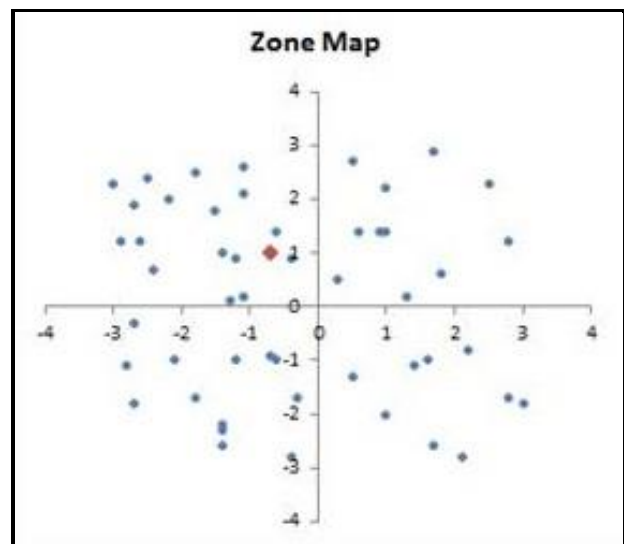
Figure 1. Example of a search map with 50 search locations (blue dots) and the command base (red diamond). The travel time between two points is directly proportional to the distance between them.

- The search is conducted by five UAVs. A maximum flight range is set for each vehicle, after which it must return to the base before leaving again (immediately) on the next route. It was decided that the flight range for all UAVs is (30).

- Each search location has a known "search complexity", randomly assigned. Places with greater complexity require larger times to complete the search. In this study, it was decided that the complexity (search time) could be (1), (2), (3) or (4), with respective probabilities of being assigned (40%), (30%), (20%) or (10%).

- Each search location has a known probability of containing a victim, randomly assigned. The total number of victims is unknown. In the present study, it was defined that the likelihood of a location having a victim could be (10%), (30%), (60%) or (90%), with chances of (30%), (20%), (20%) or (30%), respectively.

- For testing the various heuristics, four instances were generated for each map scale (50, 100 and 500 search regions).
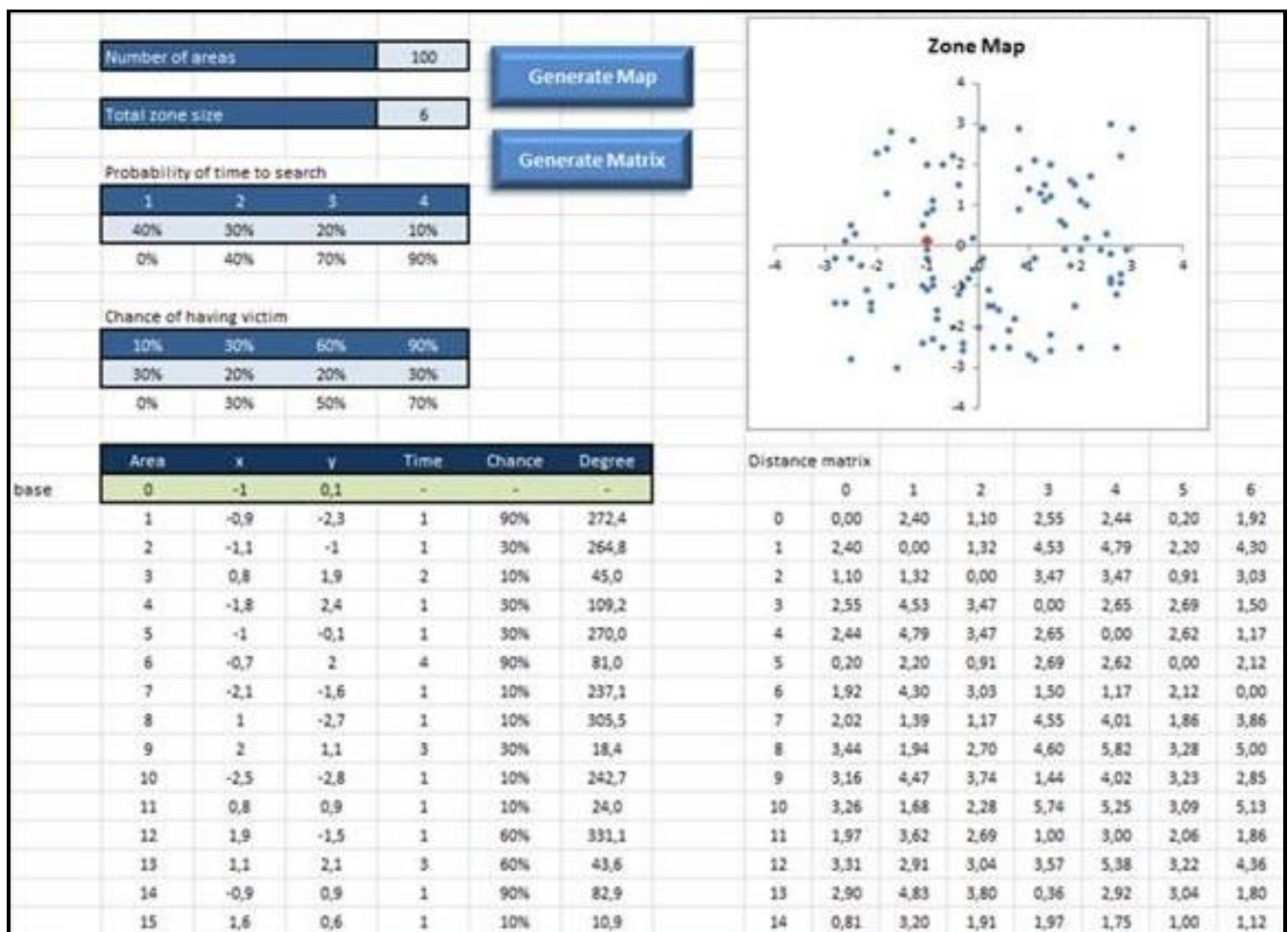

Figure 2. Interface of the map generator.

HEURISTICS TO SOLVE THE PROBLEM

For solving the proposed scenarios, two heuristics were developed, prioritizing areas where victims are most likely to be found (similar to the works of Lin & Goodrich, 2009, and Murtaza et al., 2013). After the initial results, a third hybrid heuristic was proposed. The interface developed in VBA, for the simulation of the heuristics can be seen on Figure 3.
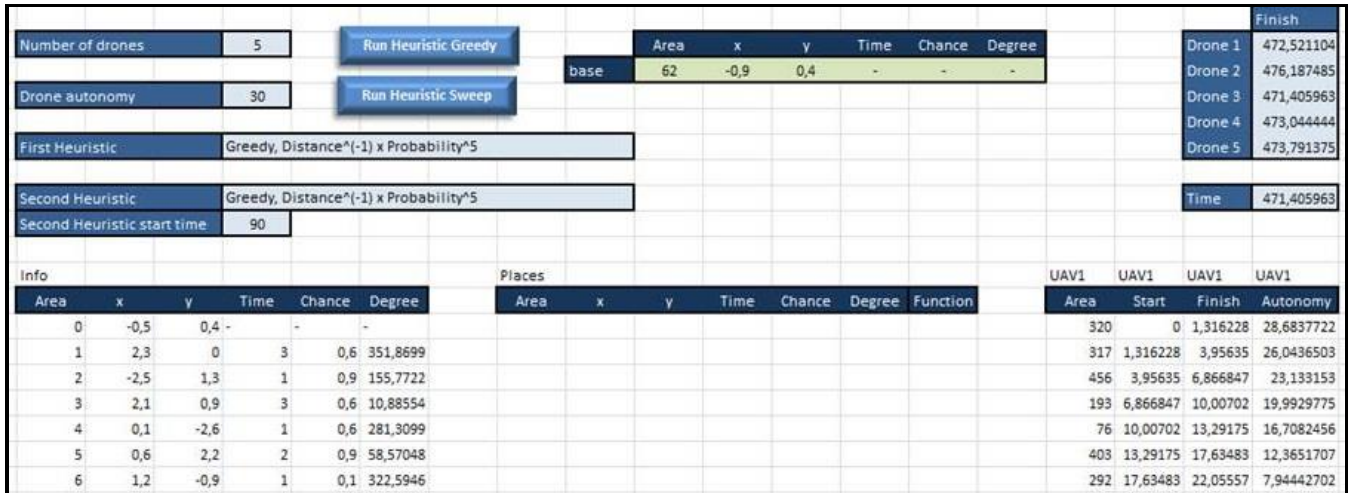

Figure 3. Simulator interface.

"Greedy" Heuristic

The first heuristic proposed is the "greedy", which takes into account the distance to the search areas, the complexity of the search operation and the probability of finding a victim, to compose a prioritization factor. Each UAV calculates the factor for all regions that have not yet been searched, and goes towards the region with the highest factor. The greedy heuristic is said to be "myopic", because it does not have long-term vision. Three different factors were tested to evaluate how the "distance" and "probability of victim" parameters affected the quality of the solution: one that considers only the shortest time to come and inspect the regions $(1/T)$; one that considers the shortest time and the square of the probability of finding a victim $(1/T*P^2)$; and one that takes the shortest time, and the fifth power of the probability of finding a victim of $(1/T*P^5)$.

"Sweep" Heuristic

The "sweep" heuristic is a simple and known vehicle routing algorithm, capable of solving a variety of problems rapidly and with relatively small average error rate (around 10%; Ballou, 2006). In this method, a line is drawn from the point of origin, and this line rotates on a defined direction. Search locations through which the line passes are the ones which will compose a route, the rotation stops when the length of the route equals the flight range of the UAV. Finally, prioritization logic is applied for all locations that compose this route, in order to define the route

sequence. Because of this two-stage process, Ballou (2006) points out possible problems in the formation of routes, such as the non-compliance of flight range restriction.

In the present problem, prioritization logic applied in the second stage was the likelihood of a location having victims, with locations of greater probability being visited first. It should be noted that the "sweep" method implemented has a major constraint for the proposed problem, because the routes are generated complete one at a time, and assigned to a UAV, so that the last search sites tend to be visited by a single vehicle (for being part of the same route), and thus allowing for idle vehicles (those that have completed their own routes). This restriction is most noticeable for problems with few locations.

Hybrid Heuristic

After the first tests of the algorithms, it was found that the "greedy" heuristic quickly finds the first victims, but are slow to find all of them. Meanwhile the "sweep" method quickly finds all the victims, but is not so effective in the first moments of the SAR operation, which are the most critical. Because of this, a hybrid method was implemented, where the first routes are generated by "greedy" heuristics and the later routes are generated by the "sweep" method. For this problem, in scenarios with 50, 100 and 500 search sites, a greedy heuristic is used until time instances of 10, 30 and 90 respectively.

RESULTS AND DISCUSSION

The simulation results can be seen on Tables 1 to 3, showing the average time needed to find the indicated percentage of survivors.

Table 1. Results of the simulation for the different algorithms (with 50 search locations), showing the average time needed to finish.

% found	Greedy			Sweep	Hybrid
	1/T	$1/T*P^2$	$1/T*P^5$		
10%	3.43	3.48	3.68	4.23	3.68
20%	5.87	6.01	5.74	6.82	5.74
30%	10.59	8.48	8.63	8.98	8.63
40%	14.23	13.28	13.68	12.28	12.96
50%	18.38	16.68	17.24	16.43	17.12
60%	22.65	21.54	21.76	19.3	20.25
70%	32.1	25	26.55	22.51	23.58
80%	39.24	31.32	32.68	27.21	27.83
90%	44.98	37.33	37.24	34.81	34.76
100%	49.07	46.43	48.13	44.44	39.46

Table 2. Results of the simulation for the different algorithms (with 100 search locations), showing the average time needed to finish.

% found	Greedy			Sweep	Hybrid
	1/T	$1/T*P^2$	$1/T*P^5$		
10%	5.37	4.26	4.26	9.33	4.26
20%	11.46	7.71	7.71	15.87	7.71
30%	18.49	13.99	13.99	32.37	13.99
40%	23.33	21.58	21.58	37.78	21.58
50%	38.95	33	28.99	45.57	28.99
60%	47.36	39.09	40.59	50.44	42.04
70%	57.43	48.42	50.27	60.65	51.01
80%	77.86	58.55	59.1	67.69	60.58
90%	84.61	69.48	69.42	72.73	75.63
100%	93.26	98.32	100.51	82.26	92.82

The "greedy" heuristics that prioritize the probability of finding survivors had good results for the early stages of the operation, while the "sweep" method is more efficient in finding all survivors in the shortest possible time. This becomes more evident with the routes generated by each method (Fig. 4., the "sweep" method creates more efficient routes). Hybrid algorithms, in turn, use the "greedy" strategy for finding many survivors in the early moments of the search, switching to the "sweep" strategy

later on in order to find all the victims faster. Figure 5 shows an example of comparative results for a specific scenario.

CONCLUSION

SAR is an essential part of humanitarian operations, and the use of UAVs for this purpose is already a reality. Still, few studies have focused on search algorithms for using UAVs and even fewer have considered the complexity and uncertainty of real-life problems. This work is a first attempt to tackle this problem.

Table 3. Results of the simulation for the different algorithms (with 500 search locations), showing the average time needed to finish.

% found	Greedy			Sweep	Hybrid
	1/T	1/T*P²	1/T*P⁵		
10%	24.16	13.87	13.87	32.39	13.87
20%	53.79	38.33	39.26	64.09	39.26
30%	85.08	60.92	70.54	97.38	70.54
40%	137.27	102.72	104.97	134.07	103.56
50%	194.46	135.69	135.56	165.09	152.81
60%	259.92	174.52	172.9	202.21	191.59
70%	307.46	225.19	223.99	240.32	227.84
80%	370.08	277.42	273.92	277.53	269.44
90%	439.58	342.6	340.62	307.46	321.49
100%	498.55	488.58	487.55	333.9	360.37
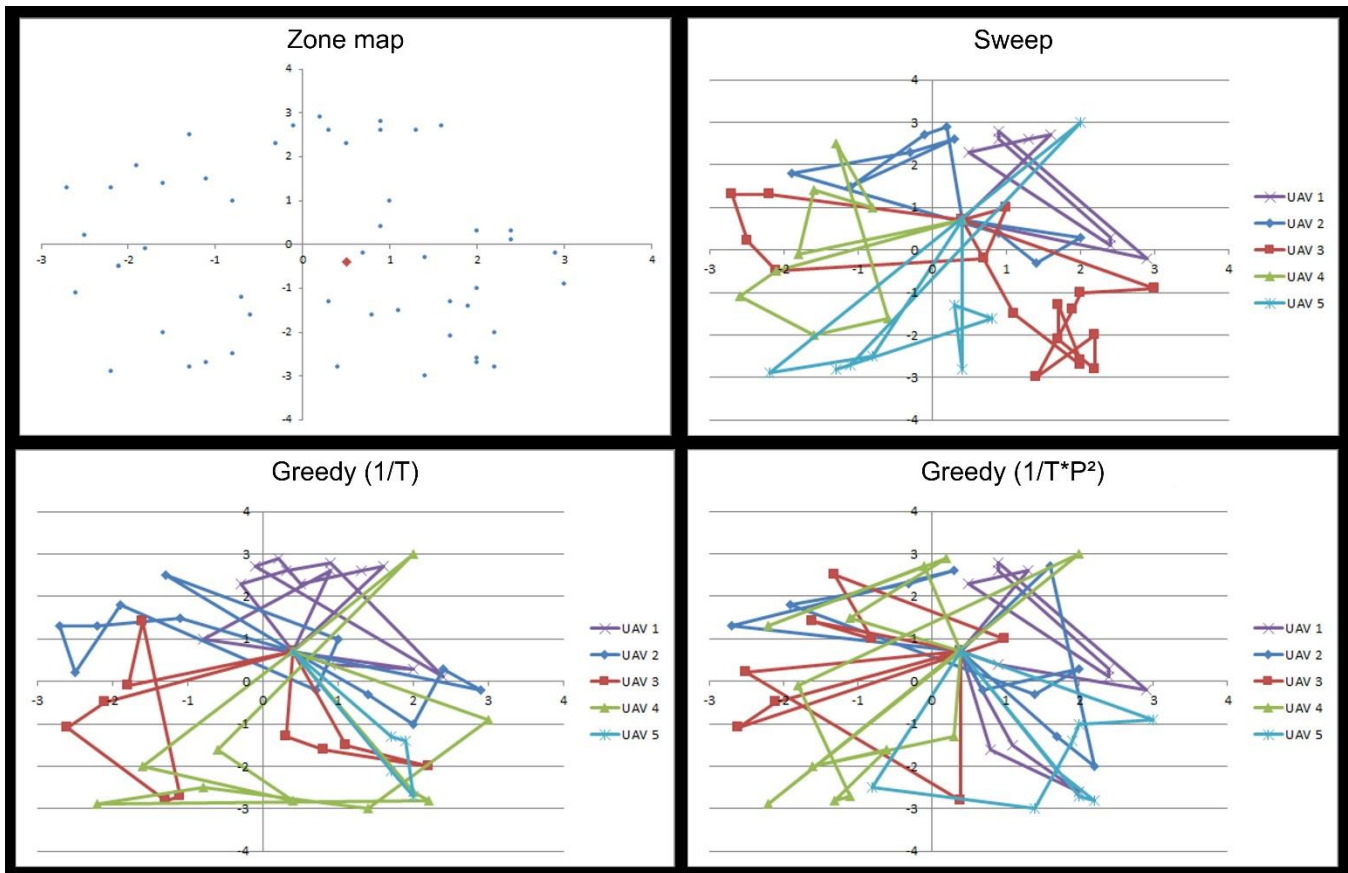
Figure 4. Example of routes generated by different algorithms for a scenario with 50 locations.

The results provided by the simulations of the hybrid model were very promising, and the balance between "greedy" and "sweep" heuristics appear to be a good solution to meet conflicting objectives. The time spent for each algorithm during a hybrid approach can be

calibrated according to the characteristics of the explored area. However, the model has a large number of complex parameters, being difficult to calibrate. A next step would be to test such model in real-life scenarios to assess the sensitivity of such parameters.

Perhaps the most obvious constraint on the proposed solutions is the lack of communication between UAVs. A more intelligent system of communication between different vehicles allows a more coordinated search (Çayurpurnar et al., 2008) and would probably show even better results, particularly in scenarios with many search sites. An idea would be to develop an UAV control simulator, where the "players" could communicate or not with each other, and the differences in performance could be analyzed systematically.

Another constraint presented in the work is the binary nature of the presence of victims on search sites. One possible improvement would be the use of Poisson distributions to set the number of victims for each location, which would affect the dynamics of prioritization factors, making the model more complex and closer to real-life scenarios.

Finally, we must remember that almost no video games include such a humanistic view on technology as SAR operations (unless it is for rescuing the main hero, of course). Although agreeing that combat, war, conflicts and violence are an important (and fun!) part of games, it is also nice to remember the positive impact brought by technological advancements, and that such education through games is always possible.
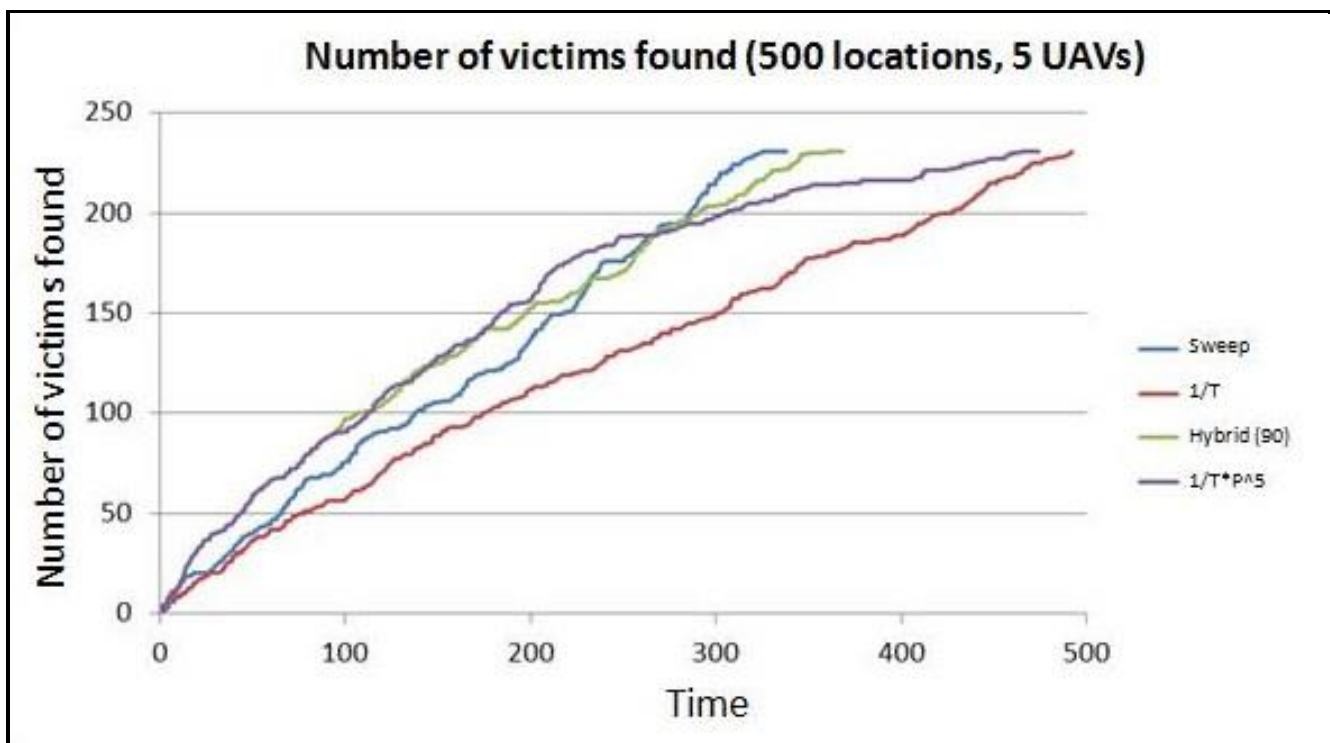
Figure 5. Example of the results of the different algorithms for a scenario with 500 locations. The "greedy" $1/T*P^2$ and $1/T*P^5$ had the same result, so only the latter is shown.

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